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"Role of Financial and Productivity Shocks in the US
and Japan: A Two-Country Economy"

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Role of Financial and Productivity Shocks in the US and Japan: A Two-Country Economy[*]

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Abstract

Jermann and Quadrini (2012) show that compared with productivity shocks, direct shocks to the credit system ("financial shocks") have contributed to the most frequently observed dynamics of both real and financial variables in the US within a closed economy framework. We develop a simple two-country model featuring an international bond market and enforcement constraints within both countries in an attempt to quantify the role of productivity and financial shocks. We construct time series of productivity shocks and financial shocks using the US and Japanese quarterly data since 2001 and conduct simultaneous replication on major indicators of real variables and aggregate financial flows. The main results were as follows. First, for both the US and Japan, productivity shocks account for most real variable dynamics such as output and investment, while financial shocks well capture the trend of consumption, current account, and labor trends in the US and succeed in replicating Japan's debt repurchase behavior. Nevertheless, it is noteworthy that financial shocks served as key factors in accounting for the observed troughs of output, labor, and consumption, as well as the peaks of debt repurchase and the US current account during the 2007-09 financial crisis. Second, it is surprising that observable international spillover effect appeared only in Japan's debt repurchases. As it is widely considered that the Japanese economy have been deeply influenced by US economic fluctuations, our quantitative results raise questions about this opinion.

Keywords: Business fluctuations, financial friction, open economy, simulation

JEL classification: E32, E37, E44, F41

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1   Introduction

This paper aims to address two main questions: (1) whether financial shocks play a greater role than productivity shocks in accounting for real business cycles in the presence of financial integration and financial frictions and (2) whether there have been international spillover effects of country-specific shocks.

The financial crisis in 2007 spurred much debate regarding the financial sector's impact on the real business cycle[1]. Post-crisis, many studies examining business cycles not only model financial frictions but also began to incorporate financial shocks, i.e., shocks originating directly from the financial sector[2], into their dynamic stochastic general equilibrium models. For example, Jermann and Quadrini (2012) quantitatively show that in a closed economy framework, financial shocks have accounted significantly for the dynamics of US business fluctuations. Christiano, Motto, and Rostagno (2008) augment a standard monetary DSGE model to include financial markets and apply the model to Eurozone and US data. They suggest that new shocks originate in the financial sector and account for a significant portion of business cycle fluctuations. However, by incorporating a global bank into a two-country business cycle model, Kollmann, Enders, and Muller (2011) show that under normal economic situations, loan default shocks make a negligible contribution to business cycle fluctuations in the US and Eurozone. Furthermore, Kollmann (2012) shows that output components that are accounted for by non-banking shocks[3] fit very closely with historical US and Eurozone GDP data, a sharp contrast to the insignificant role found for banking shocks. In reference to other countries such as Japan, Otsu (2009, 2011) and Kaihatsu and Kurozumi (2010) show that productivity shocks remain the main driving force behind real business cycles. We notice that most studies reached different conclusions regarding whether financial or productivity shocks are more important in different background settings, and few studies have focused on spillover effects from these country-specific shocks to the other countries' business cycles. Therefore, to attempt to construct a model that could shed light on these issues, we built a calibrated two-country model incorporating financial frictions within countries and financial integrations across countries. Including both these factors allows us to explore whether productivity or financial shocks are more important to real business cycles under a more enriched background,

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[1]Before that, the mainstream traditional opinion regarding the role of financial frictions, such as credit market distortions, held that they played an important role in propagating shocks originating in productive sectors ("productivity shock") or monetary authorizations ("monetary shocks"). See for example Kiyotaki and Moore (1997); Bernanke, Gertler, and Gilchrist (1999); Mendoza and Smith (2006); and Mendoza (2010).

[2]See for example Devereux and Yetman (2010, 2011), Yao (2012), and Jermann and Quadrini (2012).

[3]Non-banking shocks include productivity shocks and labor supply shocks, investment efficiency, and government purchases.

as well as attempt to determine whether international spillover effects of country-specific shocks impact other countries' business cycles.

The model used in our paper follows that of Jermann and Quadrini (2012) and Quadrini (2012). Jermann and Quadrini (2012) built a closed business cycle model emphasizing the existence of enforcement constraints and financial rigidity when firms want to switch between debt and equity financing. The degree of rigidity is reflected by the dividend adjustment's cost. Financial shocks denoted in Jermann and Quadrini (2012) are disturbances that affect firms' ability to borrow intra-period debt from the credit market. When credit market distortions become more serious, firms have to reduce their intertemporal borrowing, turning instead to equity financing. Because equity financing imposes additional adjustment costs, firms have to reduce working hours, which has a knock-on effect on production activity. However, in contrast with Jermann and Quadrini (2012), the two country model in this paper implies that countries can also borrow or lend money from foreign countries and therefore face external asset exposure, which is similar to aspects of Quadrini's (2012) structure. Therefore, leverage constraints and external asset exposure combine to generate an international financial mechanism that could possibly transfer country-specific productivity or financial shocks to each other, which we refer to as spillover effects.

This paper first introduces a simple two-country model. Each country consists of three sectors: a firm, a household and an international financial market. Firms in each country borrow intra-period debt from the domestic market in order to pay workers, suppliers of capital, shareholders, and holders of previous debt before the realizing revenues. In addition, they contract intertemporal loans from both domestic and international financial market, which are subject to the domestic interest rate or international interest rate, respectively. We assume that only firms can trade bonds internationally, and both lenders and borrowers have to pay additional fees for international transactions. Firms' intra-period borrowing is limited by enforcement constraints, which implies that intra-period borrowing, the amount of which is equal to revenue, cannot exceed a certain extent of firms' net worth. Households can only trade bonds and firm equity in their domestic markets. Each country's external asset exposure consists of bonds, which are dominated in home currency (US dollars in our paper). The key mechanism is as follows: financial or productivity shocks occurring in one country influence enforcement constraints and directly affect domestic firms' intertemporal debt plans. Because adjusting equity payouts incurs additional costs, domestic firms have to change production plans so as to control their total financing costs. On the other hand, bond transactions in international financial markets provide a mechanism by which shocks originated in one country will exert indirect influence upon foreign firms' enforcement constraints and therefore affect produc-

tion activity in foreign countries, which is considered to be the channel of international spillover effects.

Secondly we constructed productivity and financial shocks by quarterly time series for both the US and Japan. Following Jermann and Quadrini (2012), productivity shocks are computed as Solow residuals while financial shocks are computed as residuals of the model's enforcement constraints. Using the constructed shock series, we not only conducted impulse responses, but also performed simultaneous replications to show the major statistic indicators on original real variables and aggregate financial flows, which will ensure a comprehensive evaluation of the role shocks play.

Our results show that first, for both the US and Japan, productivity shocks account for most dynamics observed for both output and investment. Financial shocks have contributed significantly to fluctuations in consumption, current accounts, and labor in the US. In particular, the effect of domestic financial shocks on the US current account is quite large according to the simulated series, which have tracked quite well to their empirical counterparts over the whole periods under investigation. In terms of financial variables, financial shocks in the model have succeeded in replicating Japan's debt repurchase behavior. In addition to the above results, it is worth noting that financial shocks are key factors in accounting for the observed troughs of output, labor, and consumption, as well as the peaks of debt repurchases and US current accounts during the 2007-09 financial crisis. Second, our model revealed the unexpected finding that observable international spillover effects only appeared in Japan's debt repurchases behavior which turned out to be vulnerable to shocks originating in the US. For other variables such as output or investment, no significant effects from shocks originating in other countries are observed.

This paper is directly related to research on the role of financial frictions in real business cycles. In addition to Jermann and Quadrini (2012), Benk, Gillman, and Kejak (2005) suggested the credit shock as a candidate shock important to determining GDP; Christiano, Motto, and Rostagno (2008) suggest that the new candidate shock originates in the financial sector and accounts for a significant portion of business cycle fluctuations by using Eurozone and US data. Other papers exploring this angle include Kiyotaki and Moore (2008) and Del Negro, Eggertsson, Ferrero, and Kiyotaki (2010). Most of these studies were conducted within a closed economy.

Another topic closely related to our paper is the international business cycle model incorporating financial frictions. Devereux and Yetman (2010) introduce a model of international transmission of shocks due to interdependent portfolio holdings among leverage-constrained financial institutions. They show that when leverage constraints bind, they combine with the presence of diversified portfolios to introduce a powerful financial transmission channel that results in a high correlation among macroeconomic aggregates during

business cycle downturns. Devereux and Sutherland (2011) develops a two-country model in which financial liberalization across countries takes place in the presence of domestic credit market distortions, finding that financial integration in bond markets alone generates highly-negative related co-movement across countries. Yao (2012) is close to Devereux and Yetman (2010) in studying financial frictions and capital portfolio choice in a two-country model, and further introduces into the model both capital accumulation and endogenous labor choice. Our paper differs from their studies in two aspects: (1) we use a different form of financial friction, concentrating on financial frictions existing in the intra-period debt market rather than the intertemporal debt market; (2) the above studies focus on the co-movement of output between two countries, while our study concentrates on determining the relative importance of various shocks in accounting for historical data; and (3), we present not only impulse responses, but also conduct simulations and compare these results with the empirical data. Other studies include Faia (2007), which uses OECD data to demonstrate that business cycles are more correlated among countries having similar financial structures, then builds a two-country DSGE model with financial frictions that replicates this observed pattern.

Our study is also related to studies examining Japanese business cycles in an open economy. Kaihatsu and Kurozumi (2010) show that, in both Japan and the US, neutral technology shocks are the main driving force behind output fluctuations, and financial shocks play as important a role in investment fluctuations as technology shocks. Otsu (2009, 2011) extend the business cycle accounting method la Chari, Kehoe, and McGrattan (2007) to a two-country international business cycle model and find that disturbances to the labor market and production efficiency account for much of the recent increase in the cross-country output correlation. Chakraborty (2009) finds that efficiency and investment wedges can almost wholly account for output increases of the 1980s, while in the 1990s, efficiency, labor and investment wedges all contributed to the recession.

Our paper is structured as follows: Section 2 introduces the three-sector-two-country model expanded from Jermann and Quadrini (2012). Section 3 calibrates the model using US and Japanese quarterly data and constructs time series of productivity and financial shocks. Section 4 presents the impulse response and simulation of business cycles' major indicators. Section 5 concludes.

2 Model

2.1 Firms sector

A continuum of firms exists in the [0,1] interval in each country: "home" and "foreign." Firms in each country have the same characteristics. Their utility is given by the following expression:

$$E_t \left[\sum_{t=0}^{\infty} m^t d_t \right]$$

Firms face the problem of maximizing dividend payments' expected value, which is subject to the exogenous time preference m. They hire workers and invest in capital to engage in production activity, and pay dividends to shareholders. We assume that firms in each country can engage in bond trading both domestically and abroad. Therefore, at the beginning of the period, each firm holds capital k_{t-1}, domestic intertemporal liabilities b^f_{t-1} and foreign intertemporal liabilities n_{t-1}. Here $b^f_t > 0$ indicates holding domestic liabilities and $b^f_t < 0$ refers to domestic asset holdings, both of which are subject to domestic interest rate r_t. For foreign bonds, $n_t > 0$ indicates liabilities and $n_t < 0$ indicates assets. Following Quadrini (2012), we assume that foreign bond holdings are denominated in the home country's currency and are subject to international interest rate $\tilde{r}_t$ and are costly[4]. Here we assume that their cost is related only to foreign bond aggregate holdings (N_t), and is represented by ψN_t. Based on the above assumption, the budget constraint of each home firm can be written as

$$y_t - w_t l_t + \frac{b^f_t}{1+r_t} + \frac{n_t}{1+\tilde{r}_t} = b^f_{t-1} + i_t + n_{t-1}(1 + \psi N_{t-1}) + d_t + \kappa(d_t - \overline{d})^2 \qquad (1)$$

where y_t denotes revenue, w_t is the real wage paid to workers, l_t is working hours. d_t is the equity payout and $\kappa(d_t - \overline{d})^2$ is its adjustment cost, where $\overline{d}$ is the long-run dividend target, and κ denotes the financial rigidity of changing financing tools from debt to equity. The production function and investment are described as follows:

$$y_t = z_t k_{t-1}^{\theta} l_t^{1-\theta} \qquad (2)$$

$$i_t = k_t - (1-\delta)k_{t-1} \qquad (3)$$

Before engaging in production activities, firms take out new intertemporal loans (domestically and abroad), repay previous debts, and choose labor inputs, investments, equity payouts and their adjustment costs. Following Jermann and Quadrini (2012), we assume

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[4]This assumption is useful for making the model stationary in terms of foreign asset positions.

that payments to workers, suppliers of investments, equity holders, and previous debt holders must be made before realization of revenues; therefore, firms need to take intra-period loans (at no interest) from lenders, and promise to repay these loans after realizing their revenues. Here the intra-period loan can be considered a way to cover the cashflow mismatch during the period and is equal to $w_t l_t + i_t + d_t + \kappa(d_t - \overline{d})^2 + b_t^f + n_{t-1}(1 + \psi N_{t-1}) - \frac{b_t^f}{1+r_t} - \frac{n_t}{1+\tilde{r}_t}$. Combining with the budget constraint, we find that the intra-period loan is equal to revenue y_t. Because default on the intra-period loan could occur following the realization of revenues (firms could divert these revenues), an enforcement constraint is required on the contract to ensure repayment of the intra-period debt.

$$\xi_t(k_t - \frac{b_t^f}{1+r_t} - \frac{n_t}{1+\tilde{r}_t}) \geq y_t \tag{4}$$

This constraint can be interpreted simply as the understanding that the intra-period loan can be no greater than ξ_t times the net worth of firm ($\xi_t < 1$). Because lenders need to liquidate the involved firms when default occurs, we interpret ξ_t as a way to capture the degree of financial friction. The smaller the value of ξ_t, the larger the loss of value that will occur in liquidation, meaning that larger collateral value is required to sign the contract[5]. We assume ξ_t is stochastic and uniform for all firms, and the financial shocks we indicate are the stochastic innovations of ξ_t. To simplify the analysis, we assume enforcement constraints to be binding prior to shocks, which is possible because firms are assumed to be less patient than households.

To understand the effect of ξ_t, the enforcement constraint is rewritten as

$$\left(\frac{\xi_t}{1-\xi_t}\right)[(1-\delta)k_{t-1} - b_{t-1}^f - n_{t-1}(1 + \psi N_{t-1}) - w_t l_t - d_t - \kappa(d_t - \overline{d})^2] \geq y_t$$

The occurrence of financial shocks affects production plans according to the rigidity of substitution between debt and equity financing. If adjusting dividend payments is too costly, firms have to change their production plan and, therefore, change labor inputs. If constraints are binding all the time, financial shocks would affect the real economy through enforcement constraints.

We define η_t and λ_t^f respectively as the Lagrangian multipliers of enforcement and

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[5]Jermann and Quadrini (2012) interpret the enforcement constraint as the best solution if both lenders and firms have an interest in renegotiating debts. They deduct the enforcement constraint from the bargaining problem and incentive-compatibility constraint. Since they assume firms have full bargaining power when renegotiating debts, ξ_t is equal to the fraction recovered following the firms being sold.

budget constraints in period t. Firms' first-order conditions are

$$1 = \lambda_t^f \left[1 + 2\kappa \left(d_t - d\right)\right] \tag{5}$$

$$w_t = \left(1 - \frac{\eta_t}{\lambda_t^f}\right)(1 - \theta)\frac{y_t}{l_t} \tag{6}$$

$$1 - \frac{\eta_t}{\lambda_t^f}\xi_t = E_t m \frac{\lambda_{t+1}^f}{\lambda_t^f}\left[1 - \delta + \left(1 - \frac{\eta_{t+1}}{\lambda_{t+1}^f}\right)\theta\frac{y_{t+1}}{k_{t+1}}\right] \tag{7}$$

$$1 - \frac{\eta_t}{\lambda_t^f}\xi_t = E_t m \frac{\lambda_{t+1}^f}{\lambda_t^f}(1 + r_t) \tag{8}$$

$$1 - \frac{\eta_t}{\lambda_t^f}\xi_t = E_t m \frac{\lambda_{t+1}^f}{\lambda_t^f}(1 + \tilde{r}_t)(1 + \psi N_t) \tag{9}$$

Equation (5) implies that the marginal utility of the additional dividend unit becomes smaller than its marginal cost when the amount of equity payout is larger than the long-run target. Equation (6) reveals the main channel through which financial shocks influence the real economy. When financial conditions worsen and enforcement constraints become tighter, the Lagrangian multiplier η_t becomes positive and generates a labor wedge. This labor wedge in turn leads to a high wage rate and decreases demand for labor. Equation (7) tells us that if the enforcement constraint binds, the marginal cost of capital is less than 1 because additional capital would relax the enforcement constraint. However, capital's efficiency in the next period is reduced because an additional unit of capital implies an additional intra-period loan unit, and therefore tighter constraints, in the next period. Equation (8) implies that binding constraints will lead intertemporal debt to have a smaller marginal benefit. Equation (9) shows that although the marginal cost of foreign debt is same as intertemporal debt, it has additional cost ψN_t for every unit of debt. In addition, domestic debt is subject to domestic interest, while foreign debt is subject to international interest. Therefore, when a country is a net borrower ($N_t > 0$) in the international financial market, its domestic interest will be higher than its international interest due to the arbitrage condition. If it is a net lender, its domestic interest will be lower than its international interest.

Following the same logic, the foreign country's problem can be described as follows:

$$E_t\left[\sum_{t=0}^{\infty} m_t^* d_t^*\right]$$

s.t

$$y_t^* - w_t^* l_t^* + \frac{b_t^*}{1 + r_t^*} + \frac{e_t n_t^*}{1 + \tilde{r}_t} = b_{t-1}^* + i_t^* + e_t n_{t-1}^*(1 + \psi^* N_{t-1}^*) + d_t^* + \kappa^*(d_t^* - \overline{d^*})^2 \quad (10)$$

$$y_t^* = z_t^* k_{t-1}^{*\,\theta^*} l_t^{*1-\theta^*} \quad (11)$$

$$i_t^* = k_t^* - (1 - \delta^*)k_{t-1}^* \quad (12)$$

$$\xi_t^*(k_t^* - \frac{b_t^*}{1 + r_t^*} - \frac{e_t n_t^*}{1 + \tilde{r}_t}) \geq y_t^* \quad (13)$$

where r_t^* is the interest rate in the foreign country (on local bonds denominated in the currency of the foreign country) and e_t is the exchange rate (units of foreign currency for one unit of home country currency). We assume the law of one price holds here. n_t^* is dominated in "home" country currency, and $n_t^* < 0$ implies that the foreign country is a net lender in international financial market, and $n_t^* > 0$ implies that the foreign country is a net borrower. The first order conditions of firms in the foreign country are

$$1 = \lambda_t^{f*}\left[1 + 2\kappa^*\left(d_t^* - d^*\right)\right] \quad (14)$$

$$w_t^* = \left(1 - \frac{\eta_t^*}{\lambda_t^{f*}}\right)(1 - \theta^*)\frac{y_t^*}{l_t^*} \quad (15)$$

$$1 - \frac{\eta_t^*}{\lambda_t^{f*}}\xi^* = E_t m^* \frac{\lambda_{t+1}^{f*}}{\lambda_t^{f*}}\left[1 - \delta^* + \left(1 - \frac{\eta_{t+1}^*}{\lambda_{t+1}^{f*}}\right)\theta^* \frac{y_{t+1}^*}{k_{t+1}^*}\right] \quad (16)$$

$$1 - \frac{\eta_t^*}{\lambda_t^{f*}}\xi^* = E_t m^* \frac{\lambda_{t+1}^{f*}}{\lambda_t^{f*}}(1 + r_t^*) \quad (17)$$

$$1 - \frac{\eta_t^*}{\lambda_t^{f*}}\xi^* = E_t m^* \frac{\lambda_{t+1}^{f*}}{\lambda_t^{f*}}(1 + \tilde{r}_t)\frac{e_{t+1}}{e_t}(1 + \psi^* N_t^*) \quad (18)$$

If we combine equations (8) with (9) and (17) with (18), and further abstract from the uncertainty between $E_t m \frac{\lambda_{t+1}^{f*}}{\lambda_t^{f*}}$ and $\frac{e_{t+1}}{e_t}$ (to simplify the analysis), we obtain

$$1 + r_t = (1 + \tilde{r}_t)(1 + \psi N_t) \quad (19)$$

$$1 + r_t^* = (1 + \tilde{r}_t)(1 + \psi^* N_t^*)(\frac{e_{t+1}}{e_t}) \quad (20)$$

If using the equilibrium condition $N_t + N_t^* = 0$ and ignoring exchange rate fluctuations[6],

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[6]It helps focus on the effect of productivity shocks and financial shocks.

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we can obtain the international interest as follows:

$$\tilde{r}_t = \frac{\psi r_t^* + \psi^* r_t}{\psi + \psi^*} \tag{21}$$

Furthermore, if we abstract $\tilde{r}_t$ from equations (19) and (20), we obtain the following relationship between r_t and r_t^*:

$$\frac{1 + r_t^*}{1 + r_t} = \frac{1 - \psi^* N_t}{1 + \psi N_t} \tag{22}$$

According to equation (22), we know that the interest rate is relatively higher in countries with negative net foreign asset positions ($N_t > 0$).

2.2 Households sector

There is a continuum of homogeneous households in the [0,1] interval in each country. Domestic households only receive wages from domestic firms, trade shares of domestic firms (total amount of shares is 1 in each country), and hold noncontingent bonds issued by domestic firms in every period. They are not allowed to engage in foreign transactions. All households have the goal of maximizing their lifetime utility as follows:

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\ln(c_t - \alpha l_t) \right]$$

s.t

$$w_t l_t + s_{t-1}(d_t + p_t) + b_{t-1}^h = \frac{b_t^h}{1 + r_t} + s_t p_t + c_t \tag{23}$$

where c_t is private consumption; l_t is labor supply; and β is the household's time discount factor. Because we assume firms are less patient than households, we therefore can state that $\beta > m$. Household have a Greenwood-Hercowitz-Huffman (GHH) preference, which is chosen because the wealth effect can be abstracted from the labor supply. Therefore, changes in labor supply closely react to output fluctuations. In the utility function, α is a parameter representing the disutility of labor. Equation (23) represents the household's budget constraint. b_t^h represents domestic corporate bonds purchased by households; s_t and p_t, respectively, are the amount of equity shares and the share price. Then we derive first-order conditions as follows:

$$1 = \lambda_t^h (c_t - \alpha l_t^\nu) \tag{24}$$

$$w_t = \alpha \nu l_t^{\nu - 1} \tag{25}$$

$$1 = \beta \frac{\lambda_{t+1}^h}{\lambda_t^h}(1 + r_t) \tag{26}$$

$$1 = \beta \frac{\lambda_{t+1}^h}{\lambda_t^h}\left(\frac{d_{t+1} + p_{t+1}}{p_t}\right) \tag{27}$$

where λ_t^h is the Lagrangian multiplier of a household's budget constraint. Equation (25) is the household's decision rule on labor supply, and equation (26) is the key condition for deciding the risk-free interest rate. Comparing equation (8) and equation (26), reveals that the assumption of less patient firm is important for ensuring stationary equilibrium with the binding constraint; the effect of such an assumption is the similar to Jermann and Quadrini's (2012) assumption of tax benefits. Following the exact same logic, we can present the household's foreign country problem as follows:

$$E_t \sum_{t=0}^{\infty} \beta_t^* \left[\ln(c_t^* - \alpha^* l_t^*)\right]$$

s.t

$$w_t^* l_t^* + s_{t-1}^*(d_t^* + p_t^*) + b_{t-1}^{h*} = \frac{b_{t}^{h*}}{1 + r_t^*} + s_t^* p_t^* + c_t^* \tag{28}$$

Then we derive first-order conditions as follows:

$$1 = \lambda_t^{h*}(c_t^* - \alpha^* l_t^{*\nu^*}) \tag{29}$$

$$w_t^* = \alpha^* \nu^* l_t^{*\nu^* - 1} \tag{30}$$

$$1 = \beta^* \frac{\lambda_{t+1}^{h*}}{\lambda_t^{h*}}(1 + r_t^*) \tag{31}$$

$$1 = \beta^* \frac{\lambda_{t+1}^{h*}}{\lambda_t^{h*}}\left(\frac{d_{t+1}^* + p_{t+1}^*}{p_t^*}\right) \tag{32}$$

2.3 International financial markets

We assume that bonds can be transacted in international financial markets, and are dominated in the "home" country's currency. International financial market equilibrium can therefore be written as

$$N_t + N_t^* = 0 \tag{33}$$

This is a key condition for exploring possible international spillover effect from shocks. Any shocks affecting the enforcement constraints' tightness in one country would influence the foreign asset position and therefore this condition would affect tightness of enforcement constraints, financial decisions, and even production plans in the other country.

2.4 Competitive equilibrium of a two country economy

A competitive equilibrium is defined as a set of functions for

- Households' policies c_t, l_t, b_t^h in the home country, and c_t^*, l_t^*, b_t^{h*} in the foreign country.

- Firms' policies d_t, l_t, b_t^f, n_t, i_t in the home country, and d_t^*, l_t^*, b_t^{f*}, n_t^*, i_t^* in the foreign country.

- Aggregate prices w_t, r_t, p_t in the home country, and w_t^*, r_t^*, p_t^* in the foreign country, and $\tilde{r}_t$ in the international financial market.

Such that

- Households' policies in each country satisfy conditions (24)-(27) and (29)-(32) given aggregate prices w_t, r_t, p_t, w_t^*, r_t^*, and p_t^*, respectively.

- Firms' policies in each country are optimal, given w_t, r_t, k_{t-1}, b_{t-1}, N_{t-1}, z_t, ξ_t, w_t^*, r_t^*, k_{t-1}^*, b_{t-1}^*, N_{t-1}^*, z_t^*, ξ_t^* and $\tilde{r}_t$, respectively.

- Goods markets clear

$$Y_t + \frac{N_t}{1 + \tilde{r}_t} = I_t + C_t + N_{t-1}(1 + \psi N_{t-1}) + \kappa(D_t - \overline{D})^2 \qquad (34)$$

$$Y_t^* + \frac{e_t N_t^*}{1 + \tilde{r}_t} = I_t^* + C_t^* + e_t N_{t-1}^*(1 + \psi^* N_{t-1}^*) + \kappa^*(D_t^* - \overline{D^*})^2 \qquad (35)$$

- Local bond markets in each country clear $B_t^f + B_t^h = 0$ and $B_t^{f*} + B_t^{h*} = 0$.

- Equity markets in each country clear $S = 1$ and $S^* = 1$.

- International financial market clear $N_t + N_t^* = 0$.

- Wage and interest rates clear the labor and bond markets, and $\tilde{r}_t = \frac{\psi r_t^* + \psi^* r_t}{\psi + \psi^*}$.

3 Quantitative analysis

3.1 Data

In this section, we apply seasonally-adjusted quarterly macro data from the US and Japan to the two country model, taking the US as the home country and Japan as the foreign country. Our study covers the period from 2001Q1 to 2010Q4. We chose 2001Q1 as the

beginning period of our study because we use real value data in our simulations, and most macro data (including real GDP, GDP deflators and others) adjusted in constant (2005) prices was released from 2001Q1. We choose 2010Q4 as the ending year because official labor data from 2011Q1 to 2011Q3 is unavailable. Nominal data except interest rates are deflated by the price index (base = 2005). Data used in the simulation are detrended by Hodrick-Prescott filters with a default smoothing parameter of 1600. We will now present more detailed information regarding each data resource.

3.1.1   US Data

For the US, we obtained financial data from the Federal Reserve Board's Flow of Funds Accounts. Debt stock is that given in "Credit Market Instruments of Nonfinancial Business" (LA144104005.Q), which we seasonally adjusted and deflated by "Price Indexes for Gross Value Added in the Business Sector" (National Income and Product Accounts, NIPA, Table 1.3.4). Debt repurchases are the flow of "Credit Market Instruments of Nonfinancial Business" (FA144104005.Q). The debt repurchase to output ratio is computed by dividing debt repurchases by the Gross Value Added for the Business Sector (NIPA Table 1.3.5), adjusted by "Price Indexes for Gross Value Added in the Business Sector" (NIPA, Table 1.3.4). Dividend flow is computed by Net Dividends Paid in Nonfinancial Corporate Business (FA106121075.Q) plus Undistributed Corporate Profits excluding IVA and CCAdj in Nonfinancial Corporate Business (FA106006405.Q) minus Proprietors' Equity in Non-corporate business (FA112090205.Q) minus 'Net New Equity Issue' in the Nonfinancial Corporate(FA103164103.Q). Dividend output ratio is the dividend flow divided by the Gross Value Added for the Business Sector (NIPA Table 1.3.5), adjusted by the price index. The foreign asset position is constructed from totaling the current account adjusted by the price index. The initial position value (end of 2000) is taken from the International Investment Position of the United States at year-end (Table B-107), adjusted by the price index. Current account output ratio is computed by current account divided by the Gross Value Added for the Business Sector (NIPA Table 1.3.5).

Capital Stock is constructed from totaling Capital Expenditures of the Nonfinancial Business (FA145050005.Q) minus Consumption of Fixed Capital of Nonfinancial Corporate Business (FA106300083.Q) and Consumption of Fixed Capital of Nonfinancial Non-corporate Business (FA116300001.Q). Initial stock values are taken from the Fixed Asset Table (Table 4.1, Current-Cost Net Stock of Nonresidential Fixed Assets by Industry Group and Legal Form of Organization) for the Nonfinancial Corporate Businesses, Sole Proprietorships and Partnerships, including the stock of inventory from (NIPA Table 5.7.5) at the end of 1991. We deflated nominal values by the Price Index for Gross Private

Domestic Investment (NIPA Table 1.1.9). Investment is defined as Capital Expenditures of Nonfinancial Business (FA145050005.Q) and deflated by the price index (NIPA Table 1.1.9). Labor is taken from the Index of Aggregate Weekly Hours from the Current Employment Statistics national survey. Consumption includes nondurables and services (NIPA Table 1.1.5) and is deflated by the price index for nondurables and services (NIPA Table 1.1.9) respectively. Output is Gross Value Added for the Business Sector (NIPA Table 1.3.5.) deflated by the Price Indexes for Gross Value Added in the Business Sector (NIPA, Table 1.3.4). We construct all interest series from the monthly data by 3 month average. The interest rate used to compute firms' discount factor is the average majority prime rate published by the Federal Reserve Board that banks charge on short-term loans to businesses. The rate used to compute households' discount factor is the average rate offered on 3-month negotiable certificates of deposit.

3.1.2   Japanese Data

Financial data such as interest rate and debt stock are taken from the Bank of Japan, while other data such as corporate dividends, real gross domestic product, corporate gross capital formation, and household domestic final consumption expenditure are taken from Cabinet Office data[7]. All data are seasonally adjusted by Census X12 (except interest rate) and measured at constant 2005 prices. Debt stock is computed from Stock of Loans Liabilities of Nonfinancial Corporations (FF'FOFFFAS410L200) plus Securities other than Equity of Nonfinancial Corporations (FF'FOFFFAS410L300) plus Financial Derivatives of Nonfinancial Corporations (FF'FOFFFAS410L340) minus External Securities Issued by Residents of Nonfinancial Corporations (FF'FOFFFAS410L316), adjusted by GDP deflator in constant 2005 prices (fixed-based method). Debt repurchases are constructed from nonfinancial corporations' net decrease in debt stock. Debt repurchase to output ratio is computed by dividing the quarterly series of debt repurchase by GDP. Dividend output ratio is calculated from dividends provided by the Secondary Distribution of Income Account published by Office Portal Site of Official Statistics of Japan, divided by GDP. The foreign asset position is constructed by totaling changes of external assets published by the Cabinet Office, deflated by the GDP deflator in constant 2005 prices (fixed-based method). The initial position value (end of 2000) is taken from Japan's International Investment Position (IMF Balance of payments Manual 5th base). Current account output ratio is computed by change in foreign assets divided by GDP.

Average working hour per week is computed as follows: (average working hour per week

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[7]Data from the Cabinet Office are obtained from the Office Portal Site of Official Statistics of Japan, developed by Statistics Japan.

in all industries multiplied by working population in all industries) divided by (labor force × 24hours × 7days). Capital stock is calculated by totaling the corporate businesses' real gross capital formation[8] minus fixed capital real consumption (excluding the government). The initial value is corporate businesses' net wealth at the end of 2000. Investment is real gross capital formation at constant 2005 prices. Consumption is real final household consumption at constant 2005 prices. The average monthly Average Contracted Interest Rates on Loans and Discounts was used to compute the discount factor for Japanese firms. The Average Interest Rates on Certificates of Deposit by Maturity (New Issues) is used to compute households' discount rate.

3.2 Parametrization

Using the US empirical series, we calibrate the model as described in Table 3.1. Because the foreign asset position is dominated in home country currency, we take Japan as the foreign country and the US as the home country, as US dollars are commonly considered an international currency. For home country parameters, firms' discount factor is set to correspond to the average majority prime rate charged by banks (5.38 percent). Households' discount factor is set to match the average rate on 3-month negotiable certificates of deposit (2.59 percent). Labor's disutility is set to 1.898, corresponding to a labor supply of 0.33. The inverse elasticity of labor supply is set to 1.6 to match the Frisch labor elasticity of 0.6, which is in line with Greenwood, Hercowitz, and Huffman (1988). The production technology parameter follows the assumption in Jermann and Quadrini (2012). The depreciation rate is set to 0.039, which is nonfinancial businesses' approximate average depreciation rate. The steady state enforcement parameter value of 0.588 is the average level calculated by the empirical series. The equity payout parameter of 0.555 matches the dividend output ratio's standard deviation of 0.0248. The foreign transaction cost parameter is set to 0.0025 to match the current account to output ratio's standard deviation. We assume the capital adjustment parameter is 0.5, which lies within the reasonable range implied by the literature.

Foreign country parameters are calibrated following the same steps as given above for the home country. Firms' discount factor is set to match the average contracted interest rates on loans and discounts (1.44 percent), while households' discount factor is set to match average interest rates on certificates of deposit by maturity (0.19 percent). Labor's disutility is set to 3.163, corresponding to a labor supply of 0.33. The inverse elasticity of labor supply is set to 2 to match a Frisch labor elasticity of 1, which satisfies Kuroda and

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[8]This is calculated by subtracting government gross fixed capital formation and government inventory from gross capital formation.

Yamamoto (2008)'s estimate of 0.7 to 1.0 for both females and males in Japan. The Cobb-Douglas parameter in the production function follows Hayashi (2002). The depreciation rate is set to 0.039, which corresponds to an average depreciation rate (excluding the government). The equity payout parameter is set to 6.1 to match the standard deviation of dividend output ratio (0.006). The steady state enforcement constraint parameter is calculated as 0.371, which implies that financial friction in Japan's credit market is more serious than in the US. The foreign transaction cost parameter is set to 0.005 to indicate that Japanese firms face higher costs to engage in the international bond trade. We assume the parameter of capital adjustment cost is 0.5, which is standard in the literature. The exchange rate is 110, approximately the historical average level of the USD to JPY exchange rate.

Table 3.1: Parametrization

Home country	
Discount factor of home firm	0.9489
Discount factor of home household	0.9748
Disutility of labor	1.898
Inverse elasticity of labor supply	1.6
Production technology	0.36
Depreciation rate	0.039
Enforcement parameter	0.588
Payout cost parameter	0.555
Cost of foreign transaction	0.0025
Capital adjustment cost	0.5
Foreign country	
Discount factor of home firm	0.9858
Discount factor of home household	0.9981
Disutility of labor	3.163
Inverse elasticity of labor supply	2
Production technology	0.362
Depreciation rate	0.039
Enforcement parameter	0.371
Payout cost parameter	6.1
Cost of foreign transaction	0.005
Capital adjustment cost	0.5
Exchange rate	110

After calibrating the above parameters, we construct productivity and financial shocks. First, we follow the standard Solow residuals approach, computing productivity shocks for both home and foreign countries from the linearized forms of production functions as follows:

$$\hat{z}_t = \hat{y}_t - \theta\hat{k}_{t-1} - (1-\theta)\hat{l}_t,$$

$$\hat{z}_t^* = \hat{y}_t^* - \theta^*\hat{k}_{t-1}^* - (1-\theta^*)\hat{l}_t^*,$$

where variables with hats denote percentage deviations from deterministic trends, or long-run targets. We use series linearly detrended by the Hodrick-Prescott filter as their empirical counterparts. Next we conduct linear regression on time series $\hat{z}_t$ and $\hat{z}_t^*$ respectively:

$$\hat{z}_{t+1} = \rho_z\hat{z}_t + \epsilon_{z,t+1}$$

$$\hat{z}_{t+1}^* = \rho_z^*\hat{z}_t^* + \epsilon_{z^*,t+1}.$$

We now obtain innovations $\epsilon_{z,t}$ and $\epsilon_{z^*,t}$, the residuals generated by the regression, which we refer to as productive shocks.

Similarly, we derive innovations of the enforcement constraint parameters. We begin by computing $\hat{\xi}_t$ and $\hat{\xi}_t^*$ using a method similar to the Solow residuals approach:

$$\hat{\xi}_t = \hat{y}_t - \frac{\xi K}{Y}\hat{k}_t + \frac{\xi B}{Y}\hat{b}_t^e + \frac{\xi N}{Y}\hat{n}_t^e$$

$$\hat{\xi}_t^* = \hat{y}_t^* - \frac{\xi^* K^*}{Y^*}\hat{k}_t^* + \frac{\xi^* B^*}{Y^*}\hat{b}_t^{e*} + \frac{\xi^* N^*}{Y^*}\hat{n}_t^{e*},$$

where large characters without time scripts denote the steady-state value of aggregate variables. It is shown that fluctuation of the constructed $\hat{\xi}_t$ and $\hat{\xi}_t^*$ are always less than 100 percent. Since we assume enforcement constraints are binding at the steady state, it seems reasonable to therefore assume that enforcement constraints were binding during the entire simulation period. The end-of-period values for domestic and foreign liabilities are represented by $\hat{b}_t^e = \hat{b}_t^h/(1+r_t)$ and $\hat{n}_t^e = \hat{n}_t/(1+\tilde{r}_t)$ respectively. Following construction of productivity shocks, we derive innovations $\epsilon_{\xi,t}$ and $\epsilon_{\xi^*,t}$ by the following equations:

$$\hat{\xi}_{t+1} = \rho_\xi\hat{\xi}_t + \epsilon_{\xi,t+1}$$

$$\hat{\xi}_{t+1}^* = \rho_{\xi^*}\hat{\xi}_t^* + \epsilon_{\xi^*,t+1}$$

We summarize the properties of constructed series in Table 3.2. In the next section, we use the innovation series $\epsilon_{z,t}$, $\epsilon_{z^*,t}$, $\epsilon_{\xi,t}$ and $\epsilon_{\xi^*,t}$ to replicate continuous exogenous shocks, which allows our model to simulate real external environments.

Table 3.2: Shocks

Home country	
Std of productivity innovations	0.011
Std of financial innovations	0.034
Autocorrelation of TFP	0.850
Autocorrelation of enforcement parameter	0.929
Foreign country	
Std of productivity innovations	0.019
Std of financial innovations	0.048
Autocorrelation of TFP	0.782
Autocorrelation of enforcement parameter	0.718

4 Findings

First, we would like to examine the constructed series of productivity and financial shocks in the US and Japan. Figure 4.1 shows that productivity shocks in both the US and Japan experienced peaks and troughs in 2003-04 and 2008-09 respectively, while financial shocks, which had experienced recovery beginning in 2001, suddenly deteriorated rapidly after 2005. The trough in 2009 can be considered as corresponding to the recent financial crisis. For Japan, we find serious financial tightness during 2005-06 and 2009. Both productivity and financial shocks are the out-of-expectation aspect of market forecasts, since we suppose those conducting market analysis use auto-aggressive processes to forecast z_t, z_t^*, ξ_t, and ξ_t^*. In the following subsections, we attempt to model a real economy world in a two country model by using these unexpected components. First, we will analyze the impulse response functions (IRFs) of productivity and financial shocks and explain the model's mechanism; second, we will show the simulation results for major real and financial variables and compare the moments generated by the two country model.

4.1 Impulse response

In this section, I analyze how the two-country economy responds to a one-standard-deviation negative shock in one country. We refer to the home country as the borrowing country because its foreign assets position[9] is positive in the steady state. Correspondingly, the foreign country is considered the lending country due to its negative foreign assets position.

4.1.1 Productivity shocks originating in borrowing country

First, we examine how the economy reacts to a one-standard-deviation negative productivity shock originating in the borrowing country. As shown in figure 4.2, a negative home country productivity shock lowers the capital's marginal efficiency, which in turn causes a decline in capital investment. A fall in revenue generated by production activities implies a lower amount of intra-period loans in the home country and further alleviates enforcement constraints, causing a fall in the enforcement constraint's Lagrangian multiplier. As the marginal benefits of intertemporal debt relatively increase, equations (8) and (9) imply that firms will increase their amounts of both domestic and foreign debt, and that such demands will lead to a higher equilibrium interest rate. Since the return on foreign bonds becomes higher than their steady state value, the lending country will increases its domestic intertemporal borrowing to finance foreign lending. Conversely, because firms reduce dividend payouts so as to fund foreign lending, budget constraints' Lagrangian multiplier increases, resulting in the marginal cost of capital investment in the lending country also rising. Because the marginal efficiency of capital investment is not affected by productivity shocks originating in the borrowing country, the equilibrium investment level falls. According to figure 4.2, enforcement constraints in the lending country tighten shortly after the shocks' occurrence and therefore domestic borrowing in the lending country suddenly decreases. Consequently, the international interest rate drops and foreign lending also begins to drop. Furthermore, a tighter enforcement constraint increases labor costs, resulting in declining foreign output and demand for labor. Therefore, a negative productivity shock originating in the borrowing country exerts an immediate "crowding out" on investment and a negative effect on the lending country's output and employment soon after the shock.

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[9]Remember we assume a positive foreign assets position means borrowing from international financial markets.

4.1.2 Productivity shocks originating in the lending country

Figure 4.3 illustrates the result of a one-standard-deviation negative productivity shock in the lending country: capital's lower marginal efficiency causes capital investment to fall. The decline in production revenue, in turn, leads firms to decrease dividend payouts, causing the budget constraints' Lagrangian multipliers to rise. Furthermore, demand for intra-period loans will decrease, which helps alleviate enforcement constraints faced by firms. Therefore, the marginal cost of foreign lending increases, leading to a decrease in foreign lending. On the other hand, a smaller labor wedge will boost demand for labor. As the supply of foreign funds decreases, the borrowing country sees falls in the position of external debts, and the firms' Lagrangian multiplier of enforcement constraints become smaller. Although capital's marginal return is unaffected, its marginal cost becomes higher, which leads to reduced capital investment. Furthermore, demand for labor in the borrowing country increases in response to a higher marginal benefit, and output rises slightly. Therefore, from figure 4.3, we conjecture that a negative productivity shock in the lending country immediately exerts a "crowding out" effect on investment, but has an immediate positive effect on output and employment within the borrowing country.

4.1.3 Financial shocks originating in the borrowing country

Figure 4.4 illustrates the impact of financial shocks originating in the borrowing country. The financial shock directly tightens enforcement constraints in the borrowing country, forcing firms to reduce both their domestic and foreign intertemporal debts so as to relieve this tightness. This de-leveraging also leads to a fall in the equilibrium interest rate as well as demand for capital. Furthermore, a higher Lagrangian multiplier for enforcement constraints also causes a larger labor wedge, with a concomitant fall in demand for labor. On the other hand, declining firm demand for foreign funds leads to a drop in foreign funds' equilibrium amount. Consequently, firms in the lending country reduce their domestic intertemporal borrowing, replacing their purchases of foreign bonds with increased capital investment. Booming capital investment and shrinking intertemporal borrowing alleviates firms' enforcement constraints, stimulating a rise in hiring and output shortly after a shock's occurrence. Therefore, a negative financial shock in the borrowing country has an immediate "stimulating" effect on investment and a positive effect on output and employment in the lending country shortly after the shock's occurrence.

4.1.4   Financial shocks originating in the lending country

Figure 4.5 show how an economy reacts to a negative financial shock originating in the lending country. After a negative financial shock, firms in the lending country face tightened enforcement constraints. The Lagrangian multipliers of the lending country's enforcement constraints increase, forcing firms to reduce demand for labor. As a consequence, output falls instantly. Meanwhile, firms in the lending country begin to reduce intertemporal debt to relieve these constraints, causing a fall in the equilibrium domestic interest rate. Given lower expected returns and a shrinking source of funds, firms begin to reallocate their assets from foreign assets to domestic capital. The borrowing country, on the other hand, faces a fall in the supply of low-cost foreign funds, which forces firms to increase domestic intertemporal debt to cover this reduction. Figure 4.5 reveals that enforcement constraints become slightly tighter than those in the steady state, which causes a temporal decline in both equilibrium labor and output. Notice that enforcement constraints in the borrowing country become looser after a shock's occurrence due to a continuing depression in the foreign assets market. As a result, capital's marginal cost grows higher than marginal efficiency, resulting in falling investment. Therefore, our model indicates that negative financial shocks originating in the lending country have a "crowding out" effect on investment shortly after a shock's occurrence and a negative immediate effect on the borrowing country's output and employment.

4.2   Simulation

To study how shocks influence the model's dynamics, we feed the series of innovations constructed into the model and compute responses for both real and financial variables. Figures 4.6-4.17 plot the detrended series for output, labor, consumption, investment, current account, and debt repurchases in both the US and Japan. In order to assess whether financial or productivity shocks are more important in accounting for real business cycles, we conduct simulations covering several different aspects, including plotting series by US (Japanese) productivity shocks only, US (Japanese) financial shocks only, and series generated by shocks originating in the US or Japan. Furthermore, in order to determine the existence of international spillover effects from country-specific shocks, we also plot series for the US (Japan) with shocks originating in Japan (the US). In order to analyze the result quantitatively, we show the moments of simulated series and the data in Table 4.1.

4.2.1 Accounting for the US economy

As shown in figure 4.6, since 2001, domestic productivity shocks provide a good explanatory paradigm that accounts for most US output fluctuations. In particular, the observed deterioration of output after 2001 and the recovery after 2003 can be captured well by productivity shocks. On the other hand, the series generated only by financial shocks during this period show a general uptrend, a pattern quite different from reality. Furthermore, the US economy after 2007 declined after peaking in the fourth quarter, a trend that has also been generally replicated by the modeled productivity shocks. However, if we examine the series generated by financial shocks, we find that the US's output should have declined prior to 2007. The moments shown in Table 4.1 also prove our findings. As shown, the correlation between data and simulated productivity shock series is 0.7421, higher than the 0.6815 correlation generated by financial shocks. In addition, the standard deviation of the productivity shock simulated series is 0.0189, quite close to its 0.0175 empirical counterpart. By contrast, the standard deviation of the financial shock simulated series is only 0.0092, significantly smaller than that in the data. However, during 2007-09 financial crisis, even though the series generated by both shocks simultaneously are more volatile than the data, it does capture well the timings of both the drop and recovery of US output. Therefore, it is important to consider financial shocks when analyzing the dynamic of output during the 2007-09 financial crisis. This conjecture is also been proved by the moments revealed in Table 4.1, which shows that correlation improves to 0.7733 when both types of shocks are considered simultaneously.

In terms of other real variables, figure 4.7 indicates that financial shocks provide a stronger explanation of labor compared to productivity shocks, especially during the 2007-09 financial crisis. The simulation's performance improves further if we consider financial and productivity shocks simultaneously. The standard deviation of the simulated labor series generated by both shocks is 0.0229, quite close to the 0.0216 level in the data. For consumption, the series generated by productivity shocks are closer to the data during 2003-07, while consumption's decline during the 2007-09 financial crisis is obviously better captured by financial shocks. An interesting finding is revealed by figure 4.9, which reveals that the investment series generated by US-originating financial shocks displays very weak fluctuations, significantly smaller than that in the data. On the other hand, investment movements generated in response to productivity shocks generally capture the trends in the data, especially during 2001-03. According to figure 4.10, financial shocks only can replicate the current account data quite well, a finding that is unexpected. The correlation between real data and simulated data reaches 0.6063, and the standard deviations for the data and simulated series are 0.0016 and 0.0017 respectively. Especially during the 2007-

09 financial crisis, the current account peak is exactly replicated by financial shocks alone. By contrast, a substantial divergence opened between the data and the current account series generated by productivity shocks. For debt repurchases, although the 2003-06 downturn and the peak during the 2007-09 financial crisis can be explained well by both shocks, both shocks failed in explaining the 2007-08 trough. For spillover effects, we find shocks originating in Japan were only marginally helpful in accounting for US business cycles.

Therefore, overall, productivity shocks have been more influential in explaining output and investment dynamics, and financial shocks can capture well trends in consumption, current accounts, and labor. Furthermore, it is clear that the observed troughs of output, labor, and consumption, as well as the peaks of current accounts and debt repurchases are deeply related to financial shocks during 2007-09 financial crisis.

4.2.2   Accounting for the Japanese Economy

Figure 4.12-4.17 illustrates the simulated series and empirical counterparts for Japan. Figure 4.12 shows that domestic productivity shocks alone can well explain Japan's output dynamics. The correlation between simulated series and the data reaches 0.9597, and the standard deviations of the simulated series and their empirical counterparts are 0.0227 and 0.0208. Output explained by financial shocks implies that the economy should have quickly recovered after the financial crisis; however, negative productivity shocks delayed the recovery. Although it is widely believed that the US financial crisis should have more or less impacted the Japanese economy, at least according to our simulation, financial shocks originating in the US turned out to have no obvious effect on the Japanese economy.

In terms of labor in Japan, although the correlation between the simulated series and the data is only 0.2216, according to figure 4.13, we can see that before 2005, productivity shocks can capture well labor's dynamics. Furthermore, the figure indicates that the labor market should recover from the 2010 trough if productivity shocks alone are considered. However, after incorporating financial shocks in addition to productivity shocks, the timing of recovery after the 2007-09 financial crisis becomes consistent with the empirical counterparts. Therefore, our findings reveal that the looser domestic financial environment helped accelerate Japan's economic recovery. The simulation covering consumption shows similar results. Figure 4.14 reveals that financial shocks are important in accounting for the trough seen at the beginning of 2009. Figure 4.15 shows that productivity shocks can account for most Japanese investment fluctuations. The correlation between the simulated series and the data is 0.6286, and standard deviation is also quite close to that of the data. In contrast with the US, neither shock could explain well Japan's current

account. Figure 4.17 shows that financial shocks alone can capture well debt repurchase fluctuations; the correlation shown in Table 4.1 reaches 0.7561. In addition, the correlation further increases to 0.8483 if we consider both types of shocks simultaneously. In terms of the spillover effect, Japan's debt repurchases are the only variable vulnerable to shocks originating in the US. Furthermore, financial shocks occurring during the 2007-09 financial crises served to amplify fluctuations in debt repurchases.

In summary, productivity shocks alone can account for most dynamics of output and investment during the past 10 years, as well as for partial fluctuations in labor before 2005. While Japan's financial shocks captured well the changes in debt repurchases, and have been helpful in explaining troughs of output, labor, and consumption during the 2007-09 financial crisis. The obvious spillover effect from the US to Japan only appeared in debt repurchases, and turned out to be insignificant in terms of other variables during the past decades.

Figure 4.1: Estimates of Shocks
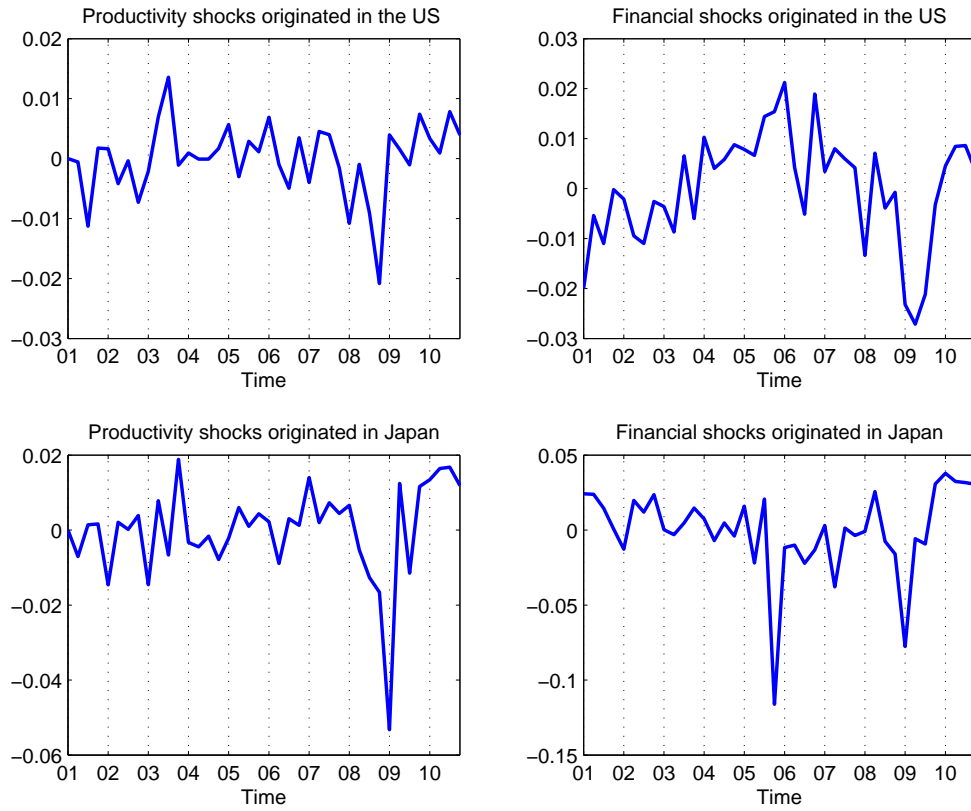
Figure 4.2: Response to one-standard-deviation negative productivity shock originated in borrowing country
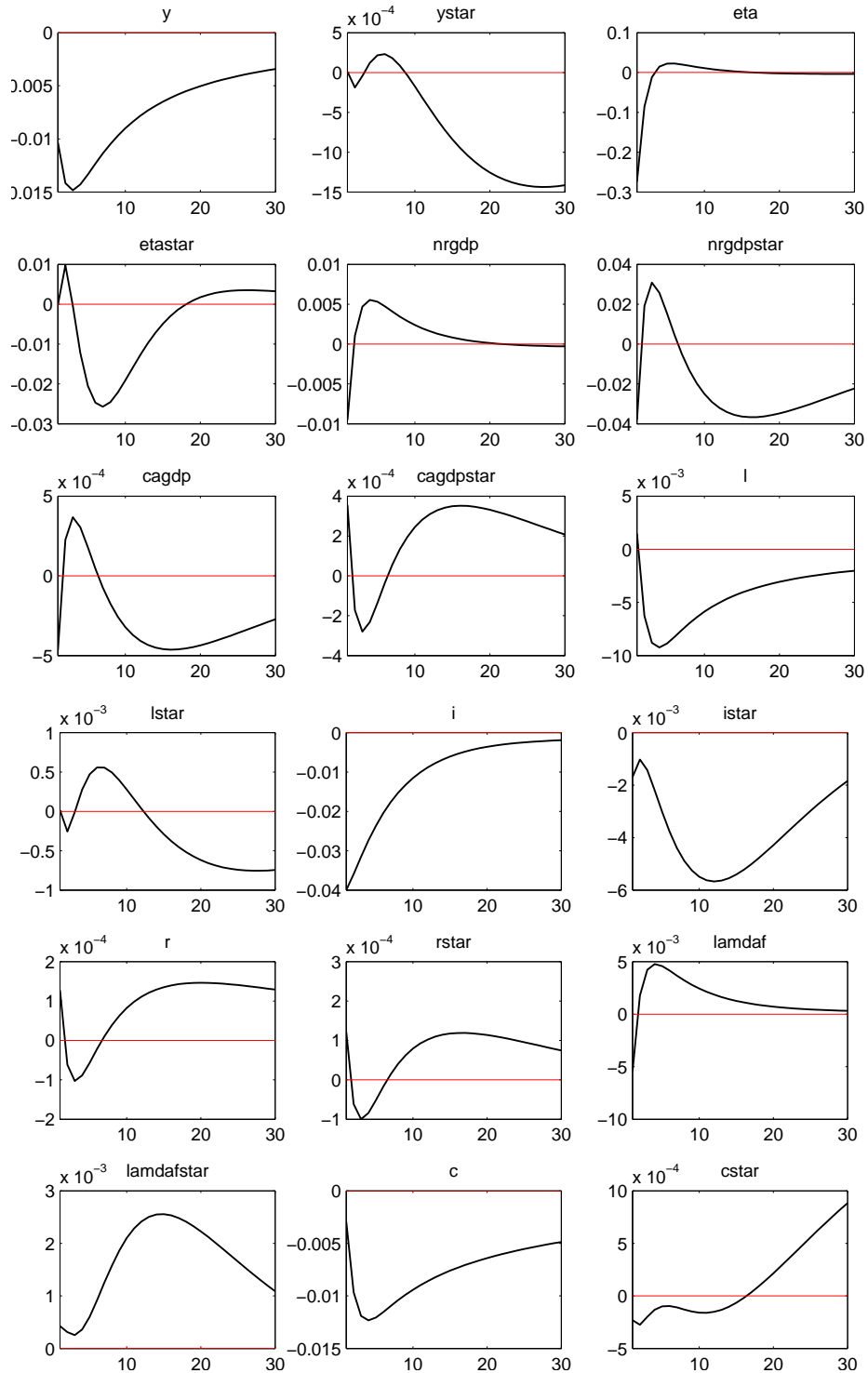
1, y, eta, nrgdp, cagdp, l, i, r, lamdaf, c indicate output, Lagrangian multiplier of enforcement constraint, debt repurchase, labor, investment, interest, Lagrangian multiplier of budget constraint and consumption in the home country. ystar, etastar, nrgdpstar, cagdpstar, lstar, istar, rstar, lamdafstar, cstar indicate output, Lagrangian multiplier of enforcement constraint, debt repurchase, labor, investment, interest, Lagrangian multiplier of budget constraint and consumption in the foreign country.

Figure 4.3: Response to one-standard-deviation negative productivity shock originated in lending country
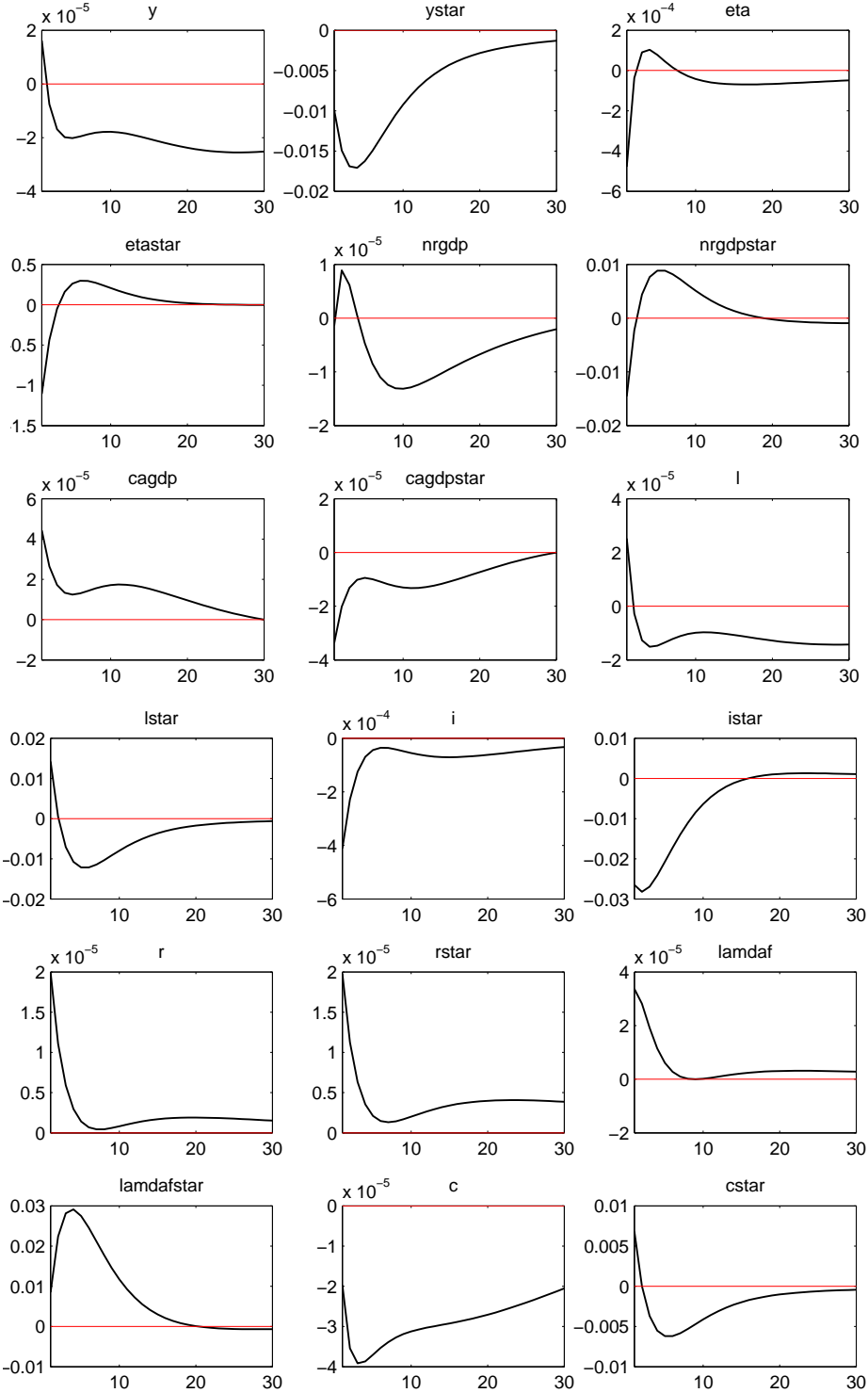
Figure 4.4: Response to one-standard-deviation negative financial shock originated in borrowing country
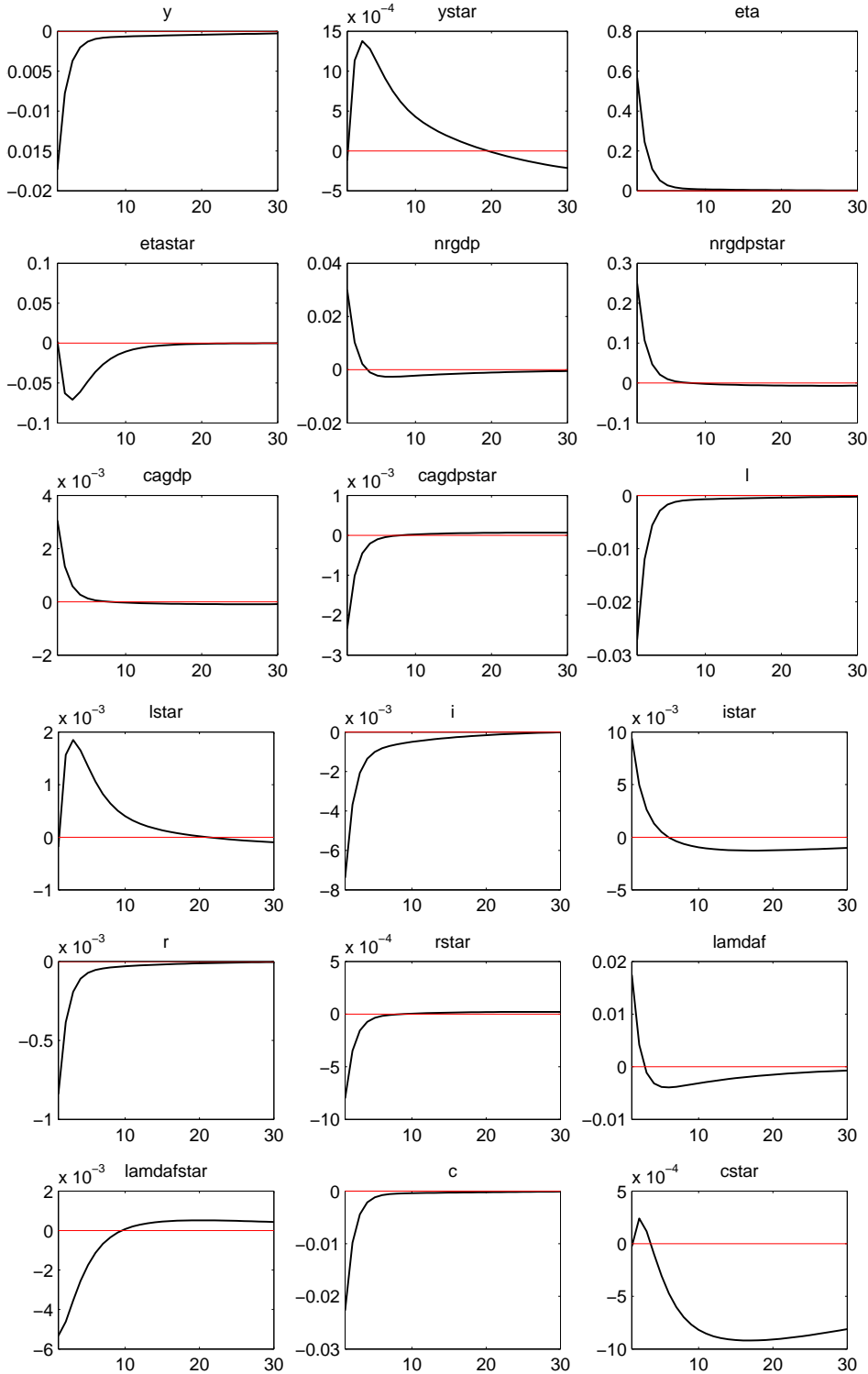
Figure 4.5: Response to one-standard-deviation negative financial shock originated in lending country
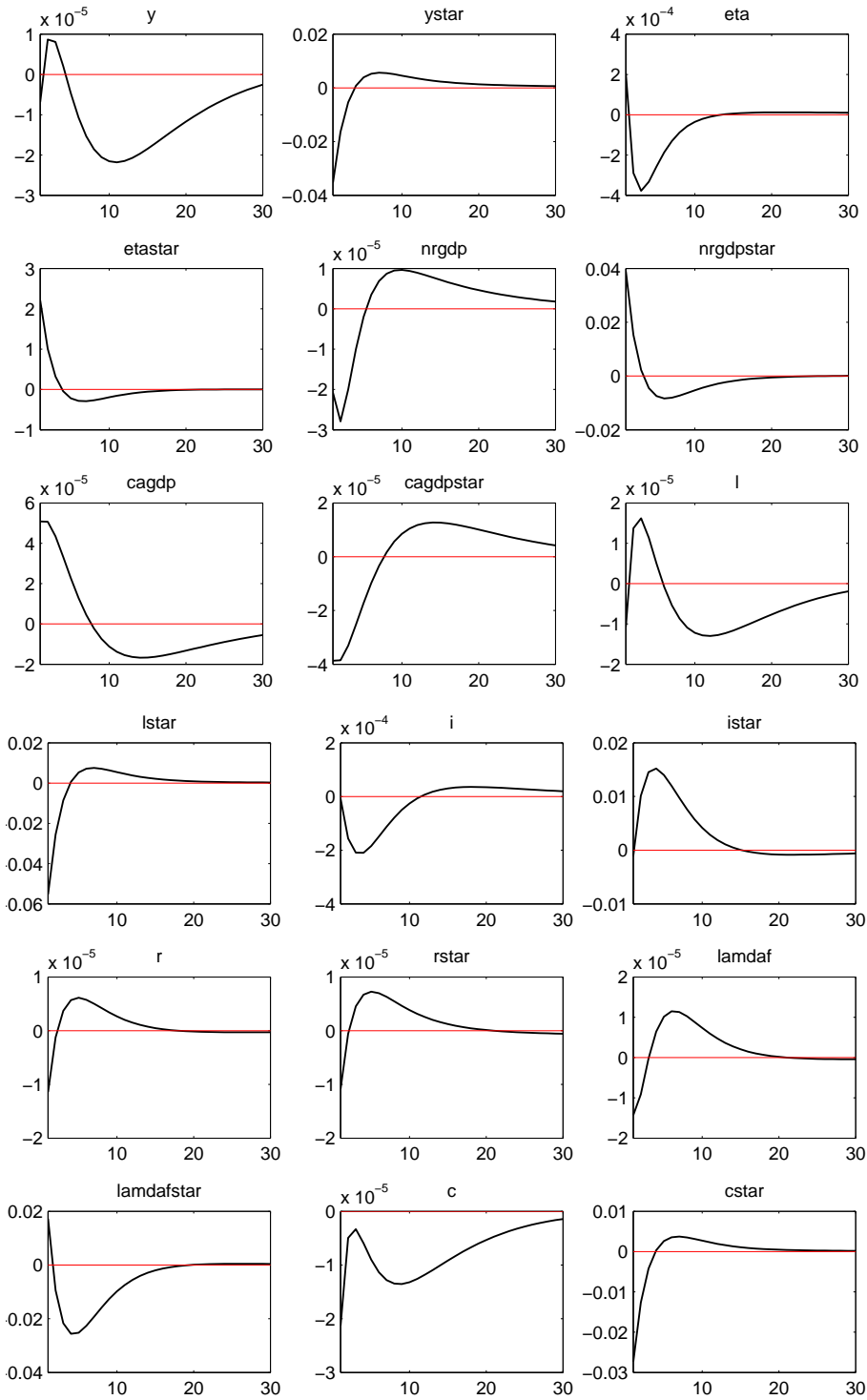
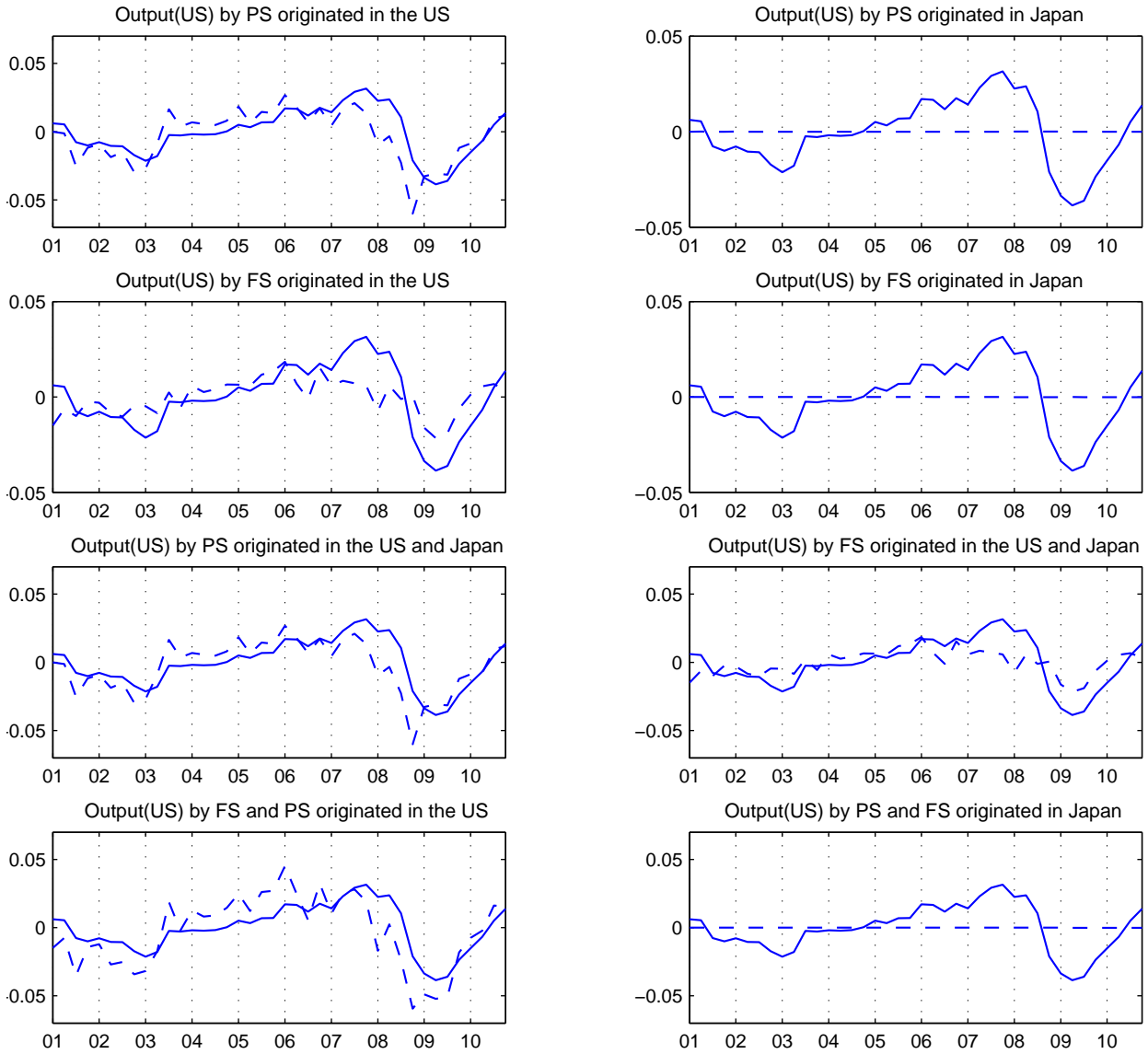Figure 4.6: Output in the US (- - -: simulated data ; — : real data)

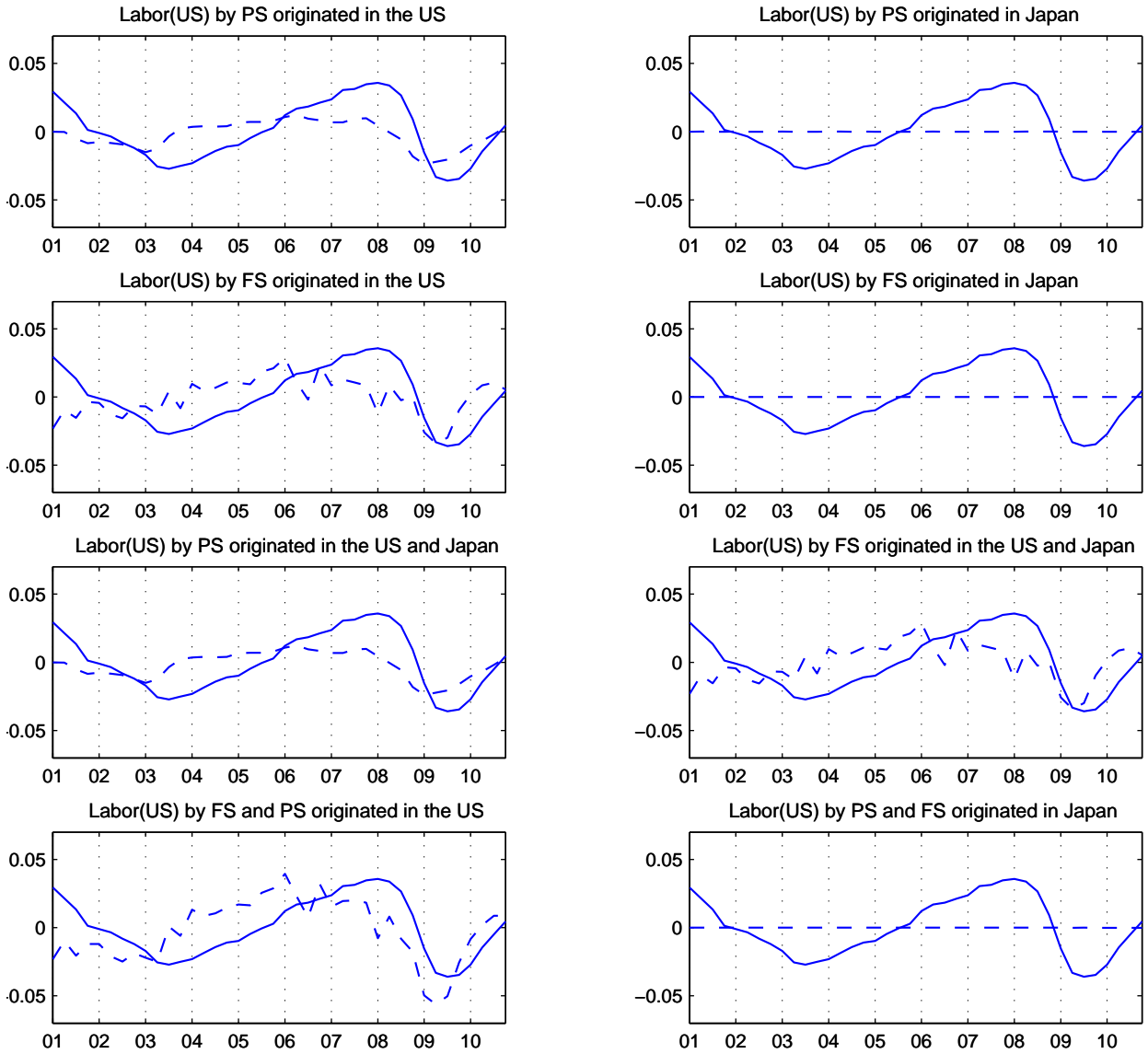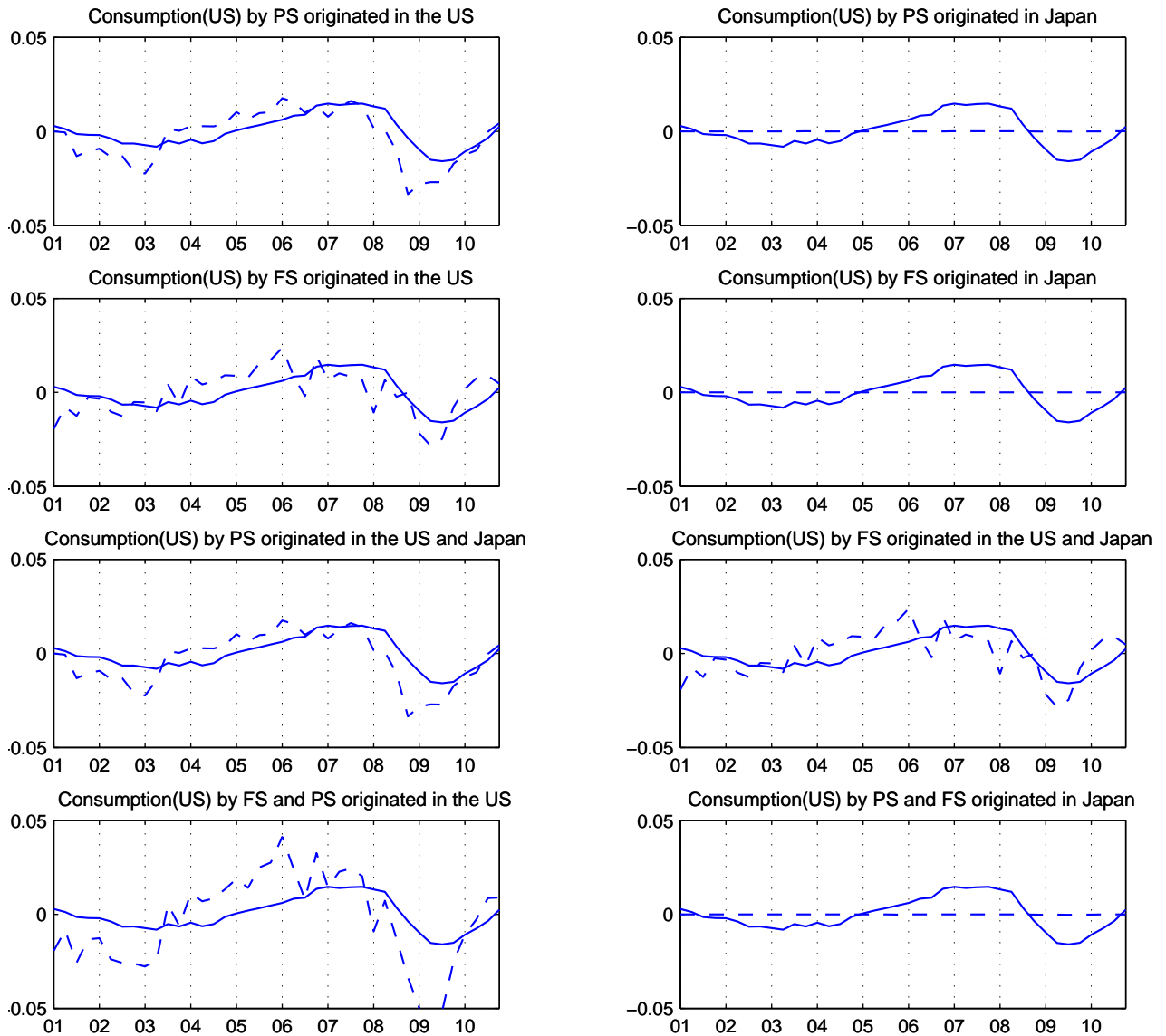Figure 4.7: Labor in the US (- - -: simulated data ; — : real data)

Labor(US) by PS originated in the US

Labor(US) by PS originated in Japan

Labor(US) by FS originated in the US

Labor(US) by FS originated in Japan

Labor(US) by PS originated in the US and Japan

Labor(US) by FS originated in the US and Japan

Labor(US) by FS and PS originated in the US

Labor(US) by PS and FS originated in Japan

Figure 4.8: Consumption in the US (- - -: simulated data ; — : real data)

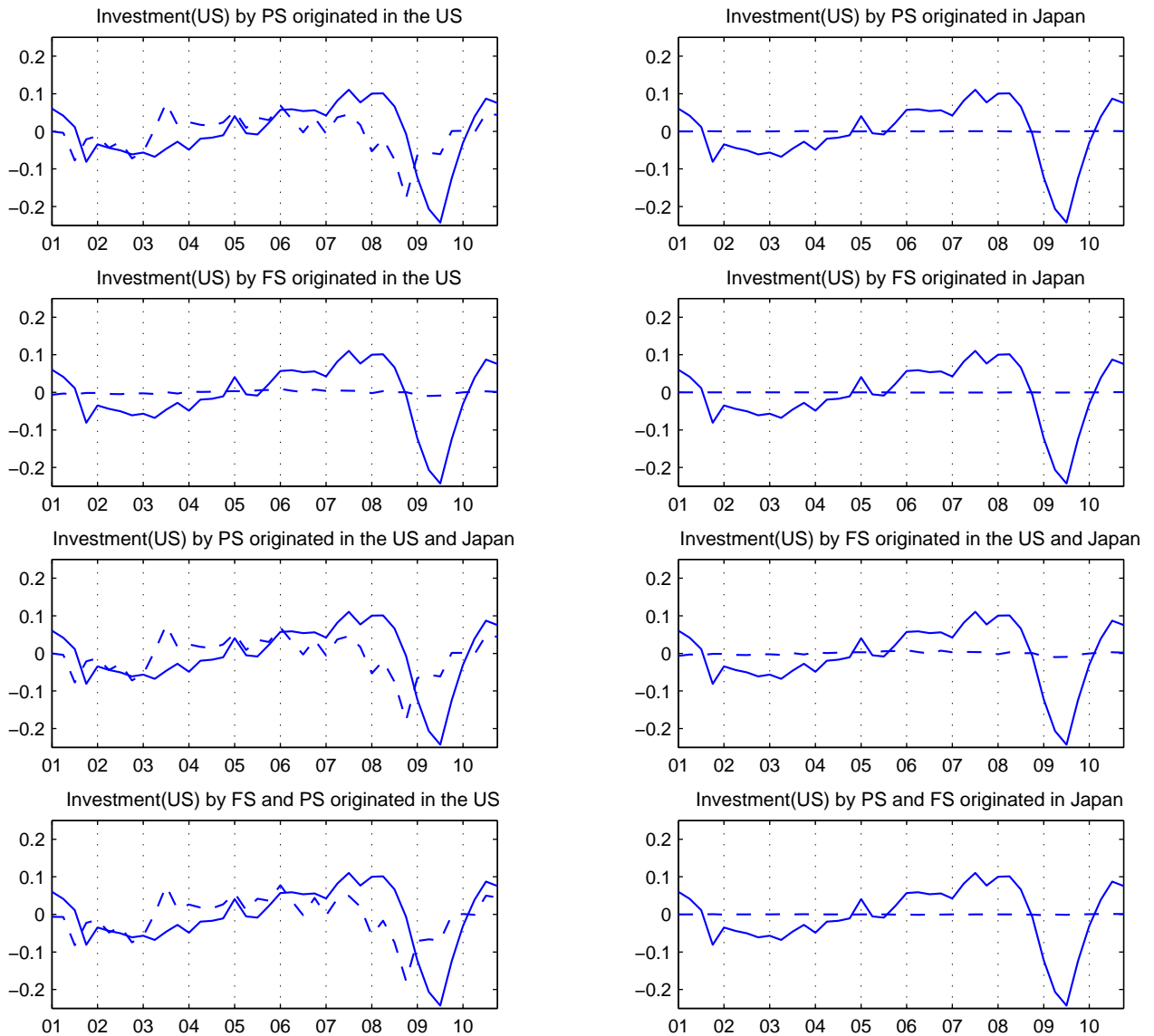Figure 4.9: Investment in the US (- - -: simulated data ; — : real data)

Figure 4.10: Current account in the US (- - -: simulated data ; — : real data)
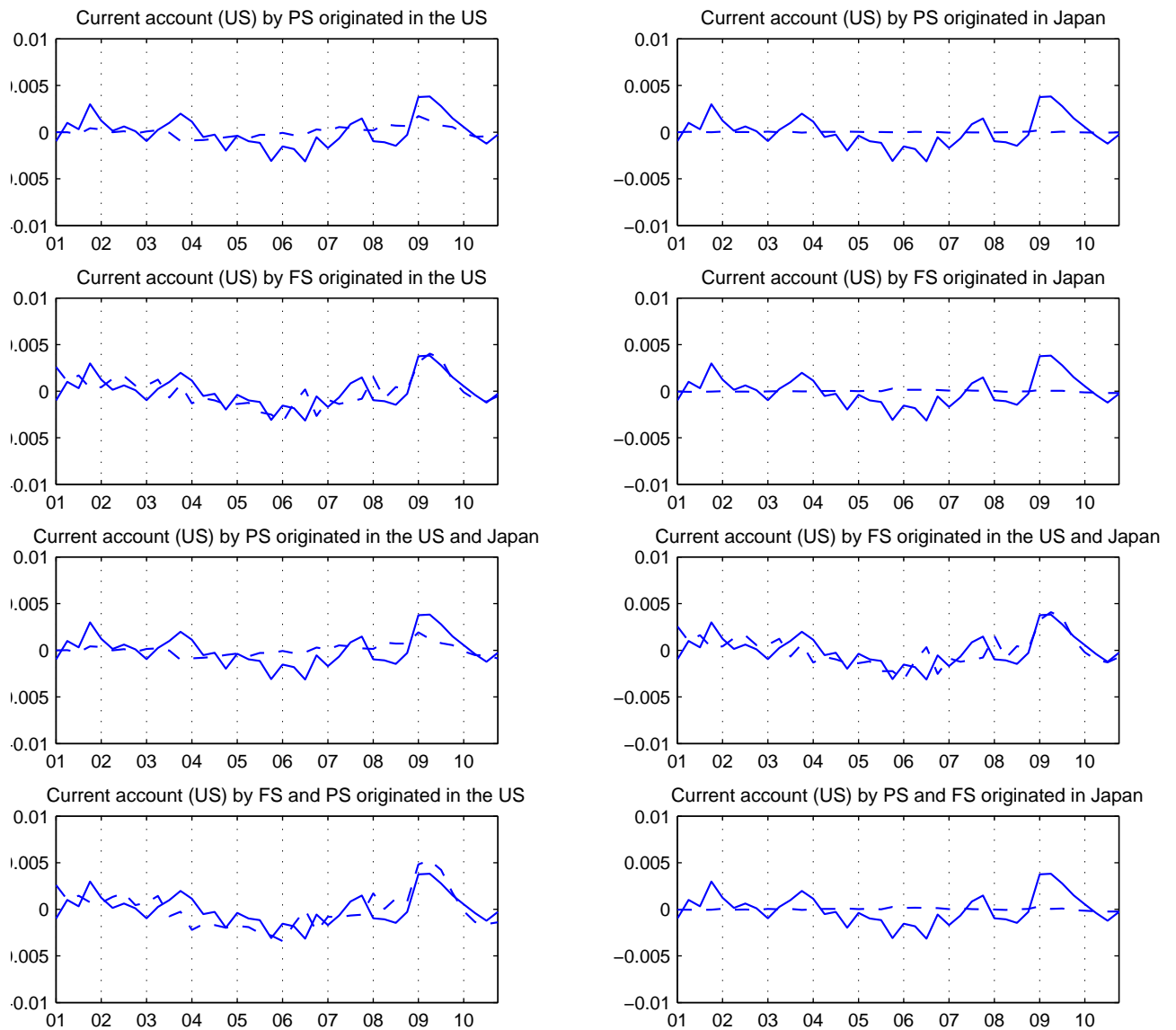
Figure 4.11: Debt repurchase in the US (- - -: simulated data ; — : real data)
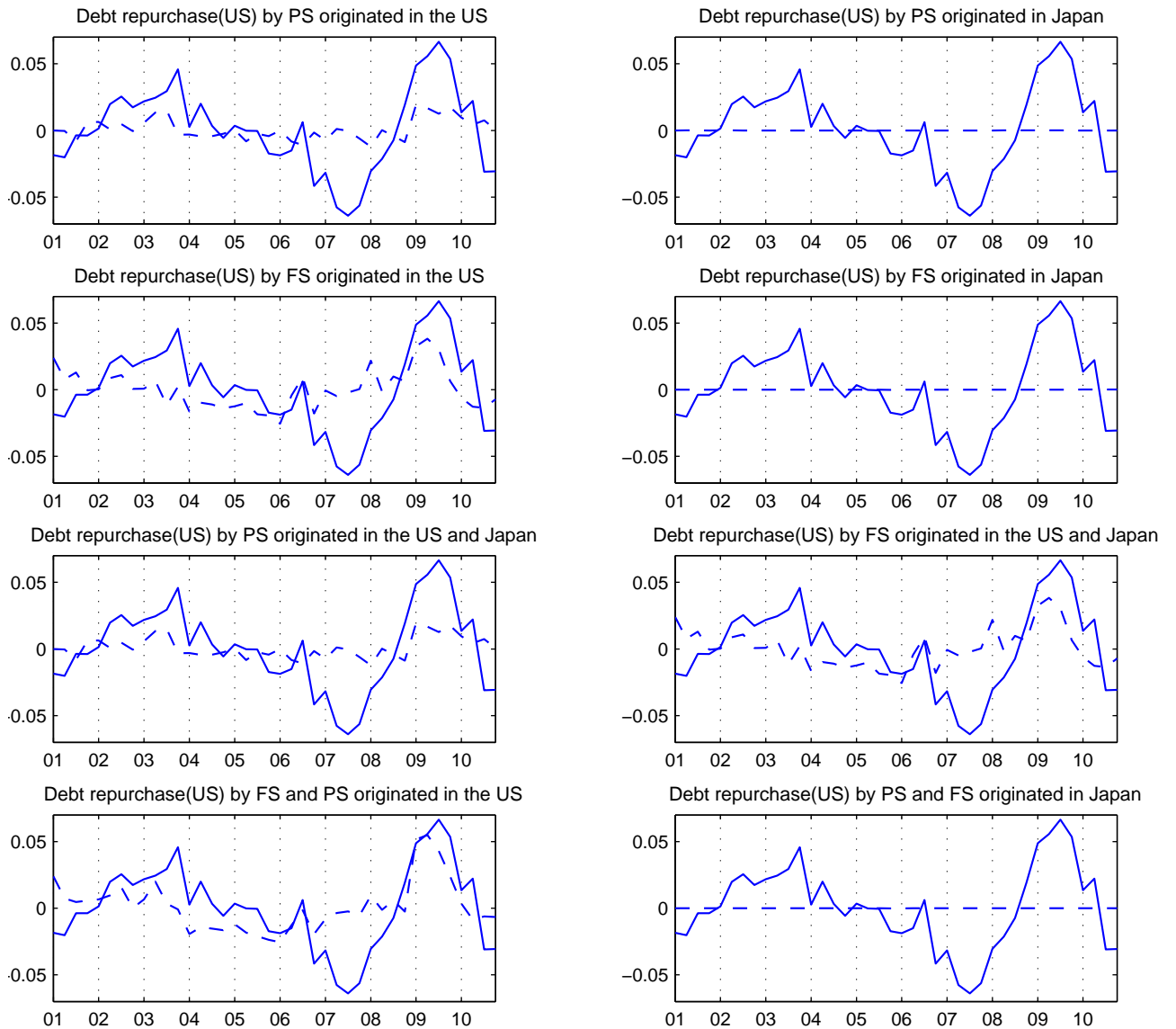
Figure 4.12: Output in Japan (- - -: simulated data ; — : real data)
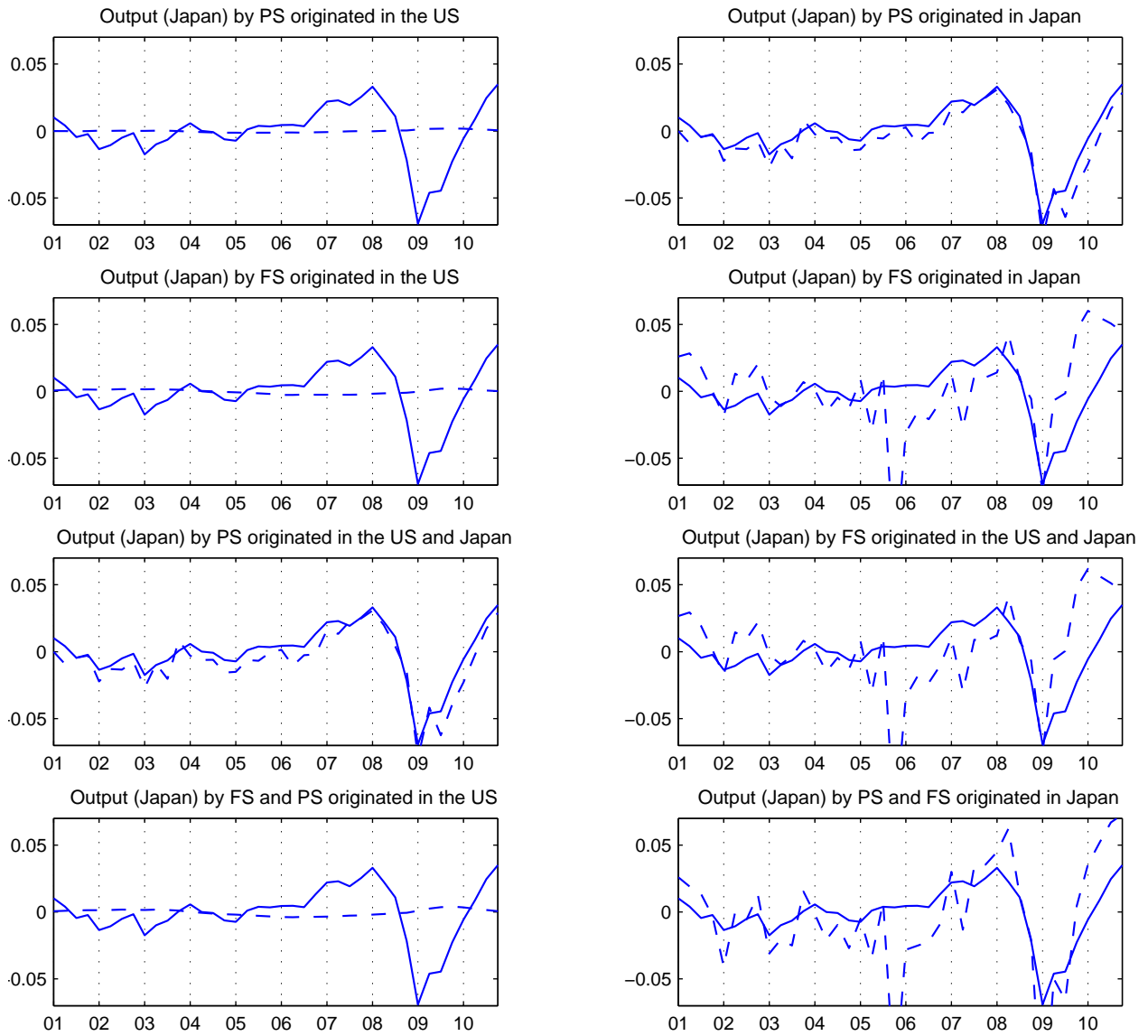
Figure 4.13: Labor in Japan (- - -: simulated data ; — : real data)
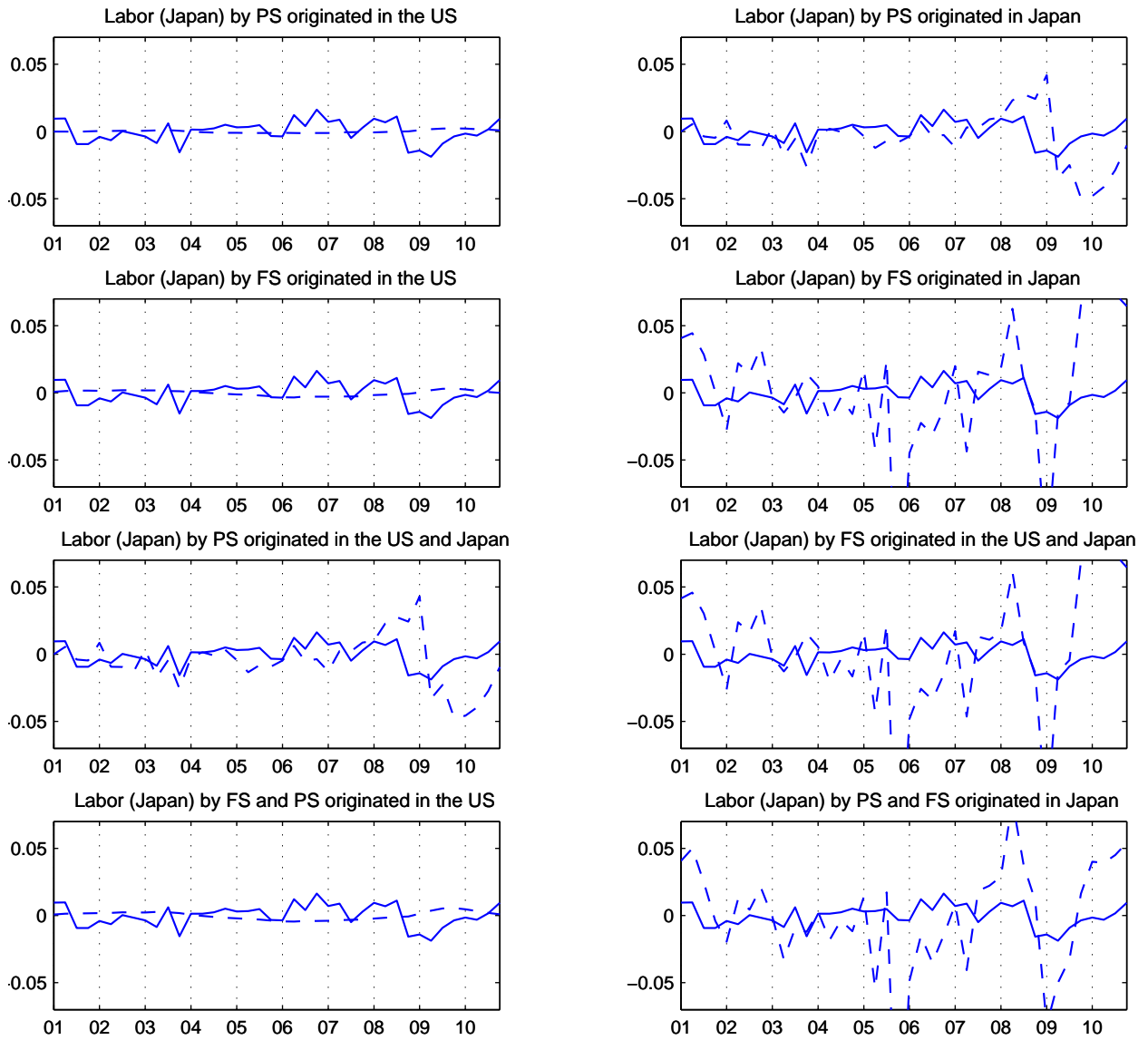
Figure 4.14: Consumption in Japan (- - -: simulated data ; — : real data)
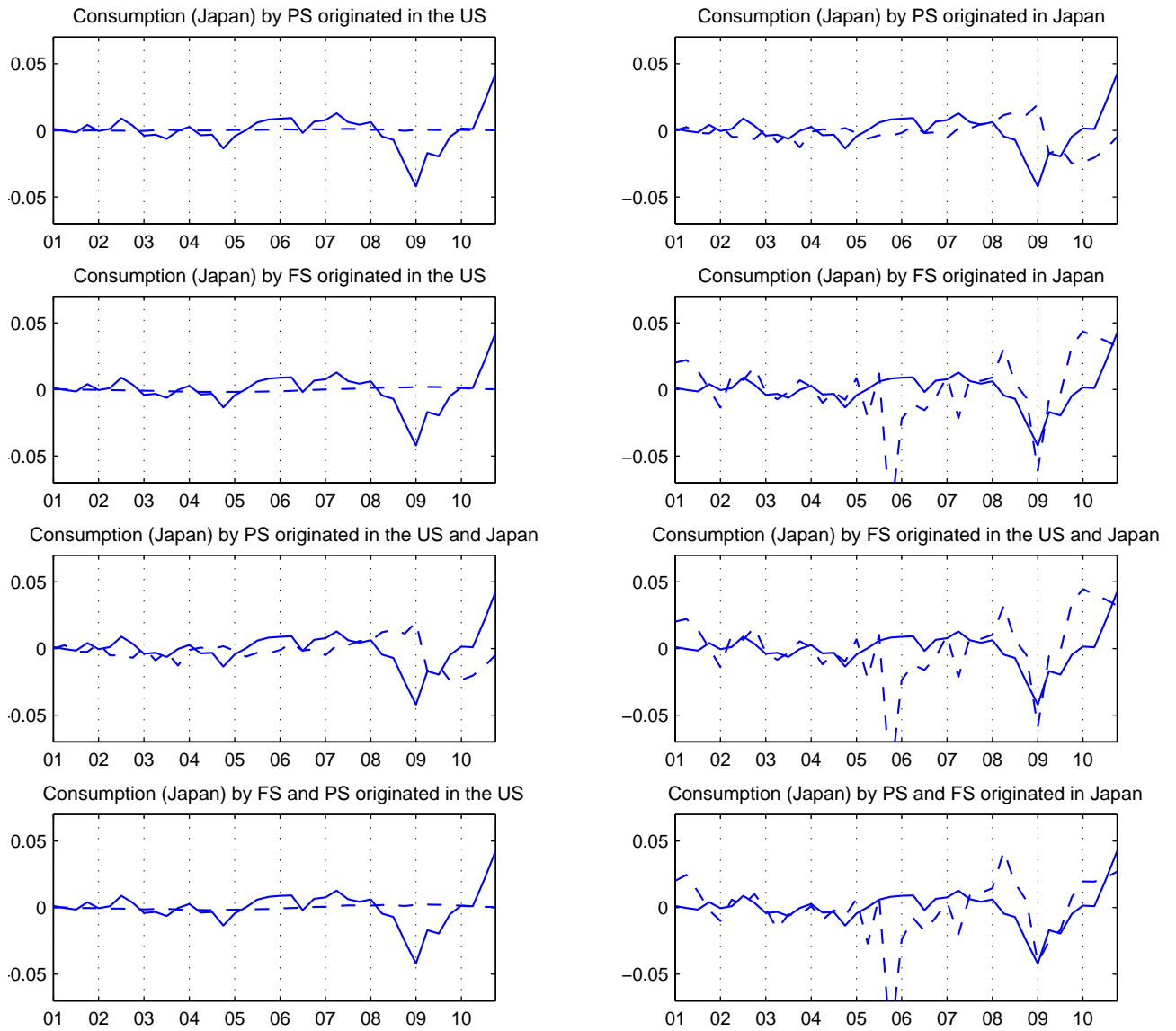
Figure 4.15: Investment in Japan (- - -: simulated data ; — : real data)
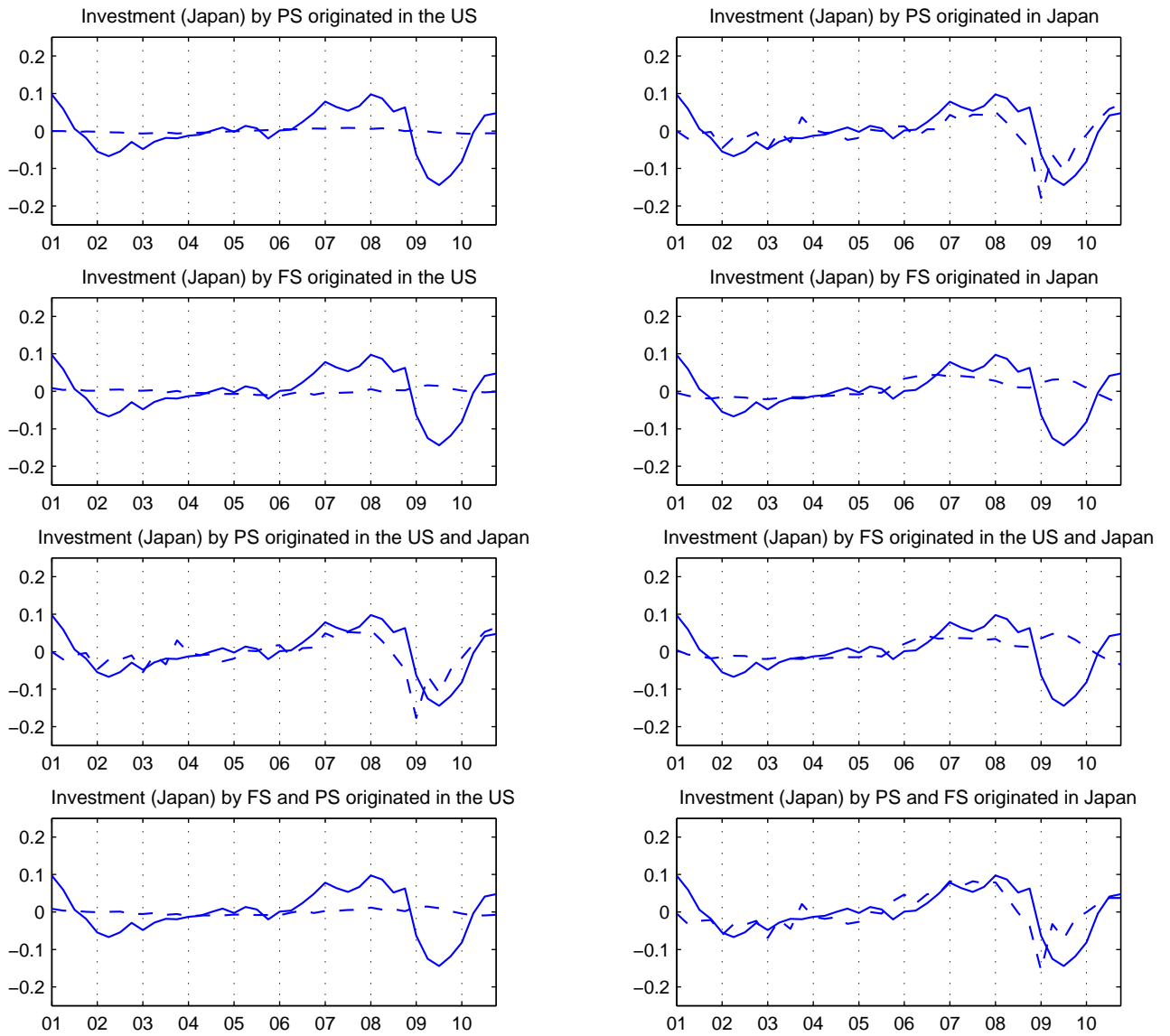
Figure 4.16: Current account in Japan (- - -: simulated data ; — : real data)
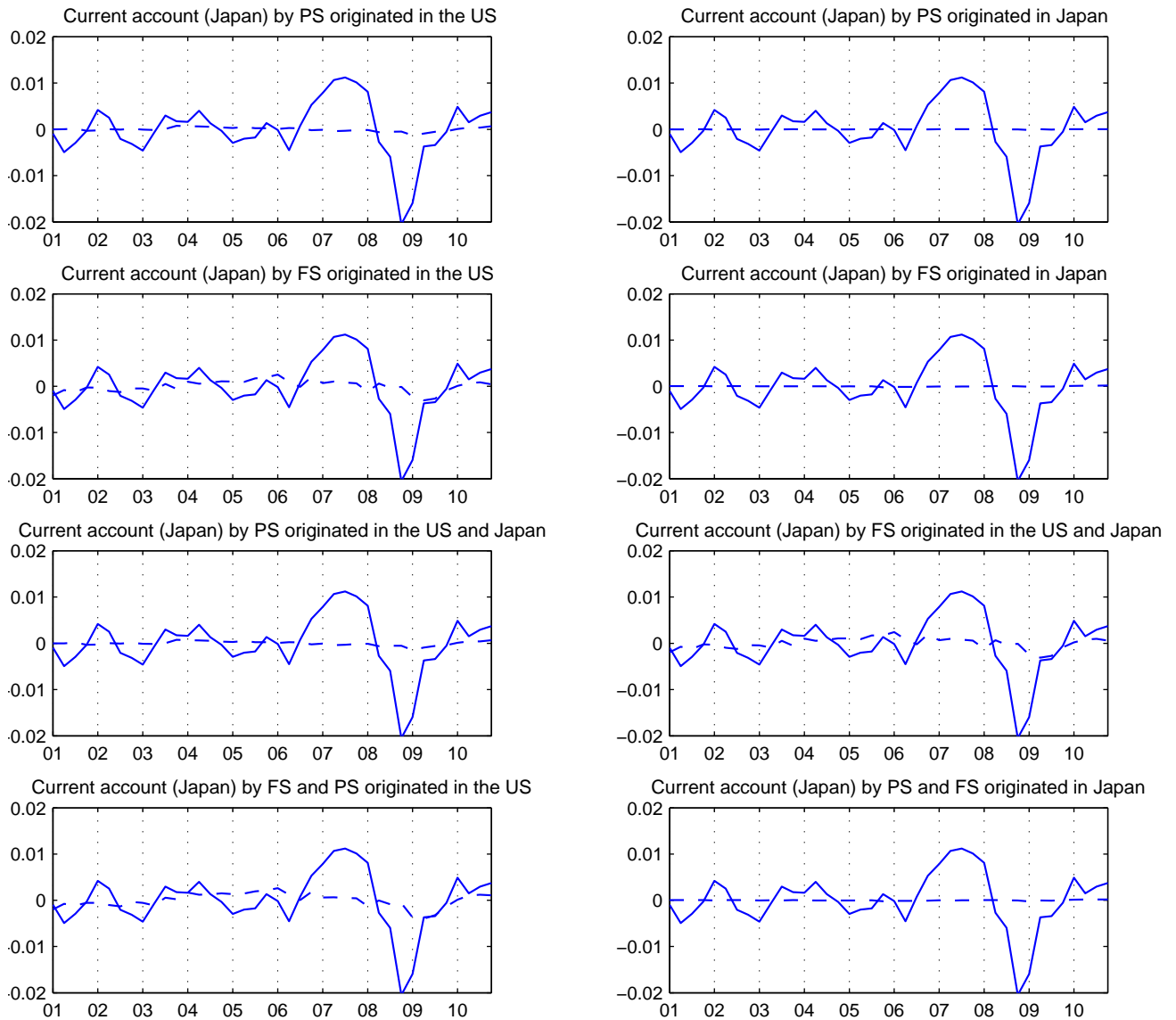
Figure 4.17: Debt repurchase in Japan (- - -: simulated data ; — : real data)

Debt repurchase (Japan) by PS originated in the US

Debt repurchase (Japan) by PS originated in Japan

Debt repurchase (Japan) by FS originated in the US

Debt repurchase (Japan) by FS originated in Japan

Debt repurchase (Japan) by PS originated in the US and Japan

Debt repurchase (Japan) by FS originated in the US and Japan

Debt repurchase (Japan) by FS and PS originated in the US

Debt repurchase (Japan) by PS and FS originated in Japan

Table 4.1: Moments

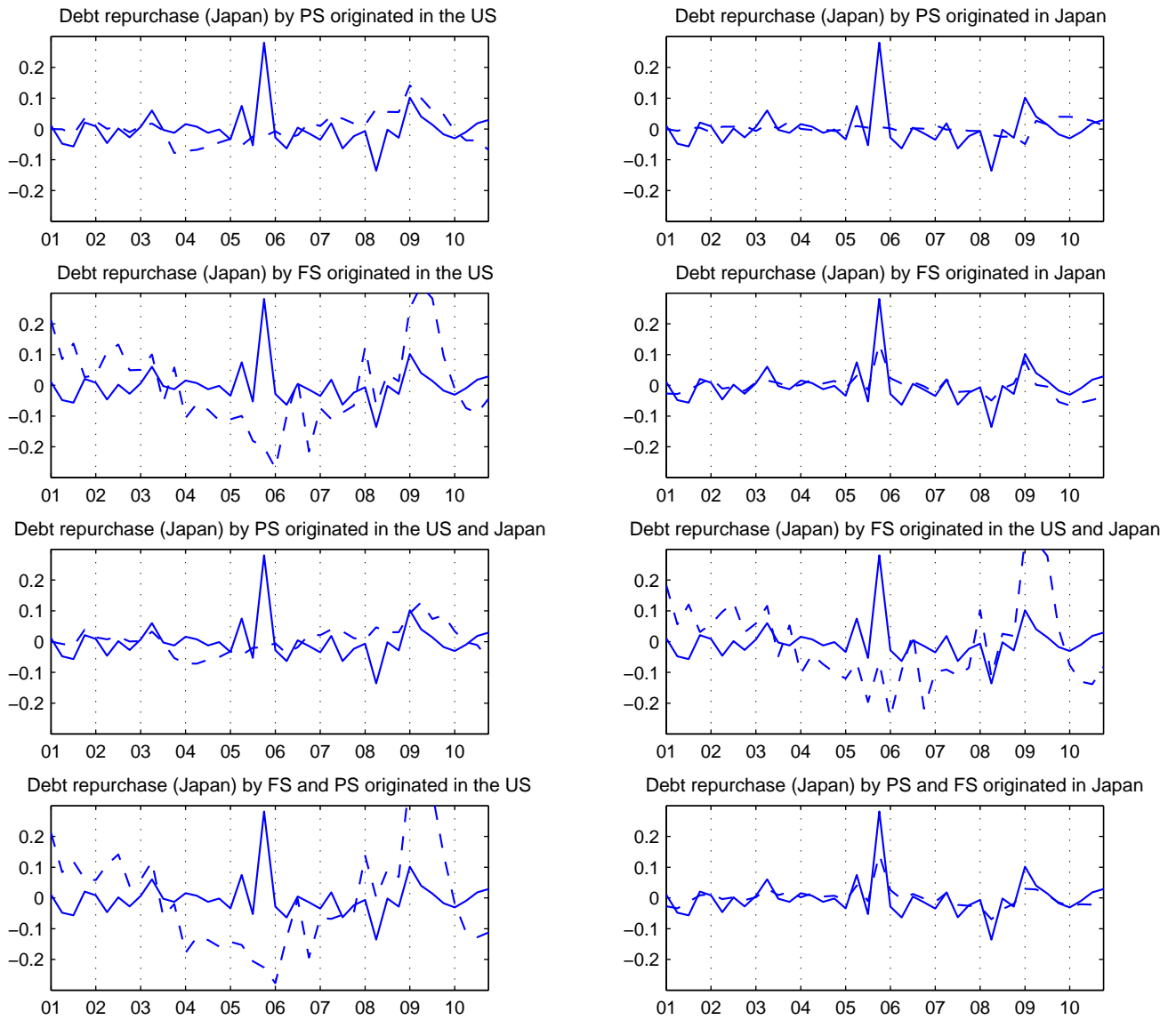|	Data	PS(US only)	PS(Japan only)	FS(US only)	FS(Japan only)	PS(Both)	FS(Both)	PS(US) and FS(US)	PS(JPN) and FS(JPN)
Corr. with output(US)	1	0.7421	0.4623	0.6815	0.1285	0.7426	0.6812	0.7733	0.2925
Std.of output(US)	0.0175	0.0189	2.2967e-05	0.0092	4.8264e-05	0.0189	0.0092	0.0263	5.7511e-05
Corr. with output(JPN)	1	-0.4146	0.9597	-0.4662	0.3298	0.9600	0.3023	-0.4928	0.7274
Std.of output(JPN)	0.0208	9.1852e-04	0.0227	0.0016	0.0340	0.0223	0.0346	0.0023	0.0454
Corr. with Labor(US)data	1.0000	0.5608	0.4762	0.3130	0.0402	0.5617	0.3128	0.4431	0.3041
Std.of Labor(US)	0.0216	0.0101	2.3823e-05	0.0144	3.2103e-05	0.0101	0.0144	0.0229	4.1545e-05
Corr. with Labor(JPN)data	1	-0.4674	0.2216	-0.4863	0.1972	0.2020	0.1763	-0.4999	0.3029
Std.of Labor(JPN)	0.0084	0.0010	0.0190	0.0020	0.0518	0.0184	0.0525	0.0029	0.0476
Corr. with Consumption(US)	1	0.7578	0.6843	0.5448	-0.1871	0.7586	0.5441	0.7057	0.4371
Std.of Consumption(US)	0.0088	0.0138	4.6602e-05	0.0119	3.1145e-05	0.0139	0.0119	0.0240	5.9625e-05
Corr. with Consumption(JPN)	1	0.1654	-0.2574	-0.2763	0.3107	-0.2498	0.2943	-0.1971	0.2350
Std.of Consumption(JPN)	0.0129	3.9816e-04	0.0093	0.0012	0.0256	0.0094	0.0259	0.0013	0.0236
Corr. with Investment(US)	1	0.3619	0.3367	0.6669	-0.1378	0.3538	0.6717	0.3901	0.1872
Std.of Investment(US)	0.0799	0.0496	4.3321e-04	0.0044	3.3389e-04	0.0497	0.0043	0.0522	5.7975e-04
Corr. with Investment(JPN)	1.0000	0.5753	0.6286	-0.4033	0.1266	0.6743	0.0136	0.0265	0.6318
Std.of Investment(JPN)	0.0596	0.0049	0.0446	0.0066	0.0236	0.0458	0.0244	0.0071	0.0491
Corr. with Current account(US)	1	0.4435	0.2718	0.6053	-0.2243	0.4490	0.6003	0.6271	-0.0808
Std.of Current account(US)	0.0016	5.8248e-04	4.3969e-05	0.0017	9.5172e-05	6.0199e-04	0.0016	0.0020	1.1630e-04
Corr. with Current account(JPN)	1	0.3259	0.6541	0.3589	-0.0177	0.3631	0.3626	0.3900	0.2328
Std.of Current account(JPN)	0.0061	4.4300e-04	3.3445e-05	0.0013	7.2370e-05	4.5784e-04	0.0013	0.0015	8.8444e-05
Corr. with Debt repurchase(US)	1.0000	0.5467	0.2950	0.4115	-0.0114	0.5472	0.4114	0.5675	0.1159
Std.of Debt repurchase(US)	0.0312	0.0080	1.7475e-05	0.0147	4.3333e-05	0.0080	0.0147	0.0188	4.0228e-05
Corr. with Debt repurchase(JPN)	1	0.0031	0.0220	0.0322	0.7561	0.0118	0.2294	0.0273	0.8483
Std.of Debt repurchase(JPN)	0.0613	0.0474	0.0172	0.1345	0.0354	0.0445	0.1354	0.1639	0.0320

5   Conclusion

This paper developed a simple two-country model incorporating an international bond market and enforcement constraints within countries, and attempted to quantify the role of productivity and financial shocks in the presence of financial integration. Quantitative results show that for both the US and Japan, productivity shocks, rather than financial shocks, can account for most dynamics observed in the real variables such as output and investment. On the other hand, financial shocks have tracked US trends of consumption, current accounts, and labor, and succeeded in replicating Japan's debt repurchases. Nevertheless, it is still worth noting that financial shocks serve as key factors accounting for the observed troughs of output, labor, and consumption, and peaks of debt repurchases and US current accounts during the 2007-09 financial crisis.

Our results imply that it is difficult to isolate which types of shocks dominated the real business cycles during the past decades because different shocks played different roles in different times. For example, although productivity shocks seem to exert a larger influence on output during normal periods, during a financial crisis, financial shocks become critical factors that account for fluctuations or output turning points. Second, we encountered the unexpected result that an observable international spillover effect only appeared in Japan's debt repurchases. As it is widely considered that the Japanese economy have been deeply influenced by US economic fluctuations, our quantitative results raise questions about this opinion. Moreover, such a two country model can be extended and applied to other countries or regions, such as the EU and China, and further comparative studies employing this model can enrich the literature examining the role played by financial and productivity shocks.

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