Development of a Regional DSGE Model in Japan: Empirical Evidence of Economic Stagnation in the Kansai Economy*

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Abstract

Using a dynamic stochastic general equilibrium model, this study empirically examines Japan's Kansai Region to ascertain causes of its long-run economic stagnation. Simulations and the empirical investigation demonstrate that stagnant private residential and equipment investments and productivity persistency are structural problems responsible for Kansai's unique economic fluctuations.

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1. Introduction

To investigate quantitatively how policies affect a global or single national economy, scholars must identify the interdependent relationships of the economy being examined. To examine the global economy, for example, they must identify sequences of international interdependence between one country and others and between markets within that country. Furthermore, examinations of a single country's (or region's) economy must acknowledge interdependent relationships between markets within that country (or region).

Work of this nature has been attempted. Recent years' examinations of monetary and fiscal policy have brought forth the Dynamic Stochastic General Equilibrium Model (DSGE), an analytical framework based on interdependent relations that quantitatively examines the effectiveness of macroeconomic policy. Compared to traditional macroeconometric and time series models, the DSGE model has clear theoretical foundations and easily traces the effects of shocks. In addition, its behavioural equations (e.g. consumption and investment functions) are derived from households' and firms' optimisation behaviours. The parameters of these functions are deep parameters such as household preferences and the firm's technology structure. Deep parameters are thought to be altered only moderately by policy shocks, and so the Lucas critique of macroeconomic models likely will not apply. Finally, DSGE models often use hypothetical calibrated parameters, so it can be argued that the data are insufficiently incorporated into the model.

The DSGE model originates in Kydland's (1982) Real Business Cycle (RBC) model, which assumes perfectly flexible prices and monetary neutrality—i.e. money does not affect the real economy and changes only nominal prices. Departing from RBC models, institutions seeking to evaluate the effectiveness of monetary policy are developing New Keynesian frameworks that assume price rigidity and non-neutrality of money. They have established medium-sized DSGE models following Christian et al. (2005) and Smits and Pouters (2003, 2007).

This study is organised as follows. Section 2 surveys previous studies involving macroeconometric models and the Kansai economy and explains features of our study. Section 3 characterises three aspects of the Kansai economy historically: trends in productivity, characteristics of private equipment and residential investment. Then we run simulations and plot impulse response functions to structural shocks. Section 4 concludes.

2. Building a Regional DSGE Model

Previous studies employ macroeconomic models of Kansai. Neighs and Nishigaki (1993) developed a model that employed aggregated macro variables of each of the seven prefectures in the Kansai Region.[2] Inada and Ogawa (1994) developed a model in which an economy within Kansai links to others via connection blocks. That is, each economy has an expenditure block, an income distribution block, a supply block and a labour block. The model has a connection block that links to each prefecture. Inada and Irie (2013) and Irie (2014) developed a specialised macromodel for short-term economic forecasts in which Kansai firms trade with firms elsewhere in Japan and abroad. Okano (2015)

[2] It contains Shiga, Kyoto, Osaka, Hyogo, Wakayama, Nara and Fukui.

calculated total factor productivity (TFP) in Kansai by estimating a Solow growth model of its economy.

Unlike this study, however, [3] none of these earlier works [4] employ the notable benefit of the DSGE model: its foundations allow theoretically based interpretations of simulation results for the transmission mechanisms of shocks and the causes of changes. Interpreting simulation results becomes more ambiguous as a model expands, causing difficulty in tracing transmission mechanisms, but the DSGE model overcomes this difficulty. Moreover, the fact that most parameters in the DSGE model are deep parameters of economic agents reduces the possibility that large changes in economic structures alter parameter values.

Nonetheless, the DSGE model presents problems. If its parameters are calibrated rather than estimated, the model does not reflect actual data and it is undeniably distant from the current state of the economy. Given the modern world's violent macroeconomic changes, informative tests likely can emerge from using up-to-date data. However, a DSGE model might be unsuited to this type of situation.

Given these characteristics, why construct a DSGE model applied to a specific regional economy? First, such a model can capture characteristics of a regional economy using a general equilibrium theoretical model, which then can be used for analytical simulations of that region. This approach reveals economic characteristics of a region that remain obscure within traditional macroeconometric models.

Second, it is possible to compare one region's DSGE to another's. For example, separate DSGE models with the same theoretical structure can be created for Kanto and Kansai. Regional differences would be expressed in different parameter calibrations and calibrated with reference to regional data from previous empirical research such that the models would somewhat reflect each area's respective characteristics. By examining which differences in parameters most affect the regions' dynamic properties, differences between their underlying economic structures can be discovered.

Third, identifying interrelationships between a regional model and a national economy facilitates testing scenarios. For example, by identifying the fiscal structure of a region and that of the central government, we can run simulations wherein policy alters links between the two governments (e.g. tax allocations). By calibrating parameters through a theoretical model, the DSGE model facilitates hypothetical simulations of policy effects and quantitative examination of issues that might receive inadequate discussion. In sum, sound reasons endorse developing a DSGE model for a regional economy.

2.1 Structure of the theoretical model

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[3] Several Japanese DSGE models have been developed in Japan. Bank of Japan has developed and uses the Japanese Economic Model (JEM, see Teranishi et al., 2004.) for macroeconomic analysis and monetary policy. It also has developed a medium-sized DSGE model (M-JEM).

[4] An alternative is to study the role of government expenditures in the standard new Keynesian model with hand-to-mouth households that face a liquidity constraint. See Gali et al. (2007) and Natvik (2009).

Our model is based upon the medium-sized DSGE model by Christian et al. (2005) and Smits and Pouters (2003, 2007). The modelled economy's agents are households, firms, the central bank and government. Households seek to maximise lifetime utility subject to budget constraints. Firms seek to maximise profits, and the government comprises the central and local government (Figure 1).

Figure 1: Central and Local Governments

Figure 2 illustrates tax flows.[5] The central government collects a consumption tax on household purchases of durable and nondurable goods, levies an income tax on wages paid to households and taxes corporate profits. Its spending consists primarily of purchases and interest payments, and it covers revenue shortfalls by issuing bonds. The central government allocates part of all three taxes collected to local governments. It also allocates a portion of central government revenues to local governments as subsidies. The structure of the model appears in Figure 2.

Figure 2: Tax Flows

2.1.1 Households

The representative household's utility function yields positive utility from consuming durable and nondurable goods and negative utility from supplying labour. The household utility function is

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[(\gamma \log C_t + (1-\gamma) \log D_t - \frac{N_t^{1+\eta}}{1+\eta} \right]. \quad (1)$$

In (1) above, C_t denotes consumption of nondurable goods and D_t consumption of durable goods (land and fixed property). Parameter γ expresses the relative weight of consumption between durables and nondurables. N_t is labour supply and η is the reciprocal of its elasticity.

Labour supplied by households to firms that produce durable and nondurable goods is assumed to display imperfect substitution, per Iacoviello and Neri (2010).

$$N_t = [b^{-l}(N_t^C)^{1+l} + (1-b)^{-l}(N_t^D)^{1+l}]^{\frac{1}{1+l}}. \quad (2)$$

N_t^C is the quantity of labour supplied to firms producing nondurable goods and N_t^D is the quantity supplied to firms producing durable goods. b is the relative weight of labour supplied to each type of firm. l expresses the degree of substitutability of each type of labour. Imperfect substitution of labour between producers of durables and nondurables creates wage inequality between the two sectors.

Below is the household's budget constraint.

$$(1+\tau_t^C)P_t^C C_t + P_t^D(1+\tau_t^D)I_t^D + B_t \leq$$
$$R_{t-1}B_{t-1} + (1-\tau_t^{WC})W_t^C N_t^C + (1-\tau_t^{WD})W_t^D N_t^D + R_t^K K_{t-1} + \Phi_t^C + \Phi_t^D. \quad (3)$$

[5]Oriol and Rabanal (2011).

P_t^C denotes the price of nondurable and P_t^D the price of durable goods. I_t^D is the amount of household investment in durable goods. W_t^C and W_t^D are nominal wages to labour producing nondurable and durable goods, respectively. Φ_t^C denotes profits on durable goods and Φ_t^D profits on nondurable goods. $B_{t\text{-}1}$ is bonds issued by the government. $R_{t\text{-}1}$is the nominal interest rate.

Households factor government taxation into their optimisation. τ_t^C is the consumption tax rate on nondurable goods and τ_t^D that on durable goods. τ_t^{WC} is the tax rate on income from producing durable goods and τ_t^{WD} the rate on income from producing nondurable goods.

Investment in durable goods is assumed to be based on the following law of motion.[6]

$$\begin{aligned} &D_t = (1-\delta^D)D_{t-1} + \left[1 - S^D\left(\frac{I_t^D}{I_{t-1}^D}\right)\right] I_t^D, \\ &\overline{S^D} = \overline{S^{D'}} = 0, \quad \overline{S^{D''}} > 0. \end{aligned} \tag{4}$$

δ^D is the depreciation rate on durable goods. We assume a necessary adjustment cost $S(\cdot)$ on investment in durable goods. Assumptions in (4) mirror those of Christian et al. (2005) and Kannan et al. (2012).

Inventory investment is assumed to be based upon the law of motion used by Christian et al. (2005).

$$\begin{aligned} &K_t = (1-\delta^K)K_{t-1} + \left[1 - S^K\left(\frac{I_t^C}{I_{t-1}^C}\right)\right] I_t^C, \\ &\overline{S^K} = \overline{S^{K'}} = 0, \quad \overline{S^{K''}} > 0. \end{aligned} \tag{5}$$

Based on the above, the household's Lagrangian is as follows:

$$\begin{aligned} L \ \equiv E_0 \sum_{t=0}^{\infty} \beta^t \Bigg\{ &(\gamma \log C_t + (1-\gamma)\log D_t - \frac{N_t^{1+\eta}}{1+\eta} \\ &+ \lambda_t [R_{t-1}B_{t-1} + (1-\tau_t^{WC})W_t^C N_t^C + (1-\tau_t^{WD})W_t^D N_t^D + R_t^K K_{t-1} \\ &+ \Phi_t^C + \Phi_t^D - (1+\tau_t^C)P_t^C C_t - P_t^D(1+\tau_t^D)I_t^D - B_t] \\ &+ \mu_t \left[(1-\delta^D)D_{t-1} + \left[1 - S^D\left(\frac{I_t^D}{I_{t-1}^D}\right)\right] I_t^D - D_t\right] \\ &+ \lambda_t Q_t \left[(1-\delta^K)K_{t-1} + \left[1 - S^K\left(\frac{I_t^C}{I_{t-1}^C}\right)\right] I_t^C - K_t\right] \Bigg\}. \end{aligned} \tag{6}$$

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[6]Oriol and Rabanal (2011).

λ_t is the Lagrange multiplier for the budget constraint. μ_t is the Lagrange multiplier for the law of motion of durable goods investment. $\lambda_t Q_t$ is the Lagrange multiplier associated with capital stock in terms of the marginal utility of consumption. Q_t is Tobin's Q.

First-order conditions are as follows.

C_t: $$\gamma \frac{1}{C} - P_t^C(1+\tau_t^C)\lambda_t = 0 \tag{7}$$

B_t: $$\lambda_t = \beta E_t R_t \lambda_{t+1} \tag{8}$$

D_t: $$(1-\gamma)\frac{1}{D_t} - \mu_t + \beta(1-\delta^D)E_t\mu_{t+1} = 0 \tag{9}$$

N_t^C: $$b^l N_t^{n-l}(N_t^C)^l - (1-\tau_t^{WC})W_t^C\lambda_t = 0 \tag{10}$$

N_t^D: $$(1-b)^{-l} N_t^{n-l}(N_t^D)^l - (1-\tau_t^{WD})W_t^D\lambda_t = 0 \tag{11}$$

I_t^D: $$\begin{aligned} &-P_t^D(1-\tau_t^D)\lambda_t + \mu_t\left[1 - S^D\left(\frac{I_t^D}{I_{t-1}^D}\right) - S^{D\prime}\left(\frac{I_t^D}{I_{t-1}^D}\right)\left(\frac{I_t^D}{I_{t-1}^D}\right)\right] \\ &+\beta E_t\mu_{t+1}S^{D\prime}\left(\frac{I_{t+1}^D}{I_t^D}\right)\left(\frac{I_{t+1}^D}{I_t^D}\right)^2 = 0 \end{aligned} \tag{12}$$

I_t^C: $$\begin{aligned} &1 - Q_t\left[1 - S^K\left(\frac{I_t^C}{I_{t-1}^C}\right) - S^{K\prime}\left(\frac{I_t^C}{I_{t-1}^C}\right)\left(\frac{I_t^C}{I_{t-1}^C}\right)\right] \\ &+\beta E_t\frac{\lambda_{t+1}}{\lambda_t}Q_{t+1}S^{K\prime}\left(\frac{I_{t+1}^C}{I_t^C}\right)\left(\frac{I_{t+1}^C}{I_t^C}\right)^2 = 0 \end{aligned} \tag{13}$$

K_t: $$Q_t = \beta E_t\frac{\lambda_{t+1}}{\lambda_t}[Y_{t+1} + Q_{t+1}(1-\delta^K)] \tag{14}$$

D_t: $$(1-\gamma)\frac{1}{D_t} - \mu_t + \beta(1-\delta^D)E_t\mu_{t+1} = 0 \tag{15}$$

2.1.2 Firms

The model captures two types of firms: producers of durable and nondurable goods.[7]

2.1.2.1 Nondurable goods producers

Firms that produce nondurable goods exist within the range 0–1, where output relies on inputs of household-owned capital stock and labour. Below is the output function of a nondurable goods firm.

$$Y_t^C(i) = A_t^C K_{t-1}^{\alpha}(i)(N_t^C)^{1-\alpha}(i) \quad \forall\ i \in [0,1]. \tag{16}$$

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[7]The local government's standard general revenue is calculated via established rules. The central government allocates taxes and subsidies to local governments to supplement their shortages of funds. Amounts depend on local government's standard general revenue.

$Y_t^C(i)$ is output of nondurable goods. K_t is capital stock. A_t^C is an exogenous variable for the technology level of the nondurable goods firm. Additionally, $\alpha \in (0,1)$. Firms producing nondurable goods solve the following cost-minimisation problem.

$$\frac{W_t^C}{P_t^C} N_t^C + \frac{R_t^C}{P_t^C} K_{t-1}^C - \varphi_t^C (A_t^C K_{t-1}^\alpha (N_t^C)^{1-\alpha} - Y_t^C). \tag{17}$$

R_t^C is the nominal rental price of capital stock. φ_t^C is the real marginal cost incurred by firms producing nondurables.

First-order conditions emerge as follows.

$$\frac{W_t^C}{P_t^C} - (1-\alpha) A_t^C K_{t-1}^\alpha (N_t^C)^{1-\alpha} \varphi_t^C = 0, \tag{18}$$

$$\frac{R_t^C}{P_t^C} - \alpha A_t^C K_{t-1}^\alpha (N_t^C)^{1-\alpha} \varphi_t^C = 0. \tag{19}$$

(19) and (20) are respectively:

$$\frac{W_t^C}{P_t^C} = (1-\alpha) \frac{\varphi_t^C Y_t}{N_t^C}, \tag{20}$$

$$\frac{R_t^C}{P_t^C} = \alpha \frac{\varphi_t^C Y_t}{K_{t-1}}. \tag{21}$$

Therefore,

$$\varphi_t^C = \frac{1}{(1-\alpha)^\alpha \alpha^\alpha} = w_t^{C^{1-\alpha}} (r_t^K)^\alpha, \tag{22}$$

$$\frac{K_{t-1}}{N_t^C} = \frac{\alpha}{1-\alpha} \frac{w_t^C}{r_t^K}. \tag{23}$$

2.1.2.2 Durable goods producers

Durable goods firms adhere to the following output function in which labour is an input and durable goods an output.

$$Y_t^D(i) = A_t^D N_t^D(i) \quad \forall \; i \in [0,1]. \tag{24}$$

Y_t^D denotes output of durable goods. A_t^D is productivity of durable goods producers.

Solving durable goods producers’ cost minimisation problem yields these first-order conditions:

$$\varphi_t^D = \frac{1}{A_t^D} W_t^D q_t^{-1}, \tag{25}$$

$$\text{where } q_t = \frac{P_t^D}{P_t^C}. \tag{26}$$

φ_t^D is the real marginal cost to durable goods firms. q_t is the relative price of durable goods in terms of the price of nondurable goods.

2.1.2.3 Calvo pricing

Modelled firms face Calvo (1983) price rigidity. When it is time for price revisions, some firms (1 − ω) can set optimal prices for the term, but the remainder cannot set or change prices (optimise). In this situation, the firm's post-tax profit maximisation problem is as follows:

$$\max \quad E_t \sum_{j=0}^{\infty} (\omega\beta)^j \left(\frac{\lambda_{t+j}}{\lambda_t}\right)^{-\sigma} \left(1-\tau_{t+j}^F\right)\Phi_{t+j}^z , \tag{27}$$

$$\Phi_{t+j}^z \equiv \left[\left(\frac{P_t^{o,z}(i)}{P_{t+j}^z}\right) - \varphi_{t+j}^z\right] Y_{t+j}^z(i) , \tag{28}$$

$$\text{subject to} \quad Y_t^z(i) = \left(\frac{P_t^z(i)}{P_t^z}\right)^{-\theta} Y_{t+j}^z(i) \quad \text{for } z = C, D. \tag{29}$$

Here, firms set prices by Amato's (2003) rule-of-thumb. That is, of the proportion of firms denoted 1 − ω that can change prices for the term, the subset 1–λ re-optimises based on rational expectations. The remaining firms (λ) price using rule-of-thumb, as in

$$P_t^{z,r} = P_{t-1}^{z,*}\left(\frac{P_{t-1}^z}{P_{t-2}}\right) \quad \text{for } z = C, D. \tag{30}$$

$P_t^{z,r}$ is the corrected price. $P_{t-1}^{z,*}$ is the optimal price for the previous term.

Given the above assumptions, the (log-linearised) New Keynesian Phillips Curve is as follows:

$$\pi_t^z = \gamma_F^z E_t \pi_{t+1}^z + \gamma_b^z \pi_{t-1}^z + K_1^z \varphi_t^z + K_2^z \tau_t^z \quad \text{for } z = C, D , \tag{31}$$

$$\gamma_F^K \equiv \frac{\omega^K \beta}{\omega^K + \lambda^K\left(1-\omega^K(1-\beta)\right)} , \tag{32}$$

$$\gamma_b^K \equiv \frac{\lambda^K}{\omega^K + \lambda^K\left(1-\omega^K(1-\beta)\right)} , \tag{33}$$

$$K_1^z \equiv \frac{(1-\omega^K)(1-\omega^K\beta)(1-\lambda^K)}{\omega^K + \lambda^K\left(1-\omega^K(1-\beta)\right)} , \tag{34}$$

$$K_2^z \equiv \frac{(1-\omega^K)(1-\omega^K\beta)(1-\lambda^K)}{\omega^K + \lambda^K\left(1-\omega^K(1-\beta)\right)} \frac{\tau^F}{1-\tau^F} . \tag{35}$$

2.1.3 Central bank

The central bank is assumed to follow simple monetary policy rules in setting the policy rate[8]. Its (log-linearised) monetary policy rules are expressed as

$$\hat{R}_t = (1-\rho_r)\left(\phi_\pi \pi_t + \phi_y \hat{Y}_t\right) + \rho_r \hat{R}_{t-1} \, . \tag{36}$$

ρ_r is the inertia term on the interest rate.

2.1.4 Government

The government comprises the central and local government. Both obtain revenues from consumption, from income taxes on households and from corporate taxes. The ratio between national and local is set by θ_i for i=C,W,F ($\theta \in [0,1]$).

The local government's budget constraint is as follows:

$$\begin{aligned} G_t^R = {} & (1-\theta_C)(\tau_t^C P_t^C C_t + \tau_t^D P_t^D I_t^D) \\ & +(1-\theta_W)(\tau_t^{WC} W_t^C N_t^C + \tau_t^{WD} W_t^D N_t^D) \\ & +(1-\theta_F)\tau^F(\Phi_t^C + \Phi_t^D) + \omega T R_t \, . \end{aligned} \tag{37}$$

G_t^R is spending by the local government. ωT_t is the portion transferred from the central government, the size of which is determined by ω ($\in(0,1)$). [9]

The central government's budget constraint is as follows:

$$\begin{aligned} G_t + B_{t+1} - B_t + \omega T R_t = {} & \theta_C(\tau_t^C P_t^C C_t + \tau_t^D P_t^D I_t^D) \\ & +\theta_W(\tau_t^{WC} W_t^C N_t^C + \tau_t^{WD} W_t^D N_t^D) \\ & +\theta_F \tau^F(\Phi_t^C + \Phi_t^D) + T_t \, . \end{aligned} \tag{38}$$

G_t is spending by the central government. T_t is the portion of funds transferred to the central government from local governments *other* than the specific local government examined in the model.

2.1.5 Equilibrium

Equilibrium conditions for aggregate output, the goods market and the labour market are given by the following:

$$Y_t^C = C_t \, , \tag{39}$$

$$Y_t^D = I_t^D \, , \tag{40}$$

$$Y_t = C_t + I_t^D + I_t^C + G_t^R \, , \tag{41}$$

$$N_t = N_t^C + N_t^D \, , \tag{42}$$

$$B_t = 0 \, , \tag{43}$$

$$N_t^\kappa = \int_0^1 N_t^\kappa(i)di \ \text{for} \ \kappa = C, D \, , \tag{44}$$

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[8] The appendix B provides a detailed discussion why a national monetary policy rule can be regarded as the regional policy rule. The appendix B is available on request.

[9] Tchakarof et al. (2004).

$$K_t = \int_0^1 K_t(i)di \,. \tag{45}$$

The above system is log-linearised around the steady state and used in simulations in the next section. Appendix A lists the log-linearised equations[10].

3. Tests Using the Regional DSGE Model

3.1 Kansai economy trends and characteristics

Section 2 concerned construction of the regional DSGE model. Next, simulations unveil unique aspects of the Kansai economy. Before conducting simulations, we examine three previously mentioned characteristics of the Kansai economy.

3.1.1 Productivity

Figure 3 displays TFP in the Kanto and Kansai economies from 1975 to 2009. From the 1970s to the 1980s, Kansai experienced lower productivity than Kanto, but without strikingly large differences between them. From 1990, however, Kansai's productivity barely grew, displaying only short-term fluctuations. Except for a temporary drop during the Lehman Shock, productivity in Kanto trends upward from 1990.

Figure 3: Total Factor Productivity (1975–2009)

To confirm existence of the above characteristics statistically, we use a Hodrick–Prescott filter to cull trends from the original series and estimate the autoregressive coefficients of the AR(1) process. The resulting estimates—Kanto 0.74 and Kansai 0.54—suggest Kansai's productivity persistence does not exceed 60% of Kanto's. The duration of a positive productivity shock would be briefer in Kansai than in Kanto.

3.1.2 Private equipment and residential investment

Figure 4 displays private equipment investment expenditures in both regions. Figure 5 displays private residential investment expenditures in Kanto only. Two characteristics stand out about equipment investment in Kansai compared to Kanto. First, the amount of investment in Kansai is approximately half that in Kanto, with no sign of momentum towards Kanto numbers. Second, in the mid-2000s and 2011, inventory investment surged in Kanto with no corresponding phenomenon in Kansai, where the trend is declining.

Figure 4: Private Equipment Investment (1975–2011)

Figure 5: Private Residential Investment (1975–2011)

The characteristics of residential investment are almost identical, with levels in Kansai half those of Kanto. Notwithstanding fluctuations in Kanto during and after the 1990s, there was a general growth trend. Kansai, however, shows almost no changes and is generally flat or stagnant. These findings indicate that equipment investment and residential investment in Kansai display no growth momentum. It is highly possible that a structural cause unique to Kansai underlies these trends.

[10] Appendix A is available on request.

3.2 Simulations

Calibrations used in the simulations for this model are collected in Table 1.

Table 1: Calibrated Parameters

Figure 6 shows an impulse response to a positive productivity shock in the nondurable goods market. As just explained, Kansai is characterised by low productivity persistence relative to Japan overall, and this distinction is maintained in the degree of persistence of shocks in Kansai and all of Japan. In Figure 6, a positive productivity shock affecting nondurable goods stimulates investment in them, which stimulates output. Increased output suppresses inflation and stimulates consumption. The real interest rate rises in response to a falling inflation rate, and the higher interest rate restrains growth in inventory investment following the positive productivity shock, eroding Tobin's Q. Although investment in nondurable goods rises, both housing investment and demand apparently decline. Hence, focusing on productivity persistence indicates that a positive productivity shock affecting nondurable goods little affects Kansai's economy compared to Japan's overall.

Figure 6: Impulse Response Given a Positive Productivity Shock

As the previous section indicated, residential and inventory investment are important to Kansai's economy. Both recently have been sluggish relative to Japan as a whole, perhaps because Kansai firms face high adjustment costs for investment. Therefore, we next examine how differences in adjustment costs affect Kansai.

Figure 7 shows the impulse response to a negative productivity shock affecting nondurable goods. A negative productivity shock suppresses investment in nondurable goods, prompting declines in output and consumption. We focus on the size of the adjustment costs for investment. To incorporate the sluggishness of Kansai inventory investment into the model, we take ψ_C=0.1 as adjustment costs for investment in Japan overall and ψ_C=2.5 for Kansai firms. In other words, investment adjustment occurs instantaneously in Japan overall, whereas it is assumed to require a relatively long time in Kansai. Figure 7 illustrates that if adjustment costs for investment are large, Kansai's economy experiences a more drastic drop in nondurable goods investment. Therefore, in this model, the slump in inventory investment in Kansai (Figure 4) can be explained somewhat by differences in adjustment costs for investment.

Figure 7: Impulse Response after a Negative Productivity Shock (Nondurable Goods)

Next, we examine the case wherein adjustment costs for housing investment are larger in Kansai than Japan. Figure 8 displays the impulse response following a negative productivity shock affecting nondurable goods. ψ=0.1 is taken as adjustment costs for housing investment in Japan and ψ=2.5 for adjustment costs for housing investment faced by Kansai firms. The negative productivity shock reduces investment in nondurables but raises residential investment and housing demand. An increase in residential investment in Kansai is small relative to Japan overall, where adjustment costs for investment are low. Accordingly, housing demand is also less in Kansai than in Japan overall. As with adjustment costs for inventory investment, differences between Kansai and Japan in adjustment costs for housing investment emerge as one cause for stagnation in Kansai's economy.

Figure 8: Impulse Response after a Negative Productivity Shock

The government of Japan raised the country's consumption tax from 5% to 8% in April 2014. A consumption tax hike from 8% to 10% is planned in October 2015. How will these two-step tax hikes affect the Kansai economy?

Figure 9 shows the impulse response to a tax shock affecting consumption of nondurables. In this simulation, we assume government announces a two-step increase in the tax rate.[11] The first increase is announced at period 5. Then government increases the consumption tax on durable goods at period 10. After the tax shock, consumption rises immediately but temporarily because the announcement of a first-time tax increase forces households to reduce consumption. However, households resume consumption before the tax increase is implemented at period 5. This effect can be regarded as hurried purchases of consumption goods. Thereafter consumption declines in the aftermath following last-minute demand, a response consistent with experience. The second-time tax increase also induces last-minute demand, but it is insufficient to restore consumption to levels existing before the first-time tax increase. The economy experiences a huge drop in consumption once the second-time tax increase is implemented.

Figure 9: Impulse Response to a Nondurable Consumption Tax Shock

CPI inflation increases following government's announcement of the tax increase because such an announcement that the government promises to raise the nondurable consumption tax rate twice stimulates output and corresponding increases in investment. Announcement of the tax increase on consumption of nondurable goods invigorates residual investment, which stimulates housing demand. Tobin's Q immediately rises in response to a nondurable consumption tax shock, whereas firms withhold inventory investment because they set prices in anticipation of demand. Accordingly, the prediction from our model implies that government's announcement of twin increases in taxation on nondurable goods consumption at a future date generates a contractionary effect on the economy.

4. Conclusion

The economy of Western Japan (Kansai) is in a protracted economic slump. To understand why, this study quantitatively examined characteristics of the Kansai economy using a macro general equilibrium model with theoretical foundations and ran several simulations.

Our DSGE model explicitly included private residential investment and private equipment investment. It distinguished between local and central governments and explicitly modelled their respective fiscal balances. The difference in regional productivity is reflected in the magnitudes of the autoregressive coefficient, which is estimated separately for each region. By employing these techniques, the model captured differences in regional economic structures and structural differences with Japan overall.

Simulation results from our model demonstrated that productivity persistence, private equipment investment, private residential investment and structural stagnation cause unique economic fluctuations in Kansai's economy.

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[11]Kumhof et al. (2010).

A positive productivity shock affecting nondurable goods stimulates nondurable goods investment and therefore output and consumption. However, our model simulations confirmed that investment in and demand for land and property declined in Kansai despite greater nondurable goods investment. The persistence of a positive productivity shock affecting nondurable goods is less for Kansai's economy than for Japan.

A negative productivity shock affecting nondurable goods suppresses nondurable goods investment, reducing output and consumption. If it is assumed that Kansai firms face higher adjustment costs for investment than Japanese firms generally, Kansai's drop in nondurable goods investment is more striking. This means low inventory investment in the Kansai economy can be explained somewhat by differences in adjustment costs for investment. A negative productivity shock affecting nondurable goods reduces investment in nondurable goods but raises residential investment and housing demand. If it is also assumed that Kansai firms face higher adjustment costs for investment in land and property, then a negative productivity shock causes little growth in residential investment and housing demand. As with inventory investment and adjustment costs, our results suggest that the difference in adjustment costs for land and property between Kansai and Japan explains the slump in residential investment in Kansai.

The impulse responses to twin tax hikes and their announcement by government show households hurriedly purchasing consumption goods twice, although purchases do not restore consumption to levels preceding the first tax increase. The announcement fuels residual investment, while firms postpone inventory investment because they set prices in anticipation of future demand. Accordingly, the government's announcement of twin increases in the nondurable consumption tax has a contractionary effect on the economy.

It is noteworthy that the preceding results were calibrated. Calibration, not estimation, means that that the data are not reflected in the model's structure and hence the model is undeniably distant from the economy's current state. A Bayesian DSGE model that estimates parameters directly from the data addresses this problem.

It is also noteworthy that ours is a closed model. Accordingly, perspectives that may be important to construction of a regional model—e.g. interdependent relations with foreign economies, imports and exports, exchange rates, terms of trade—are not addressed. International institutions interested in this problem are developing open-economy DSGE models. Examples include the IMF's Global Economic Model (GEM),[12] Global Fiscal Model (GFM)[13] and Global Integrated Monetary and Fiscal Model (GIMF)[14] and the ECB's New Area Wide Model (NAWM).[15]

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[12]Christroffel et al. (2008), Smets et al. (2010).

Appendix A Log-Linearised Equations

(1)Euler equation for non-durable goods

$$\hat{C}_t = E_t\hat{C}_{t+1} - (\hat{R}_t E_t \pi^C_{t+1}) + \frac{\tau^C}{1+\tau^C}(E_t\tau^C_{t+1} - \tau^C_t) \tag{A.1}$$

(2) FOC for durable good

$$\hat{D}_t = \frac{1}{1-\beta(1-\delta^D)}[(1-\delta^D)\beta E_t\hat{\mu}_{t+1} - \hat{\mu}_t] \tag{A.2}$$

(3) Private residential investment

$$\hat{q}_t + \hat{C}_t + \frac{\tau^C}{1+\tau^C}\hat{\tau}^C_t + \psi^D(\hat{I}^D_t - \hat{I}^D_{t-1}) - \frac{\tau^D}{1+\tau^D}\hat{\tau}^D_t = \hat{\mu}_t + E_t\hat{\mu}_{t+1} + \beta\psi^D(E_t\hat{I}^D_{t+1} - \hat{I}^D_t) \tag{A.3}$$

(4) Law of motion for durable

$$\hat{D}_t = (1-\delta^D)\hat{D}_{t-1} + \delta^D\hat{I}^D_t \tag{A.4}$$

(5) Labor

$$(\eta - l)[(1-b)\hat{N}^C_t + b\hat{N}^D_t] - l\hat{N}^C_t = \hat{W}^C_t - \hat{P}^C_t - \frac{\tau^{WC}}{1+\tau^{WC}}\hat{\tau}^{WC}_t - \frac{\tau^C}{1+\tau^C}\tau^C_t - \hat{C}_t \tag{A.5}$$

$$\hat{D}_t = (1-\delta^D)\hat{D}_{t-1} + \delta^D\hat{I}^D_t \tag{A.6}$$

$$(\eta - l)[(1-b)\hat{N}^C_t + b\hat{N}^D_t] - l\hat{N}^D_t = \hat{W}^D_t - \hat{P}^C_t - \hat{q}_t - \frac{\tau^{WD}}{1+\tau^{WD}}\hat{\tau}^{WD}_t - \frac{\tau^C}{1+\tau^C}\tau^C_t - \hat{C}_t \tag{A.7}$$

$$\hat{N}^C_t = \hat{N}^D_t + l^{-1}(\hat{w}^C_t - \hat{w}^D_t) - l^{-1}\hat{q}_t - l^{-1}(\hat{\tau}^{WC}_t - \hat{\tau}^{WD}_t) \tag{A.8}$$

(6)Tobin's Q

$$\hat{Q}_t = -(\hat{R}_t - E_t\pi_{t+1}) + \beta[R^K E_t\hat{R}^K_{t+1} + (1-\delta^K)E_t\hat{Q}_{t+1}] \tag{A.9}$$

(7)Private inventory investment

$$\hat{I}^C_t = \frac{\beta}{1+\beta}E_t\hat{I}^C_{t+1} + \frac{1}{1+\beta}\hat{I}^C_{t-1} + \frac{\psi^C}{1+\beta}\hat{Q}_t \tag{A.10}$$

(8) Law of Motion for capital stock

$$\hat{K}_t = (1-\delta^K)\hat{K}_{t-1} + \delta^K\hat{I}^K_t \tag{A.11}$$

(9) Law of motion for relative price

$$\hat{q}_t = \hat{q}_{t-1} + \pi^D_t - \pi^C_t \tag{A.12}$$

(10) NKPC

$$\pi_{C,t} = \gamma^C_f E_t\pi_{C,t+1} + \gamma^C_b\pi_{C,t-1} + K^1_C\varphi^C_t - K^2_C\hat{\tau}^F_t \tag{A.13}$$

$$\pi_{D,t} = \gamma_f^D E_t \pi_{D,t+1} + \gamma_b^D \pi_{D,t-1} + K_D^1 \varphi_t^D - K_D^2 \hat{\tau}_t^F \tag{A.14}$$

(11) Production function of a non-durable goods firm

$$\hat{Y}_t^C = \hat{A}_t^C + \alpha \hat{K}_{t-1} + (1-\alpha)\hat{N}_t^C \tag{A.15}$$

(12) Production function of a durable goods firm

$$\hat{Y}_t^D = \hat{A}_t^D + \hat{N}_t^D \tag{A.16}$$

(13) Labor demand for non-durable

$$\hat{K}_{t-1} = \hat{N}_t^C + \hat{w}_t^C - \hat{r}_t^K \tag{A.17}$$

(14) Real marginal cost for durable

$$\hat{\varphi}_t^D = -\hat{A}_t^D + \hat{w}_t^D - \hat{q}_t \tag{A.18}$$

(15) Taylor rule

$$\hat{R}_t = (1-\rho_r)(\phi_\pi \pi_t + \phi_y \hat{Y}_t) + \rho_r \hat{R}_{t-1} \tag{A.19}$$

(16) Market clearing

$$\hat{Y}_t = \frac{C}{Y}\hat{C}_t + \frac{I^D}{Y}\hat{I}_t^D + \frac{I^C}{Y}\hat{I}_t^C + \frac{G}{Y}\hat{G}_t \tag{A.20}$$

(15) Aggregate inflation

$$\pi_t = (1-\gamma)\pi_t^D + \gamma \pi_t^C \tag{A.21}$$

(16) Aggregate labor

$$\hat{N}_t = (1-\alpha)\hat{N}_t^D + \alpha \hat{N}_t^C \tag{A.22}$$

(17) Another equation

$$\hat{Y}_t^C = \hat{C}_t \text{ (or } \hat{Y}_t^D = \hat{D}_t \text{)} \tag{A.23}$$

Appendix B Applying the Taylor Rule in a Regional Model

The Bank of Japan (BOJ) manipulates the interbank rate, and the standard Taylor rule can trace its movements. Therefore, its applicability is self-evident in DSGE models of Japan's national economy. In a regional model, however, its use needs justifying because a BOJ branch cannot change the interbank rate via open market operations.

Yamori (2002) confirmed that the regional reference policy rate suggested by the Taylor rule can track the actual interbank rate. His findings endorse our use of the Taylor rule because the reference rate in our regional model is the same as the BOJ interbank rate. Per Yamori (2002), we estimate the Taylor rule using Generalised Method of Moments. The sample period is 1994:Q1–2009:Q4.

The result of this estimation is as follows:

$$r_t = \underset{(0.006)}{0.02} + \underset{(0.076)}{0.69} r_{t-1} + \underset{(0.478)}{1.24} \pi_t + \underset{(0.001)}{0.25} x_t$$ (J-statistics = 0.521),[16]

where π_t is CPI inflation in Kansai, x_t is its output gap and r_t is the nominal interest rate in Japan. According to this estimation result, all coefficients are significant, and we clear the problem of over-identification. In particular, the coefficient for inflation reaction exceeds unity. Thus, our estimation satisfies the Taylor principle. Using this empirical result, we can implement the dynamic simulation. Figure 10 showing the result of the dynamic simulation indicates that the reference policy rate tracks the actual policy rate. Again, using the Taylor rule in the Kansai DSGE model is justified.

Figure 10: Comparison of Actual Interbank Rate and the Reference Policy Rate Suggested by the Estimated Taylor Rule.

[16] The parentheses represent the standard error. Instrument variables are as follows: a constant, lags 1–2 of inflation, lags 1–2 of the output gap and one-period lag of r_{t-1}.

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Table 1: Calibrated Parameters

Parameter	Description	Value
β	Consumption discount rate	0.99
δ^D	Depreciation rate of housing	0.025
δ^K	Depreciation rate of capital stock	0.025
α	Capital's share of income	0.33
ψ^D	Intertemporal substitution of residential investment	2.5
ψ^C	Intertemporal substitution of consumption spending	2.5
φ	Intertemporal substitution of labour supply	3
l	Disutility of labour	1.5
q	Housing prices' share of general prices	0.3
γ	Weight of consumption in the utility function	0.3
ω^C	Stickiness of consumer goods prices	0.7
ω^D	Stickiness of housing prices	0.7
θ^l	Substitutability of goods in the output function	5
ϕ_π	Responsiveness of inflation in the monetary policy reaction function	1.21
ϕ_y	Responsiveness of output in the monetary policy reaction function	0.125
ρ_r	Responsiveness of interest rates (previous-term) in the monetary policy reaction function	0.75
I^D/Y	Residential investment share	0.1
I^C/Y	Inventory investment share	0.2
C/Y	Consumption spending share	0.6
G/Y	Government spending share	0.1
τ^C	Consumption tax rate (consumable goods)	0.08
τ^D	Consumption tax rate (housing)	0.08
τ^{WC}	Income tax rate on workers at consumable goods firms	0.1
τ^{WD}	Income tax rate on workers at housing firms	0.1
τ^F	Corporate tax rate	0.3
λ^C	Rule-of-thumb firms share (consumable goods)	0.65
λ^D	Rule-of-thumb firms share (housing)	0.65
ϕ_{gc}	Consumption tax share of govt revenue	0.4
ϕ_{gw}	Income tax share of govt revenue	0.4
ϕ_{ti}	Corporate tax share of govt revenue	0.1

ϕ_{tr}	Subsidies share of govt revenue	0.1
ϕ_{br}	Lump-sum tax share	0.1

Figure 1: Central and Local Government

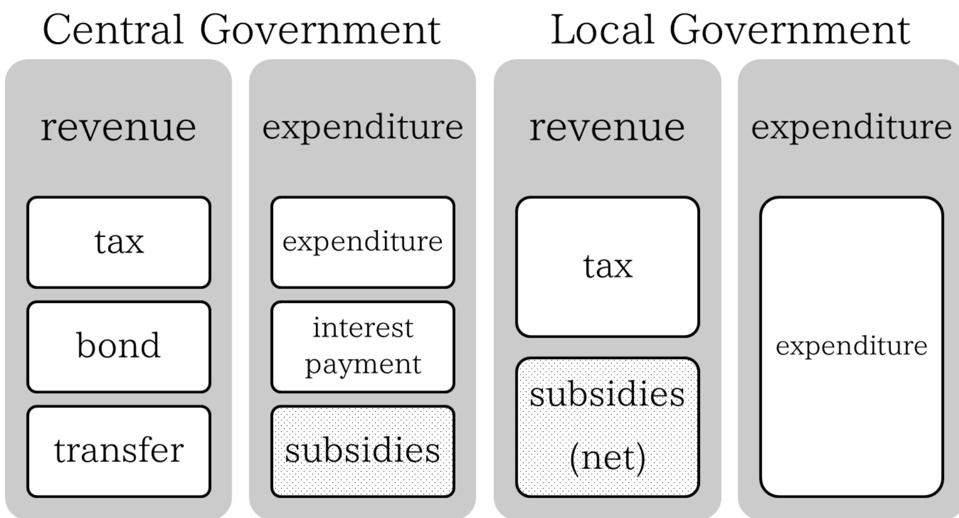


Figure 2: Flow of Tax Funds

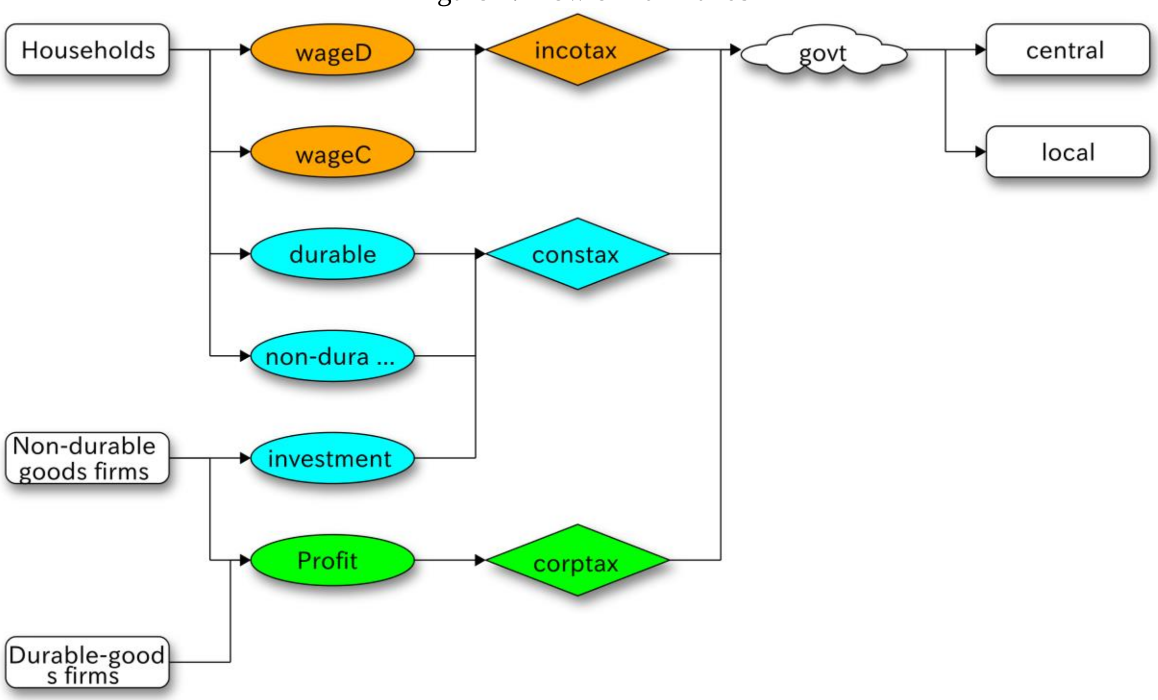
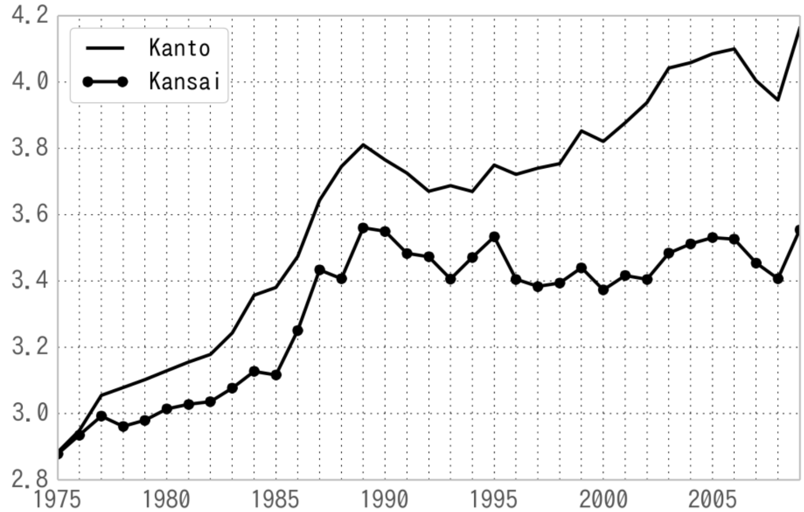
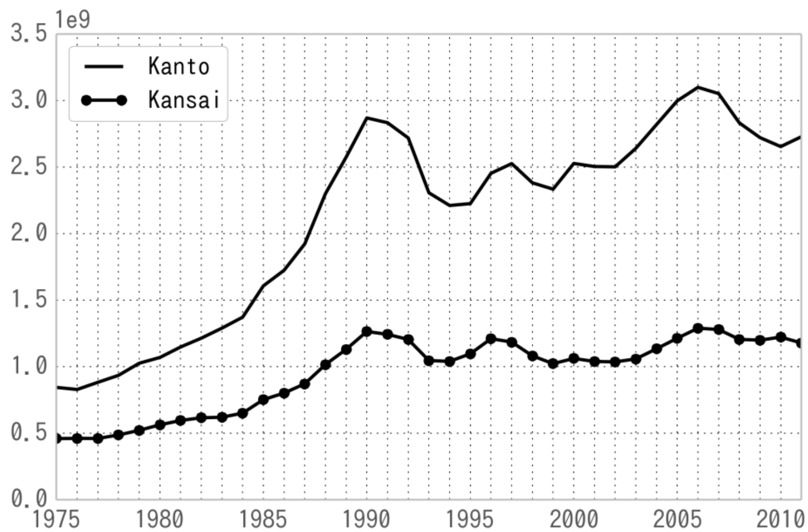


Figure3: Total Factor Productivity (1975–2009)



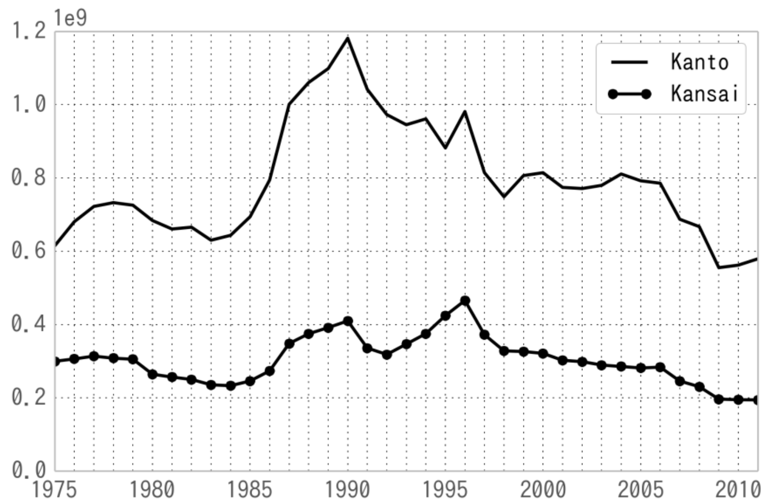
source: National Accounts of Japan

Figure 4: Private Equipment Investment (1975–2011)



source: National Accounts of Japan

Figure 5: Private Residential Investment (1975–2011)



source: National Accounts of Japan

Figure 6: Impulse Response Given a Positive Productivity Shock

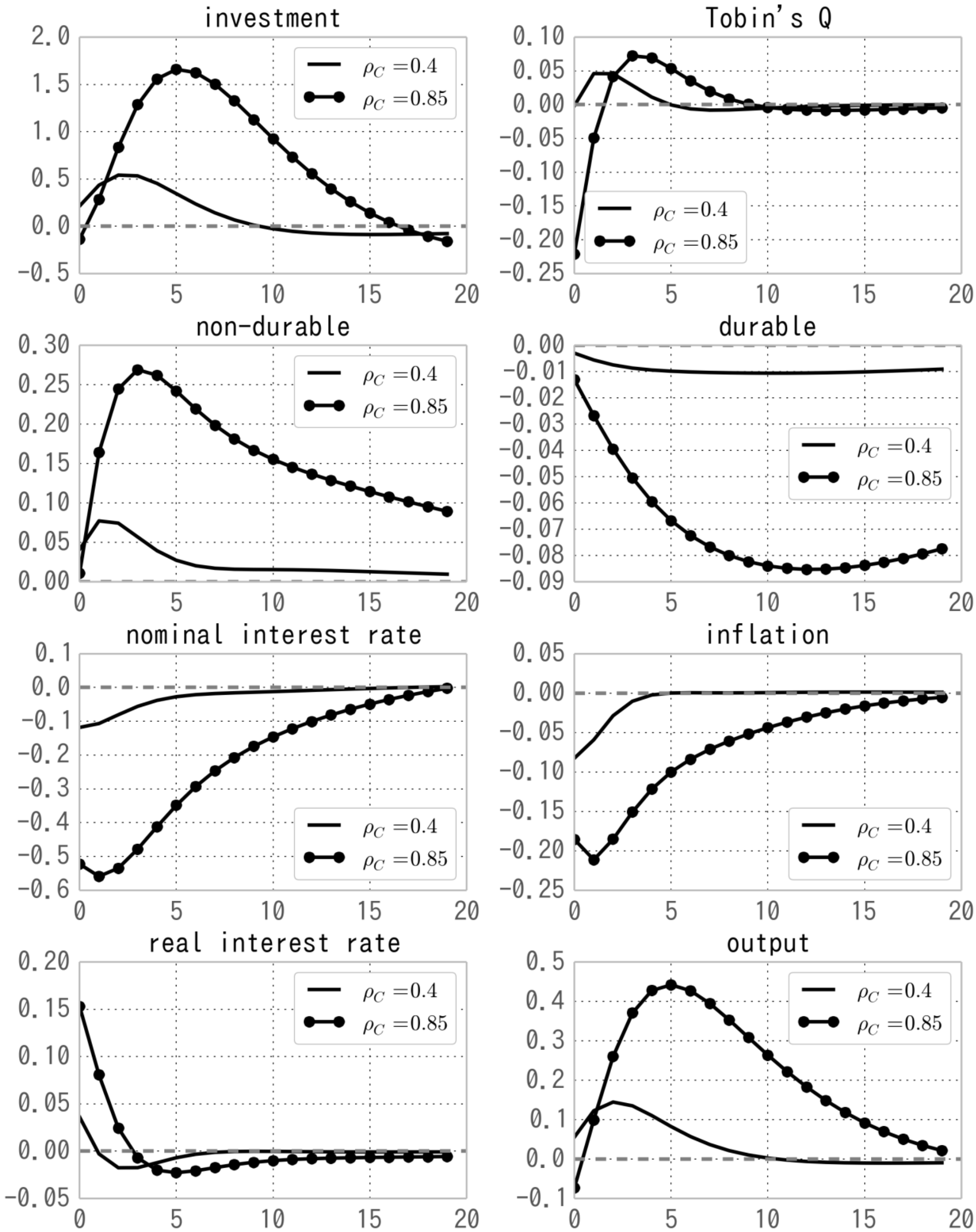


Figure 7: Impulse Response after a Negative Productivity Shock (Nondurable Goods)

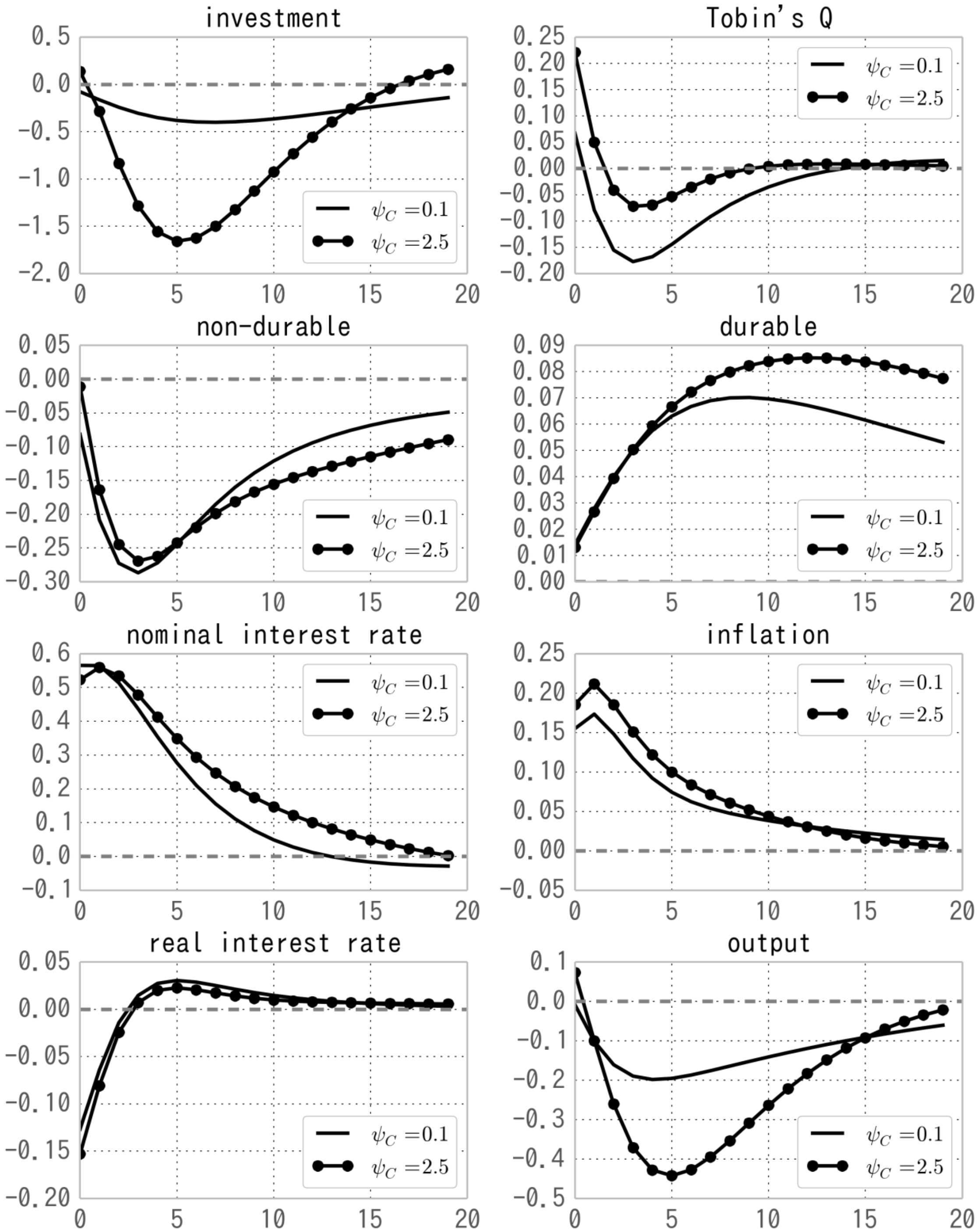


Figure 8: Impulse Response after a Negative Productivity Shock

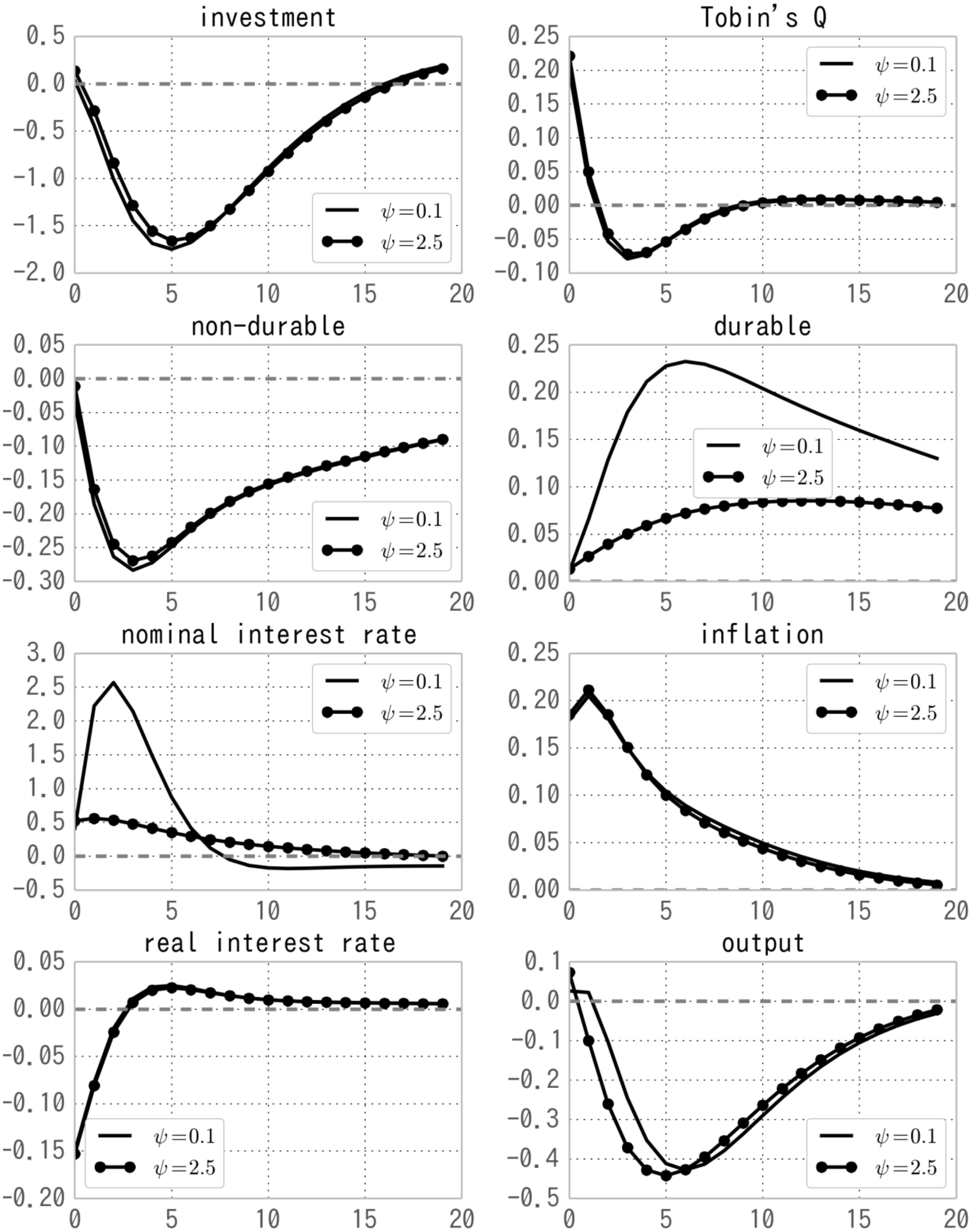


Figure 9: Impulse Response to a Nondurable Consumption Tax Shock

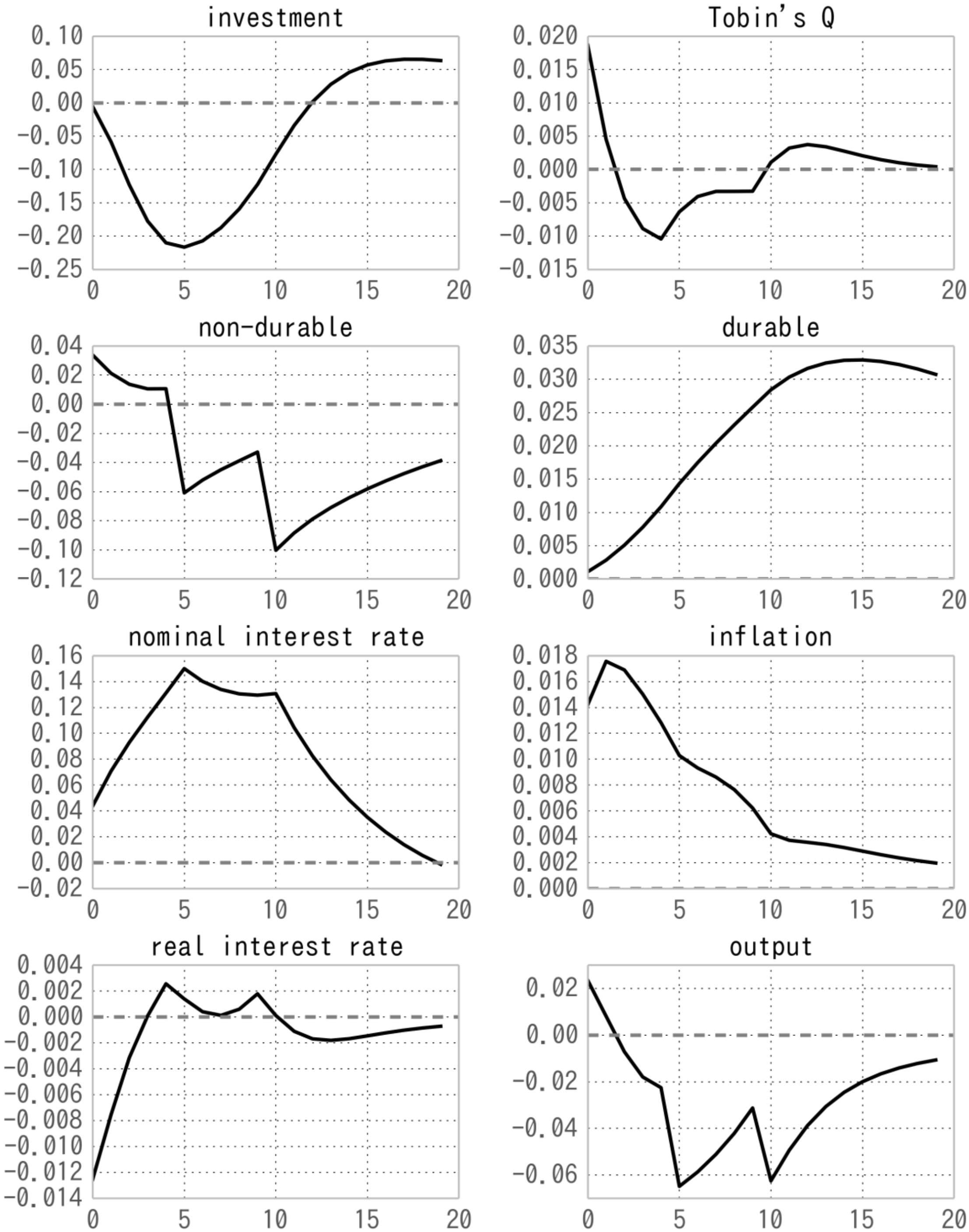


Figure 10: Comparison of Actual Interbank Rates and Reference Policy Rates Suggested by Estimated Taylor Rule.