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International Business Cycle Accounting

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Abstract

In this paper, I extend the business cycle accounting method a la Chari, Kehoe and McGrattan (2007) to a two-country international business cycle model and quantify the effect of the disturbances in relevant markets on the business cycle correlation between Japan and the US over the 1980–2008 period. I find that disturbances in the labor market and production efficiency are important in accounting for the recent increase in the cross-country output correlation. Financial globalization can be the cause of the recent increase in cross-country output correlation if it operated through an increase in the cross-country correlation of disturbances in the labor market and production efficiency, not in the domestic or international capital markets.

Keywords: Business Cycle Accounting; International Business Cycles; Financial Globalization

JEL Classification: E32; F41

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1 Introduction

The quarterly correlation of the US and Japanese business cycles during the 1980–2008 period is surprisingly low and even negative during the 1990s. Nonetheless, the well known quantity anomaly shown by Backus, Kehoe, and Kydland (1992) still holds because the cross-country correlation of consumption is even lower than the cross-country correlation of output during the period. Furthermore, while the overall cross-country output correlation is low, it dramatically increased during the 2000s. In this paper, I apply the business cycle accounting method a la Chari, Kehoe, and McGrattan (2007) to a two-country model and quantitatively account for these facts of the Japanese and US business cycle correlation.

The main results are as follows: (i) disturbances in production efficiency are important in accounting for the short run output fluctuation in Japan while disturbances in the labor market and production efficiency are equally important in accounting for the short run output fluctuation in the U.S.; (ii) disturbances in the international financial market are necessary to account for the low cross-country consumption correlation; (iii) disturbances in labor, investment and international financial markets prevent production factors to shift towards the relatively efficient country; and (iv) disturbances in the labor market and production efficiency are important in accounting for the recent increase in the cross-country output correlation. The final result implies that the cause of the recent increase in cross-country output correlation must operate through an increase in the cross-country correlation of disturbances in the labor market and production efficiency, not in the domestic or international capital markets.

The foundation of the international business cycle accounting model is a one-good two-country model a la Baxter and Crucini (1993), which consists of final good firms, households, and governments in both countries. The final good firms in both countries produce an identical final good from capital and labor using constant returns to scale production technology. The final good firms face Hicks-neutral disturbances in production efficiency. The infinitely-lived representative households in both countries gain utility from consumption and leisure. The households in each country earn income from capital stock and labor supplied to the final good firms with which they purchase consumption and investment. Moreover, they trade state contingent international claims whose returns are affected by international financial disturbances. The governments in each country collect distortionary labor income and investment taxes from the household, purchase final goods, and rebate the remainder as a lump-sum transfer.

Chari et al (2007) show that models with distortions created by various frictions can be mapped into a prototype model with distortionary taxes. Following that study, I assess where the important distortions in accounting for the business cycle correlation between Japan and the US are located. The disturbances in government expenditure, labor, investment, production efficiency, and international financial and trade markets are computed as "wedges" from equilibrium conditions using data of output, consumption, labor, investment, and government purchases. Government wedges are disturbances in the domestic resource constraints which correspond to government purchases in the data. While government wedges represents the sum of government purchases and the trade balance in the original closed economy model a la Chari et al (2007), I define government wedges as purely government purchases and separately define the trade balances in an open economy model. Labor, investment, and production efficiency wedges are identical to those introduced in the original literature. Labor wedges are disturbances in the labor first order condition that capture the discrepancy between the intratemporal marginal rate of substitution of leisure to consumption and the marginal product of labor. Investment wedges are disturbances in the capital Euler equation that capture the discrepancy between the intertemporal marginal rate of substitution and the return on investment. Production efficiency wedges are equivalent to total factor productivity, i.e., Solow residuals. Wedges in the international financial market are natural additions to the original literature made as the business cycle accounting model is extended to a two-country framework. International price wedges are disturbances in the cross-country risk sharing condition that drives wedges between the marginal utility of consumption across countries. International trade wedges are disturbances in the international resource constraint that capture the residual in the aggregate trade balance evaluated at international prices.

The quantitative results are consistent with existing closed economy business cycle accounting literature on the US and Japanese economies. The original business cycle accounting paper by Chari et al (2007) concludes that labor and efficiency wedges are important in accounting for the US output fluctuation during the Great Depression and the 1982 recession. In this paper, I show that these two wedges are important in accounting for both medium and short term fluctuations of output. In addition, I find that the investment wedges are contributing to the growth during the 1990s and early

2000s in the US. Kobayashi and Inaba (2006) show that labor and efficiency wedges are important in accounting for the lost decade in the 1990s. Otsu and Pyo (2009) and Chakraborty (2009) show that efficiency wedges and investment wedges contributed to the Japanese boom in the late 1980s. While all of these results hold in the medium run, I find that the short term output fluctuation in Japan can mostly be accounted for by efficiency wedges.

The quantitative results on cross-country business cycle correlation are deeply related to the well-known quantity anomaly in the international real business cycle literature. On one hand, the international state-contingent claim enables international consumption risk sharing that leads to extremely high cross-country consumption correlation. Therefore, international price wedges are needed in order to lower the cross-country correlation of consumption. The observational equivalence mapping assesses the attempts to endogenize the fluctuation of international price wedges. As these endogenous mechanisms have shown limited success in quantitatively accounting for the low cross-country consumption correlation, studies such as Stockman and Tesar (1995) and Wen (2007) introduce taste shocks. These shocks operate as international price wedges. On the other hand, cross-country output correlation is negative in a canonical international real business cycle model since production factors shift toward the relatively efficient country. Therefore, the fluctuations of production factors have negative cross-country correlations which bring down the cross-country output correlation even if efficiency wedges are positively correlated across countries. The international business cycle accounting results show that labor, investment and international price wedges are preventing production factors from flowing towards the relatively efficient country. This is consistent with the finding of Yakhin (2007) that real wage rigidity and financial frictions are important in accounting for the cross-country correlation of labor and investment in a two country setting; Chari et al (2007) show that real wage rigidity and financial frictions are observationally equivalent to labor and investment wedges respectively. A successful model for explaining business cycle patterns in a two-country setting must account for the movements in these key wedges.

The international business cycle accounting results also spot out the wedges that are important for considering the recent increase in the cross-country US-Japan business cycle correlation. While the cross-country correlation of all of the domestic wedges increased in the 2000s, the increases in the cross-country correlations of the labor and efficiency wedges are quantitatively important in accounting for the increase in the cross-country output correlation. Therefore, the cause of the recent increase in cross-country output correlation must operate through labor and efficiency wedges. As an example, I introduce a model based on Otsu and Saito (2009) in which financial shocks endogenously generate fluctuations in labor and efficiency wedges through a working capital constraint and its effect on the accumulation of organizational capital which determines the credit premium for firm borrowing. An increase in the correlation of financial shocks across countries, which represents financial globalization, can generate an increase in output correlation through an increase in the correlation of labor and efficiency wedges. Heathcote and Perri (2004) show that the drop in cross-country productivity correlation and financial globalization represented by an increase in foreign asset trade in the US can account for the drop in the output correlation between the US and the rest of the world over the1972-2000 period. I show that financial globalization represented by an increase in cross-country financial frictions can account for the increase in cross-country output correlation between Japan and the US during the 2000s.

The remainder of the paper is organized as follows. In section 2, I assess the business cycle fluctuation facts in Japan and the US. In section 3, I describe the prototype international business cycle accounting model. In section 4, I explain the quantitative method and present the simulation results. In section 6, I introduce a model consistent with the international business cycle accounting results that accounts for the increase in cross-country output correlation through global financial market integration. Section 7 concludes the paper.

2 Data

In this section, I present data of the recent business cycle correlation pattern between Japan and the US that focuses on output, consumption, labor, and investment. Output is defined as GDP plus the flow income from durable goods and government capital stock; consumption is defined as the sum of expenditures on nondurable goods and services and the service flow from durable goods and government capital stock; investment is defined as the sum of gross domestic capital formation and household expenditures on durable goods; and labor refers to the total hours worked. The data sources are the BEA website for the US and the Cabinet Office ESRI website for Japan.

Table 1 shows the cross-country correlations of quarterly data for 1980–

2008 after being detrended by the Hoddrick-Prescott (HP) filter. Japanese and US data show positive but low cross-country correlation of output and labor. In fact, output correlation is almost zero during the 1980s and negative during the 1990s. Heathcote and Perri (2003) and Ambler, Cardia and Zimmerman (2004) show that the cross-country correlation of output between developed countries has fallen during the 1990s, as compared to that for the time-frame used by Backus et al (1994). Surprisingly, the cross-country correlations of consumption and investment are negative on average over the entire period. Therefore, the so-called quantity anomaly such that the cross-country correlation between output is higher than that of consumption holds. The entire period is sub-divided into decades because that seemed as a natural division given the output fluctuation patterns shown below in Figure 1. The business cycle correlation of the Euro area with Japan and the US also increased during the 2000s. The cross-country output correlations of the Euro area with Japan and the US for 1991–1999 are 0.11 and 0.25, while those for 2000–2008 are 0.72 and 0.55 respectively[1]. I have not included the Euro area in the analysis because of the limited data period covered by reliable data sources[2].

Figure 1a shows the per capita output in Japan and the US linearly detrended by a common quarterly growth rate of 0.4%. During the early 1980s, the US experienced a recession, whereas Japan was relatively stable. In the late 1980s, Japan experienced a large expansion, referred to as the bubble economy, while the US was relatively stable. The business cycle correlation was negative in the 1990s because the US underwent steady growth, whereas Japan experienced two sharp output drops in 1991 and 1997 during the so called lost decade. The business cycle correlation became stronger in the 2000s. Both countries faced a mild recession in 2000. After a boom during the early to mid-2000s, both economies went into a recession in 2007. The EU output series over the 1991-2008 period is also presented, which shows that the increase in the cross-country output correlation is not only between Japan and the U.S.

Figure 1b shows the per capita output in both countries detrended with

[1]Due to data availability issues, real GDP per capita is used as output for the Euro area, and the countries included are Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Norway, the UK, and Switzerland.

[2]For instance, GDP data is available for Germany from 1991, while the data on the average weekly hours worked is available from 1998 for most countries. The data source is the Eurostat website.

the HP filter to extract the high frequency output fluctuation patterns. This figure clearly shows that the output correlation increases dramatically in the 2000s. The dramatic increase in cross-country output correlation is not solely because of the recent global recession. Excluding 2007 and 2008 from the sample does not dampen the strong cross-country correlation.

Figures 2a and 2b show the HP-filtered fluctuations in key macroeconomic variables in both countries. The comovement patterns of each variable with output follow the stylized facts of the real business cycle literature such as Cooley and Prescott (1995). Consumption, labor, and investment are all procyclical in each country over the 1980–2008 period. Consumption and labor are less volatile than output, whereas investment is much more volatile than output.

3 The Prototype Model

The model is a competitive market version of a standard two-country model a la Baxter and Crucini (1993) wherein both countries produce a single tradable final good. Each country $i = JP, US$ consists of a representative household, firm, and government. Following Chari, Kehoe and McGrattan (2007), I introduce wedges in relevant markets, represented as distortionary shocks. The full description of the model is as follows.

3.1 Firms

The firms in each country produce aggregate output Y_t from capital stock K_t and labor supply l_t using Cobb-Douglas production technology that is affected by aggregate TFP, A_t:

$$Y_t^i = A_t^i (K_t^i)^{\theta^i} (l_t^i)^{1-\theta^i}, \tag{1}$$

where θ represents the capital share[3]. I decompose the aggregate TFP into the trend component, $\Gamma_t = (1+\gamma)\Gamma_{t-1}$, also known as the labor augmenting

[3] Labor supply consists of average hours worked per worker and the number of workers per adult population. The average hours worked per worker are defined as the average weekly hours worked per worker divided by 14×7, assuming that 14 hours is the maximum that each worker can work per day. Output, capital stock and labor supply are divided by the adult population.

technical progress, and the stationary component z_t:

$$A_t^i = \exp(z_t^i)(\Gamma_t^i)^{1-\theta^i}.$$

Then, dividing both sides of (1) by Γ_t, the production function can be rewritten as

$$y_t^i = \exp(z_t^i)(k_t^i)^{\theta^i}(l_t^i)^{1-\theta^i}, \tag{2}$$

where y_t^i and k_t^i are output and capital detrended by Γ_t^i respectively. All growing variables are detrended in the same fashion in order to guarantee a stationary equilibrium. Finally, the detrended profit maximization problem for the final good firm can be written as

$$\max\left[\exp(z_t^i)(k_t^i)^{\theta^i}(l_t^i)^{1-\theta^i} - w_t^i l_t^i - r_t^i k_t^i\right],$$

where w_t^i and r_t^i are real wages and real return on capital respectively[4].

3.2 Households

The households in each country maximize lifetime utility:

$$U = \sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi(s^t)u(c_t^i(s^t), l_t^i(s^t)),$$

where c_t^i and l_t^i denote detrended consumption and labor supply respectively. The current state is defined as s^t, while the unconditional probability of that state to occur is denoted as $\pi(s^t)$. I assume the following conventional periodical preference function:

$$u(c_t^i(s^t), l_t^i(s^t)) = \Psi^i \ln c_t^i(s^t) + (1-\Psi^i)\ln(1-l_t^i(s^t)). \tag{3}$$

The maximization problem is subject to a budget constraint:

$$\begin{aligned}
& (1-\tau_{lt}^i(s^t))w_t^i(s^t)l_t^i(s^t) + r_t^i(s^t)k_t^i(s^t) + p_t^i(s^t)d_t^i(s^t) + tr_t^i(s^t) \\
= \; & c_t^i(s^t) + (1+\tau_{xt}^i(s^t))x_t^i(s^t) + p_t^i(s^t)\sum_{s_t^{t+1}|s^t} q_t(s^{t+1}|s^t)d_{t+1}^i(s^{t+1}|s^t) + \Phi_t(s^t)k_t^i(s^{t-1}),
\end{aligned}$$

[4] In the model real wages grow as the labor augmenting technical progress Γ_t increases and the real interest rates are stationary which are consistent with the Kaldor facts. To render the model stationarity, wages are detrended by Γ_t.

where x_t^i is investment, d_t^i is the state contingent international claim, q_t is the price of the claim that matures one period after it is purchased, p_t^i is the conversion rate of the matured international claim to final goods, τ_{lt}^i and τ_{xt}^i represent distortionary taxes on labor income and investment respectively, and tr_t^i is the lump-sum transfer from the government. Future variables depend on the future state conditional on the current state $s^{t+1}|s^t$.

The capital law of motion is:

$$\Gamma^i k_{t+1}^i(s^t) = x_t^i(s^t) + (1-\delta^i)k_t^i(s^{t-1}). \tag{4}$$

The investment adjustment cost Φ_t^i is assumed to take the form of

$$\Phi_t^i(s^t) = \frac{\phi^i}{2}\left(\frac{x_t^i(s^t)}{k_t^i(s^{t-1})} - \Omega^i\right)^2,$$

where $\Omega^i = \Gamma^i - (1-\delta^i)$[5]. Following Christiano and Davis (2006), I set the parameter of capital adjustment cost ϕ^i so that the marginal Tobin's q is equal to one.

3.3 International Financial Market

The state contingent international claims are traded at the international price q_t. The international financial constraint can be written as

$$[q_t(s^{t+1}|s^t)d_{t+1}^{JP}(s^{t+1}|s^t) - d_t^{JP}(s^t)] + [q_t(s^{t+1}|s^t)d_{t+1}^{US}(s^{t+1}|s^t) - d_t^{US}(s^t)] = \tau_t(s^t).$$

The international trade wedge τ_t captures the flow of resources from Japan or the US to other countries in the world and vice versa which is not captured in the model. This term is important because we need both domestic and international resource constraints to hold in order to operate the accounting procedure.

This condition can be rewritten into an international trade balance constraint

$$tb_t^{JP}(s^t) + tb_t^{US}(s^t)/p_t(s^t) = \tau_t(s^t), \tag{5}$$

[5]This guarantees that the adjustment cost is equal to zero in the steady state.

where tb_t^i is the trade balance and

$$p_t(s^t) = \frac{p_t^{US}(s^t)}{p_t^{JP}(s^t)}.$$

The international price wedge p_t can be considered as trade or transaction costs in the international financial market[6]. The naming of the wedge follows the convention of interpreting p_t as the real exchange rate.

Several structural models can give rise to p_t. Incomplete capital market models such as Baxter and Crucini (1995) endogenously account for changes in international price wedges by limiting international risk sharing. Backus, Kehoe, and Kydland (1994) extends the two-country one-good model to a two-country two-good model with intermediate goods where p_t shows up as a function of the relative price of these intermediate goods. Stockman and Tesar (1995) introduce a two-country model with tradables and nontradables where p_t shows up as a function of the international relative price of nontradables. Such extensions can be interpreted as endogenizing the movements of international price wedges. Taste shocks in a two country model a la Stockman and Tesar (1995) and Wen (2007) manifest themselves as international price wedges. An observational equivalence mapping from these international real business cycle models to the prototype international business cycle accounting model with international price wedges is provided in the appendix.

3.4 Government

The government collects taxes from households, purchases goods and services, and rebates the remaining to the household as a lump-sum transfer in order to satisfy the government budget constraint:

$$\tau_{lt}^i(s^t)w_t^i(s^t)l_t^i(s^t) + \tau_{xt}^i(s^t)x_t^i(s^t) = tr_t^i(s^t) + g_t^i(s^t). \tag{6}$$

The main focus of this paper is not to analyze the effect of distortionary taxes, but to identify the wedges that are important in accounting for the business cycle correlation in Japan and the US. Chari, Kehoe and McGrattan (2007) show that several sophisticated models can be mapped into the

[6] Since only the ratio of p_t^is matters in the model, I assume $p_t^{JP} = 1$ in order to derive (5) without loss of generality.

prototype model with distortionary taxes. For instance, monetary shocks with sticky nominal wages manifest themselves as distortions in the labor market. On the other hand, financial frictions such as in Bernanke, Gertler, and Gilchrist (1998) and Carlstrom and Fuerst (1997) manifest themselves as distortions in the investment market. Focusing only on distortionary taxes will overlook the effect of these channels. Therefore, I do not use actual data of distortionary taxes in this paper[7].

3.5 Shocks

The 10 exogenous state variables are $\widetilde{s} = \{\widetilde{g^i}, \widetilde{\tau_l^i}, \widetilde{\tau_x^i}, \widetilde{z^i}, \widetilde{p}, \widetilde{\tau}\}$ where "$\sim$" denotes the deviation from steady state. I assume that they follow a VAR process, as follows:

$$\widetilde{s_t} = P * \widetilde{s_{t-1}} + \varepsilon_t, \tag{7}$$

where $\varepsilon = \{\varepsilon_g^i, \varepsilon_l^i, \varepsilon_x^i, \varepsilon_z^i, \varepsilon_p, \varepsilon_\tau\}$. I assume that the error terms ε are normally distributed with a mean zero, while there are no restrictions on its variance-covariance matrix V. Agents form rational expectations on future levels of exogenous variables according to this process.

3.6 Equilibrium

The competitive equilibrium is characterized by the prices and quantities $\{y^i, c^i, l^i, x^i, tb^i, k^i, w^i, r^i, tr^i, g^i, \tau_l^i, \tau_x^i, z^i, q, p, \tau\}$, such that (i) households optimize given prices and wedges $\{w^i, r^i, q, p, \tau^i, \tau_l^i, \tau_x^i\}$; (ii) final goods firms optimize given prices and wedges $\{w^i, r^i, z^i\}$; (iii) government budget constraint (6) holds; (iv) the domestic resource constraints,

$$y_t^i(s^t) = c_t^i(s^t) + x_t^i(s^t) + g_t^i(s^t) + tb_t^i(s^t) + \Phi_t^i(s^t)k_t^i(s^{t-1}), \tag{8}$$

hold; and (v) wedges follow the stochastic process (7).

The equilibrium can be summarized by the following 12 equations. The

[7] Braun (1994) and McGrattan (1994) show that distortionary taxes played an important role in accounting for the postwar US business cycles.

Euler equation in both countries[8]

$$\Gamma^i(1+\tau^i_{xt}+\Phi^{i\prime}_t)u^i_{ct} = \beta^i E_t\left[u^i_{ct+1}\left(\theta^i\frac{y^i_{t+1}}{k^i_{t+1}} + (1-\delta^i)(1+\tau^i_{xt+1}) + \Phi^{i\prime}_{t+1}\frac{k_{t+2}}{k_{t+1}} + \Phi^i_{t+1}\right)\right], \tag{9}$$

the labor first order condition in both countries

$$-\frac{u^i_{lt}}{u^i_{ct}} = (1-\tau^i_{lt})(1-\theta^i)\frac{y^i_t}{l^i_t}, \tag{10}$$

the international risk sharing condition

$$p_t = \frac{u^{JP}_{ct}}{u^{US}_{ct}}\kappa, \tag{11}$$

the domestic resource constraints in both countries (8), the production function in both countries (2), the capital law of motion in both countries (4), and the international resource constraint (5), where $u^i_{ct} = \Psi^i/c^i_t$ and $u^i_{lt} = -(1-\Psi^i)/(1-l^i_t)$. The constant term κ in the international risk sharing condition (11) depends on the initial conditions of the economy. Without loss of generality, if we assume a symmetric initial state, we get $\kappa = 1$[9]. These 12 equations characterize the equilibrium of the following 12 endogenous variables $\{y^i, c^i, l^i, x^i, tb^i, k^i\}$, given 10 exogenous variables $\{g^i, \tau^i_l, \tau^i_x, z^i, p, \tau\}$, and the initial value of capital stock, the endogenous state variable, in both countries.

[8] For simplicity, I abbreviate the state notations and use the conventional expectation operator instead.

[9] The international first order condition

$$p_t\frac{u^{US}_{ct}}{u^{JP}_{ct}} = p_{t+1}\frac{\beta^{US}u^{US}_{ct+1}}{\beta^{JP}u^{JP}_{ct+1}}$$

must hold for every possible state owing to the complete markets assumption. This condition can be iterated backwards, which yields

$$p_t\frac{u^{US}_{ct}}{u^{JP}_{ct}} = p_0\frac{(\beta^{US})^{-t}u^{US}_{c0}}{(\beta^{JP})^{-t}u^{JP}_{c0}} = \kappa.$$

If $\beta^{US} = \beta^{JP}$, $p_0 = 1$ and $u^{US}_{c0} = u^{JP}_{c0}$, then $\kappa = 1$.

4 Quantitative Analysis

The business cycle accounting procedure is conducted as follows. First, I use the equilibrium conditions and data of output, consumption, labor, investment, and government purchases for 1980–2008 to calibrate and estimate the parameter values. Second, I obtain linear decision rules for endogenous variables using the method of undetermined coefficients. Third, I compute the wedges using data and linear decision rules. Finally, I simulate the model using the computed wedges and linear decision rules. In this section, I explain the quantitative method in detail and present the simulation results.

4.1 Parameter Values

I assume a symmetric steady state across the two countries. Therefore, I use the average of the separately calibrated parameter values as the common parameter values in both countries. The values of structural parameters are listed in Table 2. The detailed calibration procedure is as follows.

The capital share parameter θ is calibrated as follows for each country. First, the capital income share

$$\theta_p = \frac{\text{unambiguous capital income + fixed capital consumption}}{GDP \text{ - ambiguous capital income}}$$

is directly calculated from national income and product accounts[10]. The values are 0.36 for Japan and 0.29 for the US[11]. Since output is defined as GDP plus the flow income from durable and government capital stock ($FLOW$), the capital share is computed as

$$\theta = \frac{\theta_p \times GDP + FLOW}{GDP + FLOW}.$$

The depreciation rate is computed directly from the data using the capital law of motion (4)[12]. The average growth rate of per capita output is used for the growth trend Γ. The subjective discount rate β is calibrated to the data

[10] For details, see Cooley and Prescott (1995).

[11] The value for Japan is the average computed using the Hayashi and Prescott (2002) data set over the 1980–2002 period. The value for the U.S. is the average computed from the BEA data over the 1980–2006 period.

[12] Depreciation rates of residential capital stock, non-residential capital stock, government capital stock, and durable goods stock are separately computed using the perpetual

of the average capital-output ratio using the steady state version of capital Euler equation (9)

$$\Gamma^i(1+\tau_x^i) = \beta^i \left(\theta^i \frac{y^i}{k^i} + (1-\delta^i)(1+\tau_x^i) \right).$$

The utility parameter Ψ is calibrated to match the data of average labor and consumption-output ratio with the steady state version of the labor first order condition (10)

$$\frac{1-\Psi^i}{1-l^i} = (1-\tau_l^i)(1-\theta^i)\frac{y^i}{l^i}\frac{\Psi^i}{c^i}.$$

I assume that the steady state values of wedges $\{\tau_l^i, \tau_x^i, z^i\}$ are equal to zero for simplification. The steady state levels of government wedges g are computed directly from the data. The steady state levels of international prices p and trade shocks τ are computed from the steady state versions of (11) and (5) respectively.

The persistence parameters of the shock process (7) are obtained using maximum likelihood estimation[13]. For the estimation, I use linearly detrended data of output, consumption, labor, investment, and government purchases for both countries as observable variables. Since there are 10 shocks and 10 observable variables, the system is just identified. Since there are no restrictions on the variance-covariance matrix of the error terms, they are contemporaneously correlated. Unlike the structural parameters, I do not assume symmetry across countries in the stochastic process as this will not violate the symmetric steady state assumption. The point estimates of the

inventory method by interpolating the reported stock level in 1980 and the latest possible year using the flow investment data for each type of capital. The aggregate depreciation rate is computed from the aggregate capital stock and the aggregate investment data.

[13] Government wedges, labor wedges, production efficiency wedges, and international wedges can all be directly computed from the equilibrium conditions. However, computing investment wedges involves expectational terms. Hence, they cannot be directly computed. Therefore, the entire system must be estimated.

parameters are as follows[14].

$$P = \begin{vmatrix} 0.68 & 0.21 & -0.03 & -0.24 & -0.10 & 0.00 & 0.08 & 0.31 & -0.07 & -0.29 \\ 0.03 & 0.65 & -0.03 & 0.01 & -0.29 & 0.01 & 0.09 & 0.41 & 0.33 & 0.05 \\ -0.08 & 0.59 & 0.91 & -0.62 & 0.07 & -0.04 & 0.01 & 0.02 & -0.45 & 0.04 \\ 0.09 & -0.11 & -0.09 & 0.70 & -0.15 & 0.03 & 0.06 & 0.37 & 0.18 & -0.04 \\ -0.15 & -0.16 & 0.05 & 0.33 & 0.94 & 0.06 & -0.02 & -0.16 & 0.09 & -0.10 \\ 0.05 & 0.09 & 0.03 & 0.06 & 0.13 & 0.86 & 0.01 & -0.32 & 0.00 & 0.04 \\ 0.21 & 0.68 & -0.27 & -0.72 & 0.58 & 0.07 & 0.65 & -0.80 & -0.41 & 0.31 \\ 0.00 & -0.12 & 0.06 & 0.24 & -0.02 & -0.03 & 0.04 & 0.91 & 0.07 & -0.05 \\ -0.06 & -0.22 & 0.13 & 0.55 & -0.01 & 0.04 & -0.04 & -0.26 & 1.01 & -0.02 \\ -0.02 & -0.05 & -0.02 & 0.21 & 0.05 & 0.07 & -0.06 & -0.40 & 0.01 & 0.081 \end{vmatrix}$$

$$\begin{aligned} V &= 1.00E-04 * \\ & \begin{vmatrix} 0.76 & -0.01 & 0.08 & 0.04 & 0.09 & 0.01 & 0.13 & 0.00 & 0.01 & 0.00 \\ -0.01 & 0.62 & -0.17 & 0.11 & 0.02 & 0.00 & 0.09 & 0.34 & -0.09 & 0.07 \\ 0.08 & -0.17 & 1.09 & 0.06 & 0.06 & 0.04 & -0.40 & -0.02 & 0.46 & -0.06 \\ 0.04 & 0.11 & 0.06 & 0.24 & -0.05 & 0.02 & 0.03 & 0.03 & -0.01 & 0.05 \\ 0.09 & 0.02 & 0.06 & -0.05 & 0.33 & -0.01 & 0.04 & -0.28 & -0.18 & 0.06 \\ 0.01 & 0.00 & 0.04 & 0.02 & -0.01 & 0.23 & -0.17 & -0.03 & 0.09 & 0.01 \\ 0.13 & 0.09 & -0.40 & 0.03 & 0.04 & -0.17 & 2.17 & 0.09 & -0.51 & 0.00 \\ 0.00 & 0.34 & -0.02 & 0.03 & -0.28 & -0.03 & 0.09 & 3.60 & 0.08 & -0.46 \\ 0.01 & -0.09 & 0.46 & -0.01 & -0.18 & 0.09 & -0.50 & 0.08 & 0.47 & -0.02 \\ 0.00 & 0.07 & -0.06 & 0.05 & 0.06 & 0.01 & 0.00 & -0.46 & -0.00 & 0.16 \end{vmatrix} \end{aligned}$$

4.2 Wedges

Once the parameter values are obtained, the model can be numerically solved for decision rules. I use the linear solution method a la Uhlig (1999) to solve the model. Following Chari et al (2007), I compute the wedges using the obtained linear decision rules and the data of the observable variables used for the estimation.

The linear decision rules DR of endogenous variables are functions of

[14] The initial guess of the persistence matrix parameters are 0.5 for the diagonal parameters and 0 for the off diagonal parameters. The initial guess of the variance covariance matrix parameters are 0.05 for the standard deviations and 0 for the correlation coefficients between the error terms. Although the point estimates are some what sensitive to the initial guess, the simulation results are not.

state variables $\{\widetilde{k^i}, \widetilde{g^i}, \widetilde{\tau^i_l}, \widetilde{\tau^i_x}, \widetilde{z^i}, \widetilde{p}, \widetilde{\tau}\}$. Initial capital stock in each country is assumed to be at the steady state level. Once the initial capital stock level is given, the entire series of wedges can be computed. The detailed procedure is as follows.

1. Solve the model for linear decision rules:

$$\{\widetilde{k^i_{t+1}}, \widetilde{y^i_t}, \widetilde{c^i_t}, \widetilde{l^i_t}, \widetilde{x^i_t}, \widetilde{g^i_t}\} = DR_{\{k^i,y^i,c^i,l^i,x^i,g^i\}}(\widetilde{k^i_t}, \widetilde{g^i_t}, \widetilde{\tau^i_{lt}}, \widetilde{\tau^i_{xt}}, \widetilde{z^i_t}, \widetilde{p_t}, \widetilde{\tau_t}).$$

2. Assuming $\widetilde{k^i_0} = 0$, compute $\{\widetilde{g^i_0}, \widetilde{\tau^i_{l0}}, \widetilde{\tau^i_{x0}}, \widetilde{z^i_0}, \widetilde{p_0}, \widetilde{\tau_0}\}$ from

$$\{\widetilde{y^i_0}, \widetilde{c^i_0}, \widetilde{l^i_0}, \widetilde{x^i_0}, \widetilde{g^i_0}\} = DR_{\{y^i,c^i,l^i,x^i,g^i\}}(\widetilde{k^i_0}, \widetilde{g^i_0}, \widetilde{\tau^i_{l0}}, \widetilde{\tau^i_{x0}}, \widetilde{z^i_0}, \widetilde{p_0}, \widetilde{\tau_0}).$$

3. Compute $\widetilde{k^i_1}$ from

$$\widetilde{k^i_1} = DR_{\{k^i\}}(\widetilde{k^i_0}, \widetilde{g^i_0}, \widetilde{\tau^i_{l0}}, \widetilde{\tau^i_{x0}}, \widetilde{z^i_0}, \widetilde{p_0}, \widetilde{\tau_0}).$$

4. Solve for $\{\widetilde{g^i_1}, \widetilde{\tau^i_{l1}}, \widetilde{\tau^i_{x1}}, \widetilde{z^i_1}, \widetilde{p_1}, \widetilde{\tau_1}\}$ from

$$\{\widetilde{y^i_1}, \widetilde{c^i_1}, \widetilde{l^i_1}, \widetilde{x^i_1}, \widetilde{g^i_1}\} = DR_{\{y^i,c^i,l^i,x^i,g^i\}}(\widetilde{k^i_1}, \widetilde{g^i_1}, \widetilde{\tau^i_{l1}}, \widetilde{\tau^i_{x1}}, \widetilde{z^i_1}, \widetilde{p_1}, \widetilde{\tau_1}).$$

5. Repeat 4 and 5 for the whole period.

Figures 3a and 3b plot the domestic wedges in each country along with linearly detrended output. Investment wedges are more volatile than the other wedges in each country. However, this does not immediately imply that investment wedges are important in accounting for business cycles. In order to evaluate the importance of each wedge, we have to simulate the model. In Japan, the fluctuations of efficiency wedges are similar to that of output. Labor and government wedges are growing throughout the entire period. Investment wedges fall during the bubble period and increase during the lost decade. This implies that the investment conditions were good in during the former while they deteriorated during the later. In the US, government and investment wedge are declining throughout the entire period. Labor wedges are clearly negatively correlated to the output.

Figure 3c plots the international wedges. One notable fact is that the model predicts a fall in relative prices of Japanese goods during the late 1980s and mid-1990s, which is when the yen actually appreciated in real terms against US dollars to a historical level. The fact that international price wedges cannot replicate real exchange rates is related to the international price anomaly a la Backus and Smith (1993)[15]. The international trade wedges represent the sum of trade balances in Japan and the US. The US has been running a trade deficit after 1990 while Japan has been running a trade surplus. The decline in the international trade wedges implies that the increase in the US deficit exceeded the increase in the Japanese surplus.

The key economic effects of the changes in each wedge are as follows. A rise in government wedges generates a negative income effect for the household which reduces consumption and leisure leading to an increase in labor and output. An increase in labor wedges increases the relative price of leisure to consumption, which causes a substitution effect that leads the household to reduce consumption and increase leisure. A decrease in labor leads to an output decline. An increase in current investment wedges increases the relative price of investment to consumption, which leads to an increase in consumption and a reduction in investment. An increase in production efficiency wedges causes a real business cycle effect that increases output, consumption, labor, and investment. An improvement in production efficiency directly increases production. Labor increases because a rise in the marginal product of labor drives up labor demand and a resulting increase in wages leads to an increase in consumption. Investment increases as the expected future marginal product of capital is high because of an expectation of high efficiency to persist. A rise in the international price wedges raises the price of Japanese resources relative to US resources which creates negative wealth effects in Japan. This leads to a fall in Japanese consumption and leisure and a rise in US consumption and leisure. Therefore, labor and output will increase in Japan and decrease in the US. Finally, a rise in international trade wedges operates in the same fashion as a rise in government wedges.

Table 3 presents the correlation of HP filtered domestic wedges with HP filtered output in each country as well as the cross-country correlation of the HP filtered wedges. In both countries, government wedges have low correlation, investment wedges have strong negative correlations, and efficiency wedges have strong positive correlations with domestic output. Further-

[15] Recent studies such as Corsetti, Dedola and Leduc (2008) and Raffo (2010) attempt to solve this puzzle by introducing non-tradable goods, incomplete asset markets and non-separable preferences.

more, the cross-country correlations of government, labor, investment, and efficiency wedges all increased during the 2000–2008 period. Therefore, the fact that output correlation increased during 2000–2008 can be attributed to the rise in cross-country correlation of wedges. In the following section, I simulate the model in order to investigate the quantitative impact of each wedge.

4.3 Simulation

The simulations are done by plugging the computed wedges into the linear decision rules. Figures 4a and 4b plot the reaction of output in each country to changes in each domestic wedges. In Japan, efficiency wedges account for most of the changes in output until 2000. Investment wedges contributed to the rapid growth during the late 1980s as shown in Chakraborty (2009) and Otsu and Pyo (2009). Labor wedges have persistent depressing effects over the entire period as shown in Kobayashi and Inaba (2006). In the US, Labor wedges account for most of the fluctuation in output throughout the entire period while efficiency wedges are important during the early 1980 recession and the early 2000 recession. These results are consistent with those of Chari et al (2007). However, the role of investment wedges in accounting for the early 1980s recession appears to be slightly stronger than that in their results. One reason for this discrepancy is that extending the model to an open economy setting creates differences in the estimation and simulation results. Another reason is because of the difference in the estimation period. The estimated investment wedges turn out to have depressing effects on output up to early 1990s and have booming effects after that. Therefore, part of the depressing effect of investment wedges during the early 1980s recession is coming from this medium term trend which does not exist in the original literature[16].

In order to focus on the short run fluctuations I detrend the results with the HP-filter. Figures 5a and 5b plot the filtered simulation results. In Japan,

[16] Another reason why investment wedges have significant effects is because I assume large investment adjustment costs. According to Christiano and Davis (2006) large investment adjustment costs increase the importance of investment wedges. Chari et al (2007) address this issue by comparing results with alternative investment adjustment costs. They show that adding the adjustment cost does not change the results dramatically. As shown in the sensitivity analysis section, lowering the adjustment cost indeed reduces the importance of investment wedges.

most of the short run fluctuation of output is accounted for by changes in the efficiency wedges. In the US, the short run fluctuation of output is mainly accounted for by changes in the labor and efficiency wedges.

Table 4 reports the contribution index

$$corr(\widetilde{X_{model}}, \widetilde{X_{data}}) \times \frac{std(\widetilde{X_{model}})}{std(\widetilde{X_{data}})}$$

where $\widetilde{X_{model}}$ is the log deviation of variable X from its trend level in the model simulation and $\widetilde{X_{data}}$ corresponds to the log deviation of the analog in the data. This index shows whether the simulated variable in response to each wedge is moving in the correct direction (the correlation between the simulated variable and the data is positive) and whether its generated fluctuation is large (the relative volatility of the simulated variable to the data is large)[17]. Notice that since the data can be perfectly replicated once all of the wedges are plugged into the linear decision rules, the sum of these indexes is equal to one for all variables. Therefore, the index represents the contribution of each wedge to the actual fluctuation of each variable. The table shows that in Japan, efficiency wedges are important in accounting for fluctuations in output; efficiency and international price wedges are important in accounting for fluctuations in consumption; labor wedges are important in accounting for fluctuations in labor[18]; and investment wedges are important in accounting for fluctuations in investment. In the US, labor and efficiency wedges are important in accounting for fluctuations in output; international price wedges are important in accounting for fluctuations in consumption; labor wedges are important in accounting for fluctuations in labor; and investment wedges are important in accounting for fluctuations in investment. Notice that although international price wedges are important in accounting for consumption fluctuation in both countries, they drive output in the wrong

[17] The measure can be rewritten as

$$\frac{cov(Model, Data)}{var(Data)}$$

by definition. Measuring the fit using mean squared errors between the model and the data leads to similar results to those presented below.

[18] Notice that while labor wedges in Japan are important in accounting for the fluctuation of labor, it has negative contribution to output fluctuation i.e. the correlation coefficient of the simulated output and data is negative.

direction in both countries due to the above mentioned wealth effect. In addition to the simulation with only one wedge at a time, I simulate the model with efficiency wedges in both countries, which corresponds to a canonical international real business cycle model a la Baxter and Crucini (1993)[19]. The results listed in the bottom row show that while the contribution of efficiency wedges to the fluctuation of output is high in both Japan and the US, those to the fluctuation of consumption, labor, and investment are all low in a canonical real business cycle model.

Table 5 presents the cross-country correlation of HP-filtered simulated variables, which is useful to break down the sources of the quantity anomaly[20]. First, without international price wedges the cross-country correlation of consumption is always equal to one. This is obvious from the international risk sharing condition (11), which guarantees that consumption across countries is perfectly correlated without international price wedges. Therefore, international price wedges are necessary to account for the low cross-country correlation of consumption. Second, output, labor, and investment are all negatively correlated across countries with only efficiency wedges in either country. When efficiency is high in one country, the efficient country will increase labor due to the high marginal product of labor, and increase current consumption as well as future consumption by increasing savings in the form of domestic investment and foreign lending. The other country is better off postponing labor and investment and borrows from the efficient country in order to increase consumption. Thus, production factors and output rises in the country that enjoys high efficiency and should fall in the other. The negative correlation of inputs is present even when efficiency is high in both countries as long as the efficiency in one country is higher than the other. Therefore, canonical international real business cycle models with only productivity shocks fail to explain the order of cross-country correlations of output and consumption. The result in the bottom row shows that the cross-country correlation of output is far below that of consumption, i.e., the quantity anomaly.

Next, I conduct a simulation in which all computed wedges except for

[19] The only difference is that there are spillover effects from efficiency wedges onto other wedges.

[20] The correlation coefficients reported are those computed from the counterfactual simulations using the selected computed wedges. Similar results can be obtained from counterfactual simulations using random draws of innovations to the selected wedges and assuming zero innovations to the other wedges.

selected ones are fed into the model. By doing so, we can evaluate the importance of the wedges that were excluded given that feeding in all wedges will perfectly reproduce the data. Table 6 presents the cross-country correlation of the simulated output by decade. For instance, the first column shows the results of the simulation with all wedges except for government wedges in both countries. The difference between the simulated cross-country correlation and data is very small. Therefore, government wedges are not important in accounting for the correlation patterns between Japan and the U.S. The first line summarizes the correlation of output over the entire period. Without labor, investment, efficiency and international wedges, the output correlation would have been negative. One interpretation of this result is that while efficiency wedges are the main driving forces of output fluctuation as in canonical international real business cycle models, labor, investment and international wedges are preventing the resources from flowing into the relatively efficient country. Moreover, the difference between the third and forth line shows the increase in cross country output correlation from the 1990s to the 2000s. In the data, the cross-country correlation increases by 103 percentage points. The increase in the correlation is equivalent to data in the simulations without government, investment and international wedges, whereas it increases in the simulations without labor wedges and efficiency wedges by only 24 percentage points and 60 percentage points respectively. This means that the increase in cross-country labor and efficiency wedges during the 2000s, shown in Table 3, is important in accounting for the increase in cross-country output correlation. This result is important because it implies that the cause of the recent rise in cross-country output correlation between Japan and the U.S. must operate as an increase in cross-country correlation of efficiency and labor wedges. In the following sector I propose a model in which global financial integration serves as this cause.

4.4 Sensitivity Analysis

In this section, the prototype model results are tested for robustness. First, I test for the case in which investment adjustment cost does not exist focusing on the role of investment wedges. Next, I consider alternative preferences: nonseparable preferences, habit formation preferences, and GHH preferences focusing on the quantity anomaly.

4.4.1 The Role of Capital Adjustment Costs

International real business cycle models typically assume capital adjustment costs because the fluctuation of simulated investment is extremely sensitive to productivity shocks. Since the international business cycle accounting model is based on a canonical two-country model, the prototype model includes adjustment costs. The role of capital adjustment costs have been under debate in the closed economy business cycle accounting literature. Chari et al (2007) show that investment wedges without capital adjustment costs are not important in accounting for the US output drop during the Great Depression. Christiano and Davis (2006) claim that capital adjustment cost increases the importance of investment wedges. In this section, I investigate the role of capital adjustment costs by simulating the model without them.

Table 7 shows the contributions of each wedge in the model without capital adjustment costs, which corresponds to Table 4. Indeed, the quantitative importance of investment wedges is lower without capital adjustment costs. The contribution of investment wedges on output falls from 0.14 to -0.05 in Japan and from 0.21 to -0.02 in the U.S. Instead, the result that efficiency and labor wedges are important in the US in accounting for output fluctuation is emphasized. The contributions of efficiency and labor wedges rise from 0.50 to 0.65 and from 0.52 to 0.62 respectively in the U.S. Otherwise, the results are quite similar across the two simulations[21].

Table 8 reports the cross-country correlation of simulated output without selected wedges, which corresponds to Table 6. The results with all wedges except for investment wedges shows that investment wedges are not important in accounting for the cross-country correlation of output even on average. This means that the role of investment wedges without capital adjustment costs on output correlation is even weaker than in the prototype model. Instead, the role of efficiency wedges are larger in accounting for the average cross-country output correlation while the role of labor wedges are larger in accounting for the recent increase in it.

[21] One interesting result is that the fluctuation of simulated investment is reasonable even without adjustment costs. This is because the estimated stochastic process has spill-over effects across all wedges. A sensitivity analysis forcing the shock persistence matrix to be orthogonal without capital adjustment costs shows that investment is extremely sensitive to efficiency wedges.

4.4.2 Models with Alternative Preferences

For the sensitivity analysis, I focus on how alternating preferences affect the quantity anomaly. Therefore, I report the cross country output correlation in response to efficiency wedges in both countries, which corresponds to the canonical international real business cycle model. The results are summarized in Table 9.

Non-Separable Utility First, consider a preference function that is non-separable between consumption and leisure

$$u(c,l) = \frac{(c_t^{\Psi}(1-l_t)^{1-\Psi})^{1-\sigma}}{1-\sigma}.$$

The curvature parameter represents the degree of risk aversion of the household. The preference in (3) is a special case of this preference function in which $\sigma = 1$. With non-separable preferences, $\sigma \neq 1$, marginal utilities of consumption in each countries are not only functions of consumption, but also labor.

The marginal utilities for non-separable preferences are $u_{ct}^i = \Psi^i (c_t^i)^{\Psi^i(1-\sigma)-1}(1-l_t^i)^{(1-\Psi^i)(1-\sigma)}$ and $u_{lt}^i = (1-\Psi^i)(c_t^i)^{\Psi^i(1-\sigma)}(1-l_t^i)^{(1-\Psi^i)(1-\sigma)-1}$. The labor first order condition (10) is identical to that in the prototype model. However, the capital Euler equation (9) and the international first order condition (11) are affected by the additional leisure term that enters the marginal utility. The reported results in Table 9 are those for the case of $\sigma = 5$. This shows that nonseparability does not help much in solving the quantity anomaly.

Habit Formation Utility Next, consider a case in which the household consumption forms habit persistence

$$u(c,l) = \Psi \log(c_t - b\widehat{c}_{t-1}) + (1-\Psi)\log(1-l_t).$$

The habit persistence parameter b is assumed to be equal to 0.65, following Christiano, Eichenbaum, and Evans (2005). For simplicity, I assume external habit formation such that the habit is formed upon the lagged aggregate consumption $\widehat{c}$, which is not internalized by the households. This preference helps inducing persistence in consumption. Since both countries want to gradually increase consumption when one of the countries experiences high efficiency, they have a motive to accumulate wealth for the future. Dmitriev and Krznar (2009) find that this channel is strong enough to generate positive cross-country investment correlations when the adjustment cost for capital is sufficiently high.

With habit persistence, the marginal utility of consumption is $u^i_{ct} = \Psi^i/(c^i_t - b\widehat{c}^i_{t-1})$, while the marginal utility of labor is the same as in the prototype model. This alternation affects the capital Euler equation (9), labor first order condition (10), and international first order condition (11). However, although the marginal utility of consumption is different from that in the prototype model, the international first order condition still guarantees that consumption is perfectly correlated across countries without international price wedges as long as the utility is separable. Sensitivity analysis shows that the habit formation preferences cannot solve the quantity anomaly.

GHH Preferences Finally, consider the GHH preferences a la Greenwood, Hercowitz, and Huffman (1988):

$$u(c, l) = \log(c_t - \chi l^{\nu}_t).$$

GHH preferences are widely used in the small open economy literature because of their ability to generate high volatility in consumption and countercyclical trade balance through the lack of income effects on labor supply. Greenwood, Rogerson and Wright (1995) show that the GHH preference function is a reduced-form of preferences with home production.

The marginal utilities are $u^i_{ct} = 1/(c^i_t - \chi(l^i_t)^{\nu})$ and $u^i_{lt} = \chi\nu(l^i_t)^{\nu-1}/(c^i_t - \chi(l^i_t)^{\nu})$. This alternation affects the capital Euler equation (9), labor first order condition (10), and international first order condition (11). With the lack of income effects on labor, the marginal rate of substitution of labor to consumption is independent from consumption. Since there is no utility trade-off between consumption and labor, shocks to efficiency wedges generate larger fluctuations in consumption than in the case with Cobb-Douglas preferences[22]. The more the consumption reacts to domestic efficiency wedges, the lower is the cross-country consumption correlation. Furthermore, labor reacts less to foreign efficiency wedges because of the lack

[22]Raffo (2008) shows that the Backus et al (1994) two-country model with GHH preferences can generate a countercyclical trade balance through countercyclical fluctuation of goods rather than countercyclical international prices. This result is driven by the fact that the fluctuation of domestic absorption in response to productivity shock is greater than that of output.

of income effects[23]. Therefore, consumption and labor become more volatile and procyclical, which leads to higher cross-country output correlation and a lower cross-country consumption correlation. The sensitivity analysis shows that the simulated cross-country correlation of output and consumption in response to efficiency wedges in both countries are -0.13 and 0.14 respectively, compared to -0.66 and 1.00 in the prototype model. Therefore, the GHH preferences improve the results significantly but the quantity anomaly is not solved. In other words, the international price wedge is still needed even with this special preference setting.

5 A Model of Financial Globalization

The quantitative results show that the fact that the cross-country output correlation is recently increasing can be accounted for by the increase in the cross-country correlation of labor and efficiency wedges and not that of investment wedges. However, this does not immediately dismiss structural shocks that manifest themselves primarily as investment wedges as the driving force of this fact. In this section, I describe a model based on Otsu and Saito (2009) in which financial shocks that primarily manifest themselves as investment wedges generate an increase in cross-country output correlation through their endogenous effects on labor and efficiency wedges.

Consider a one-good two-country model with households, firms, financial intermediaries, and governments in each country. The household problem in each country is almost identical to those in the prototype model without wedges except that the households do not hold capital; the firms do. The firm borrows funds from a financial intermediary in the beginning of the period in order to pay a fraction α^i of the wage bill in cash due to a working capital constraint and pays it back in the end of the period with interest R^i_{kt}. Labor l^i_t is allocated in two activities; production l^i_{1t} and accumulation of organizational capital l^i_{2t}:

$$l_t = l_{1t} + l_{2t}.$$

[23]From the international first order condition (11), marginal utilities of consumption across countries can be equalized by movements not only in consumption but also in labor. The link between consumption and leisure across countries weakens because a simultaneous increase in consumption and leisure nullifies any movement in the marginal utility.

The firms profit maximization problem is

$$\max \pi_t = \left(k_t^i\right)^\theta \left(l_{1t}^i\right)^{1-\theta} - (1+\alpha^i(R_{kt}^i - 1))w_t^i l_t^i - x_t^i - \Phi_t^i k_t^i,$$

assuming that there are no disturbances in the firm level productivity. Organizational capital H_{t+1}^i is used in financial contracts where high organizational capital leads to lower credit spread the firm faces[24]. For simplicity, assume

$$R_{kt}^i = \left(\frac{\overline{H}}{H_{t+1}}\right)^\alpha R_t^i,$$

where $\overline{H}$ is the upper-bound of organizational capital[25]. The risk free rate of return R_t^i will be equal across countries in equilibrium due to the complete markets assumption. The organizational capital follows a law of motion

$$H_{t+1}^i = (1-\delta_H^i)H_t^i + l_{2t}^i + \varsigma_t^i,$$

where δ_H^i is the depreciation rate of organizational capital and ς_t^i is the financial shock.

Since the financial shocks directly affect the credit spread and create additional cost for investment, they primarily show up as investment wedges. An interesting feature of this model is that the financial shocks generate endogenous fluctuations in the efficiency wedges. Consider the case in which the economy was hit by a negative financial shock ς_t^i. Since the loss in organizational capital leads to a high credit spread and a reduction in profits, the firm will try to rebuild organizational capital by increasing l_2. The measured efficiency wedges:

$$z_t^i = \left(\frac{\left(k_t^i\right)^\theta \left(l_{1t}^i\right)^{1-\theta}}{\left(k_t^i\right)^\theta (l_{1,t}^i + l_{2,t}^i)^{1-\theta}}\right)^{\frac{1}{1-\theta}}$$

will fall as labor will shift from production activity towards the accumulation of organizational capital even if the firm productivity z is unchanged. Financial shocks also affect labor wedges through the borrowing cost for the

[24] The organizational capital can be thought of as a firm-specific knowledge that enhances the financial relationship between firms and outside lenders.

[25] This functional form gurantees that the credit premium disappears when organizational capital reaches the upperbound or when there is no need to borrow for the working capital ($\alpha = 0$).

working capital. That is, a negative financial shock increases the borrowing cost which appears as an increase in labor wedges:

$$-\frac{u^i_{lt}}{u^i_{ct}} = \frac{1}{1+\alpha^i(R^i_{kt}-1)}(1-\theta^i)\frac{y^i_t}{l^i_{1t}}.$$

The financial shock ς^i_t is divided into globally common factors $\widetilde{\varsigma}_t$ and country specific factors $\widehat{\varsigma}_t$ that are orthogonal to each other:

$$\varsigma^i_t = \omega\widetilde{\varsigma}^i_t + (1-\omega)\widehat{\varsigma}_t, corr(\widetilde{\varsigma}^i_t, \widehat{\varsigma}_t) = 0.$$

An increase in the share of globally common financial shocks ω in both countries represents the degree of financial globalization[26]. This can be caused by an increase in international transactions among financial intermediaries and/or an expansion of cross-border branches of financial intermediaries.

Figure 6 plots the simulated cross-country correlation of output, efficiency wedges and labor wedges for different values of ω[27]. The correlations of all variables are monotonically increasing in ω. This shows that financial globalization leads to an increase in cross-country output correlation through the increase in the cross-country correlation of labor and efficiency wedges, which is consistent with the business cycle accounting results in Table 6[28].

6 Conclusion

This paper extends the business cycle accounting method a la Chari, Kehoe, and McGrattan (2007) to a two-country open economy framework for considering the business cycle correlation patterns between Japan and the U.S. over the 1980-2008 period. I find that (i) efficiency wedges are important in accounting for the fluctuation of output in Japan, while labor and efficiency wedges are important in the U.S. (ii) international price wedges are necessary

[26] Heathcote and Perri (2004) define financial globalization as the increase in foreign asset trade in the US.

[27] The working capital parameter α is assumed to be 0.5. The qualitative results are not sensitive to the choice of the parameter. The values of other parameters follow Otsu and Saito (2009).

[28] Since the main focus is the cross-country output correlation, the model does not include any mechanism to reduce the cross-country consumption. From the discussion above, adding more market structure, alternating the preference function, and introducing additional shocks can improve the results in this aspect.

to account for the low cross-country consumption correlation even in settings that partially endogenize them and with alternative preferences, (iii) labor, investment and international price wedges prevent resources from flowing into the relatively efficient country and increase cross-country output correlation, furthermore (iv) the increase in the cross-country correlation of the labor and efficiency wedges is important in accounting for the recent increase in the cross-country output correlation. A successful model for business cycle correlations between Japan and the U.S. must account for these features.

Although identifying the structural shocks that consist of the wedges is out of the scope of the paper, I propose a two-country model that can account for the recent increase in cross-country output correlation by financial globalization. This model is consistent with the business cycle accounting results because higher cross-country financial shock correlation endogenously leads to an increase in cross-country output correlation through an increase in cross-country labor and efficiency wedges correlations. The business cycle accounting method is useful to narrow down potentially successful structural models not only in a closed-economy setting but also in an open-economy framework.

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A Observational Equivalence

Early international business cycle models such as Backus et al (1994), Stockman and Tesar (1995) and Baxter and Crucini (1995) attempted to solve the quantity anomaly by reducing consumption risk sharing. In this section, I show how these models with intermediate goods, non-tradables and incomplete capital markets can all be mapped into the prototype international business cycle accounting model with efficiency and international price wedges[29]. In addition, taste shocks a la Stockman and Tesar (1995) and Wen (2007) can be mapped into the prototype model with labor, investment and international price wedges.

A.1 A Two-Good Model with Intermediate Goods

Consider a model in which two countries specialize in producing separate intermediate goods as in Backus et al (1994). The intermediate goods are combined in both countries to form final goods according to an Armington aggregator

$$G_t^i = \left(\eta^i (a_t^i)^{\frac{\varepsilon-1}{\varepsilon}} + (1-\eta^i)(b_t^i)^{\frac{\varepsilon-1}{\varepsilon}}\right)^{\frac{\varepsilon}{\varepsilon-1}},$$

where a and b are intermediate goods produced in each country. The production technologies for intermediate goods in each country are

$$\begin{aligned} f_t^{JP} &= v_t^{JP}\left(k_t^{JP}\right)^{\theta^{JP}}\left(l_t^{JP}\right)^{1-\theta^{JP}} = a_t^{JP} + a_t^{US} \\ f_t^{US} &= v_t^{US}\left(k_t^{US}\right)^{\theta^{US}}\left(l_t^{US}\right)^{1-\theta^{US}} = b_t^{JP} + b_t^{US} \end{aligned}$$

where v_t^i are productivity shocks. It is easy to show that output in each country are $y^{JP} = G_a^{JP} f^{JP}$ and $y^{US} = G_b^{US} f^{US}$ where G_a^{JP} and G_b^{US} are the prices of the produced intermediate goods relative to final goods in Japan and the U.S. respectively. Notice that in this model, productivity shocks v_t^i are not equivalent to the efficiency wedges z_t^i. The efficiency wedges computed as Solow residuals include changes in intermediate good productivity and

[29] The simple mapping presented in this section only focuses on the resource allocations in the prototype model and the alternative model. I do not provide formal proofs because they are obvious. Inaba and Nutahara (2009) show equivalence conditions not only for resource allocation, but also for the stochastic process in the two models.

changes in the relative price of intermediate goods to final goods:

$$z_t^{JP} = G_{at}^{JP} v_t^{JP}, z_t^{US} = G_{bt}^{US} v_t^{US}. \tag{12}$$

Assuming complete markets as in the prototype model, the international first order condition is

$$\frac{u_{ct}^{JP}}{u_{ct}^{US}} = \frac{G_{at}^{US}}{G_{at}^{JP}} = \frac{G_{bt}^{US}}{G_{bt}^{JP}}. \tag{13}$$

From (13) and (11), if

$$\frac{G_{at}^{US}}{G_{at}^{JP}} = \frac{G_{bt}^{US}}{G_{bt}^{JP}} = p_t$$

holds along with (12), the two-good model with productivity shocks in intermediate goods production is observationally equivalent to the prototype model with efficiency and international price wedges.

In this setting, productivity shocks to intermediate goods firms v^i in both countries endogenously shift the international relative prices $\frac{G_{at}^{US}}{G_{at}^{JP}} = \frac{G_{bt}^{US}}{G_{bt}^{JP}}$. The extent to which the productivity shocks in each country affect the international price wedge depends on the elasticity of substitution between home goods and foreign goods ε, and the home bias η. Backus et al (1994) show that with $\varepsilon = 1.5$ and $\eta = 0.7$ an increase in productivity in the home country and/or a decrease in the foreign country productivity leads to a reduction in the international relative price of home country goods. However, they find that the endogenous fluctuations in the international relative price is not large enough to solve the quantity anomaly.

A.2 A Two-Good Model with Non-Tradables

Consider a model in which each country produces tradable and nontradable goods as in Stockman and Tesar (1995). For simplicity, assume that tradables are used for final consumption by the household and the government and capital accumulation while nontradables are only used for household consumption:

$$\begin{aligned} z_{Tt}^i \left(k_{Tt}^i\right)^{\theta_T^i} \left(l_{Tt}^i\right)^{1-\theta_T^i} &= c_{Tt}^i + x_t^i + g_t^i + tb_t^i \\ z_{Nt}^i \left(k_{Nt}^i\right)^{\theta_N^i} \left(l_{Nt}^i\right)^{1-\theta_N^i} &= c_{Nt}^i \end{aligned}$$

where c_T and c_N stand for household consumption of tradables and non-tradables respectively. Tradables can be freely shifted across countries using the state-contingent international claim as in the prototype model. Labor and investment are freely mobile across sectors.

Assume that the households in each country are consuming a composite consumption good

$$c_t^i = (c_{Tt}^i)^\gamma (c_{Nt}^i)^{1-\gamma}.$$

Therefore the periodical preferences can be rewritten as

$$u(c_{Tt}^i, c_{Nt}^i, l_{Tt}^i, l_{Nt}^i) = \Psi^i \left(\gamma \ln c_{Tt}^i + (1-\gamma) \ln c_{Nt}^i\right) + (1-\Psi^i) \ln(1 - l_{Tt}^i - l_{Nt}^i).$$

Due to complete markets, the international first order condition for tradables and non-tradables are

$$\frac{u_{c_T t}^{JP}}{u_{c_T t}^{US}} = 1 \text{ and } \frac{u_{c_N t}^{JP}}{u_{c_N t}^{US}} = \frac{p_{Nt}^{JP}}{p_{Nt}^{US}}$$

where p_{Nt}^i is the price of nontradables relative to the tradables. Therefore, even without international price wedges the composite consumption is not perfectly correlated due to changes in non-tradable prices. In other words, the international first order condition for the composite consumption good is

$$\frac{u_{ct}^{JP}}{u_{ct}^{US}} = \left(\frac{p_{Nt}^{JP}}{p_{Nt}^{US}}\right)^{1-\gamma} \tag{14}$$

given that the price of tradables are equal across countries in the absence of international price wedges[30]. Thus, from (14) and (11), the model with tradable and nontradable goods is observationally equivalent to the prototype model with efficiency and international price wedges if

$$\left(\frac{p_{NT}^{JP}}{p_{NT}^{US}}\right)^{1-\gamma} = p_t$$

holds and the sector weighted sum of productivity shocks z_{Tt}^i and z_{Nt}^i are equal to z_t^i[31].

[30] See Obstfeld and Rogoff (1996) chapter 4 for details of the derivation.

[31] The latter condition is quite tight as this requires the equilibrium capital-labor ratio and factor income shares in both sectors to be in line with the aggregate capital-labor

Productivity shocks in each sector affect the international relative price through typical Harrod-Balassa-Samuelson effects. For instance, a rise in productivity in the Japanese tradable good sector leads to a rise in Japanese nontradable prices which results in an increase in the relative price of Japanese consumption. This endogenous mechanism surely reduces the cross-country consumption correlation. However, Stockman and Tesar (1995) show that this endogenous mechanism is not large enough to solve the quantity anomaly[32].

A.3 The Incomplete Asset Market Model

Consider a two-country economy in which only a risk free bond b_t is traded in the international financial market instead of the state-contingent claim d_t. In this case, the households in each country cannot diversify country-specific risks because the return on the bond is predetermined. The only difference from the prototype model is that the household receives $d_t(s^{t-1})$ from the bond and purchases $q_t(s^t)d_{t+1}(s^t)$ for the future.

The international first order condition with incomplete markets is

$$\frac{u_{ct}^{JP}}{u_{ct}^{US}} = \frac{\beta^{JP} E_t \left[u_{ct+1}^{JP}\right]}{\beta^{US} E_t \left[u_{ct+1}^{US}\right]}. \tag{15}$$

From (15) and (11), the incomplete asset market model is observationally equivalent to the prototype model with efficiency and international price wedges if

$$\frac{\beta^{JP} E_t \left[u_{ct+1}^{JP}\right]}{\beta^{US} E_t \left[u_{ct+1}^{US}\right]} = p_t.$$

Baxter and Crucini (1995) find that if shocks are trend-stationary and there are cross-country spillovers of productivity shocks, complete markets and incomplete markets yield very similar allocations. When productivity shocks are considered to be permanent, they have large effects on the right hand side of (15) which can be considered as endogenously generating changes in the international price wedge. This causes large fluctuations in consump-

ratio and aggregate factor income shares.

[32] Stockman and Tesar (1995) introduce taste shocks that directly affect the marginal utility of consumption in order to solve the quantity anomaly. Asymmetric taste shocks across countries will operate exactly like international price wedges.

tion. Therefore, the incomplete asset market model can endogenously account for p_t and solve the quantity anomaly only when the productivity shocks follow a random walk process. However, once the shock process deviates from random walk, these effects die out.

A.4 The Model with Taste Shocks

Stockman and Tesar (1995) and Wen (2007) show that taste shocks which appear as international price wedges in the international first order condition (11) are effective in accounting for the low cross-country correlation in consumption. Consider taste shocks in the form of shocks to the preference weights of consumption ψ_t^i so that

$$u(c_t^i, l_t^i) = \Psi^i \psi_t^i \log c_t^i + (1 - \Psi^i \psi_t^i) \log(1 - l_t^i).$$

It is easy to show that if

$$\frac{\psi_t^{JP}}{\psi_t^{US}} = p_t$$

taste shocks can perfectly replace the international price wedges.

Taste shocks will also appear in the labor first order condition (10) and capital Euler equation (9) as the marginal utilities are changed to $u_{ct}^i = \Psi^i \psi_t^i / c_t^i$ and $u_{lt}^i = -(1 - \Psi^i \psi_t^i)/(1 - l_t^i)$. Therefore, taste shocks manifest themselves as labor, investment and international price wedges. there are several ways to compute them from data. In other words, they are not well identified.

B Tables and Figures

Table 1. Japan-US Quarterly Business Cycle Correlation (1980-2008)

	y	c	l	x
total period	0.06	-0.08	0.24	-0.06
1980-1989	0.09	-0.14	-0.04	-0.01
1990-1999	-0.33	-0.11	-0.08	-0.47
2000-2008	0.70	0.23	0.73	0.63

Table 2. Parameter Values

	Japan	US	Common
θ	0.457	0.387	0.422
δ	0.02	0.014	0.017
Γ	1.004	1.005	1.004
β	0.982	0.986	0.984
Ψ	0.269	0.214	0.241
l	0.252	0.202	0.227
c/y	0.592	0.659	0.626
x/y	0.258	0.220	0.239
g/y	0.134	0.145	0.139

Table 3. Correlation of Wedges

<table>
<tr><td colspan="6">Correlation with Japanese Output (total period)</td></tr>
<tr><td>g^{JP}</td><td>τ_l^{JP}</td><td>τ_x^{JP}</td><td>z^{JP}</td><td>p</td><td>τ</td></tr>
<tr><td>0.04</td><td>0.23</td><td>-0.79</td><td>0.89</td><td>-0.31</td><td>0.57</td></tr>
<tr><td colspan="6">Correlation with US Output (total period)</td></tr>
<tr><td>g^{US}</td><td>τ_l^{US}</td><td>τ_x^{US}</td><td>z^{US}</td><td>p</td><td>τ</td></tr>
<tr><td>-0.06</td><td>-0.73</td><td>-0.89</td><td>0.71</td><td>0.75</td><td>-0.17</td></tr>
<tr><td colspan="6">Correlation across Countries</td></tr>
<tr><td></td><td>g^{JP}, g^{US}</td><td>τ_l^{JP}, τ_l^{US}</td><td>τ_x^{JP}, τ_x^{US}</td><td>z^{JP}, z^{US}</td><td></td></tr>
<tr><td>total period</td><td>-0.21</td><td>0.14</td><td>-0.03</td><td>-0.13</td><td></td></tr>
<tr><td>1980-1989</td><td>-0.42</td><td>-0.30</td><td>0.03</td><td>-0.06</td><td></td></tr>
<tr><td>1990-1999</td><td>-0.06</td><td>0.24</td><td>-0.41</td><td>-0.36</td><td></td></tr>
<tr><td>2000-2008</td><td>0.07</td><td>0.48</td><td>0.50</td><td>0.08</td><td></td></tr>
</table>

Table 4. Simulation Results

	Contribution of Each Wedge[33]							
	Japan				US			
	y	c	l	x	y	c	l	x
g^{JP}	0.00	0.01	0.01	0.00	-0.01	0.02	-0.02	0.01
τ_l^{JP}	-0.12	0.05	0.76	-0.06	-0.01	0.06	-0.02	0.00
τ_x^{JP}	0.14	-0.02	0.15	0.74	0.04	-0.07	0.08	0.00
z^{JP}	1.04	0.44	0.08	0.37	0.00	-0.04	-0.03	0.00
g^{US}	-0.01	0.01	-0.02	0.00	0.00	0.00	-0.01	0.00
τ_l^{US}	-0.04	-0.02	-0.16	-0.02	0.50	0.39	0.97	0.10
τ_x^{US}	-0.03	0.10	0.04	0.00	0.21	-0.24	0.25	0.76
z^{US}	0.04	-0.12	0.02	0.01	0.52	0.26	0.10	0.13
p	-0.11	0.57	0.06	-0.01	-0.22	0.51	-0.30	-0.02
τ	0.08	-0.02	0.07	-0.04	-0.02	0.11	-0.02	0.01
Data	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
z^{JP}, z^{US}	1.08	0.32	0.09	0.38	0.51	0.22	0.07	0.13

Table 5. Simulation Results

	Cross-Country Correlation			
	y	c	l	x
g^{JP}	0.97	1.00	0.99	-1.00
τ_l^{JP}	-1.00	1.00	-1.00	-1.00
τ_x^{JP}	0.53	1.00	0.88	0.01
z^{JP}	-1.00	1.00	-1.00	-1.00
g^{US}	0.97	1.00	0.99	0.99
τ_l^{US}	-1.00	1.00	-1.00	-1.00
τ_x^{US}	0.67	1.00	0.92	-0.84
z^{US}	-1.00	1.00	-1.00	-1.00
p	-1.00	-1.00	-1.00	-1.00
τ	0.99	1.00	1.00	1.00
Data	0.06	-0.08	0.24	-0.06
z^{JP}, z^{US}	-0.66	1.00	-1.00	-0.45

[33] The contribution of each wedge is defined as

$$corr(\widetilde{X_{model}}, \widetilde{X_{data}}) \times \frac{std(\widetilde{X_{model}})}{std(\widetilde{X_{data}})}$$

Table 6. Simulation Results

Cross-Country Correlation of Simulated Output without						
	g^{JP}, g^{US}	τ_l^{JP}, τ_l^{US}	τ_x^{JP}, τ_x^{US}	z^{JP}, z^{US}	$p\&\tau$	Data
total period	0.08	-0.12	-0.26	-0.12	-0.32	0.06
1980-1989	0.11	0.05	-0.21	-0.28	-0.45	0.09
1990-1999	-0.33	-0.36	-0.64	-0.38	-0.58	-0.33
2000-2008	0.72	-0.12	0.43	0.22	0.48	0.70

Table 7. Sensitivity Analysis with no Adjustment Costs

	Contribution of Each Wedge							
	Japan				US			
	y	c	l	x	y	c	l	x
g^{JP}	0.00	0.01	0.02	0.00	-0.02	0.03	-0.03	-0.01
τ_l^{JP}	-0.12	0.06	0.74	-0.01	0.00	0.07	-0.01	-0.01
τ_x^{JP}	-0.05	-0.02	-0.04	0.38	0.03	0.04	0.01	0.47
z^{JP}	1.10	0.38	0.10	0.33	-0.01	-0.06	-0.03	-0.03
g^{US}	-0.01	0.01	-0.03	-0.01	0.00	0.00	-0.02	-0.01
τ_l^{US}	0.00	0.00	-0.03	0.11	0.65	0.05	1.24	0.30
τ_x^{US}	0.09	0.06	0.14	0.26	-0.02	0.11	0.00	-0.02
z^{US}	0.02	-0.07	0.01	-0.05	0.62	0.15	0.15	0.26
p	-0.11	0.58	0.05	0.00	-0.22	0.51	-0.30	0.03
τ	0.07	-0.01	0.05	-0.02	-0.01	0.10	-0.02	0.01
Data	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
z^{JP}, z^{US}	1.12	0.31	0.10	0.28	0.60	0.09	0.12	0.23

Table 8. Sensitivity Analysis with no Adjustment Costs

Cross-Country Correlation of Output Simulated without						
	$g^{JP}\&g^{US}$	$\tau_l^{JP}\&\tau_l^{US}$	$\tau_x^{JP}\&\tau_x^{US}$	$z^{JP}\&z^{US}$	$p\&\tau$	Data
total period	0.09	-0.15	0.03	-0.23	-0.32	0.06
1980-1989	0.13	-0.11	0.20	-0.57	-0.44	0.09
1990-1999	-0.32	-0.27	-0.45	-0.41	-0.58	-0.33
2000-2008	0.72	-0.10	0.61	0.23	0.48	0.70

Table 9. Sensitivity Analysis with Alternative Preferences

Cross-Country Correlation of Simulated Variables with z^{JP}&z^{US}

	y	c	l	x
Prototype	-0.66	1.00	-1.00	-0.45
Nonseparable	-0.46	0.66	-0.98	0.28
Habit	-0.75	1.00	-0.84	0.92
GHH	-0.13	0.14	-0.13	-0.08
Data	0.06	-0.08	0.24	-0.06

Figure 1a. Linearly Detrended Output in Japan and US

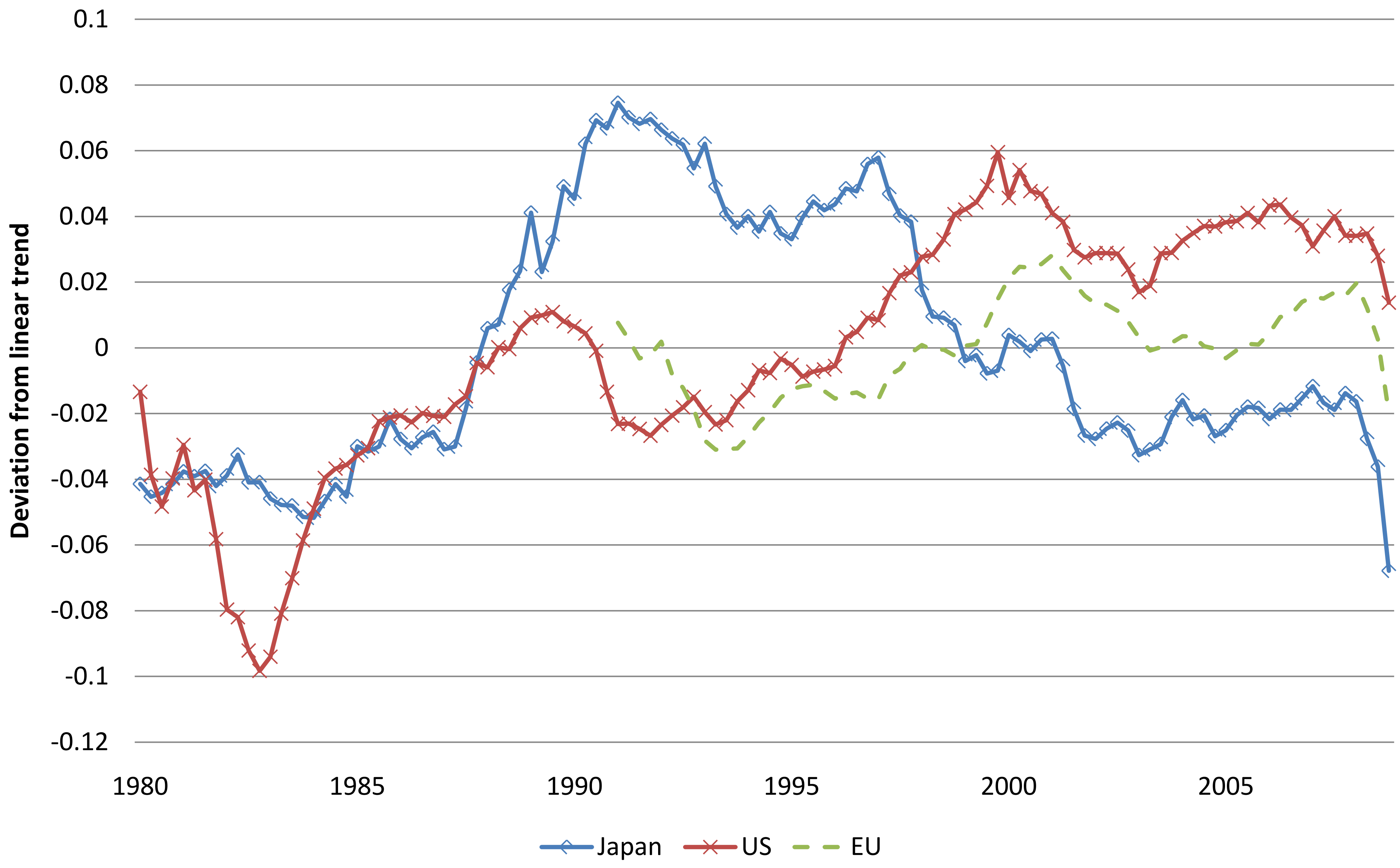
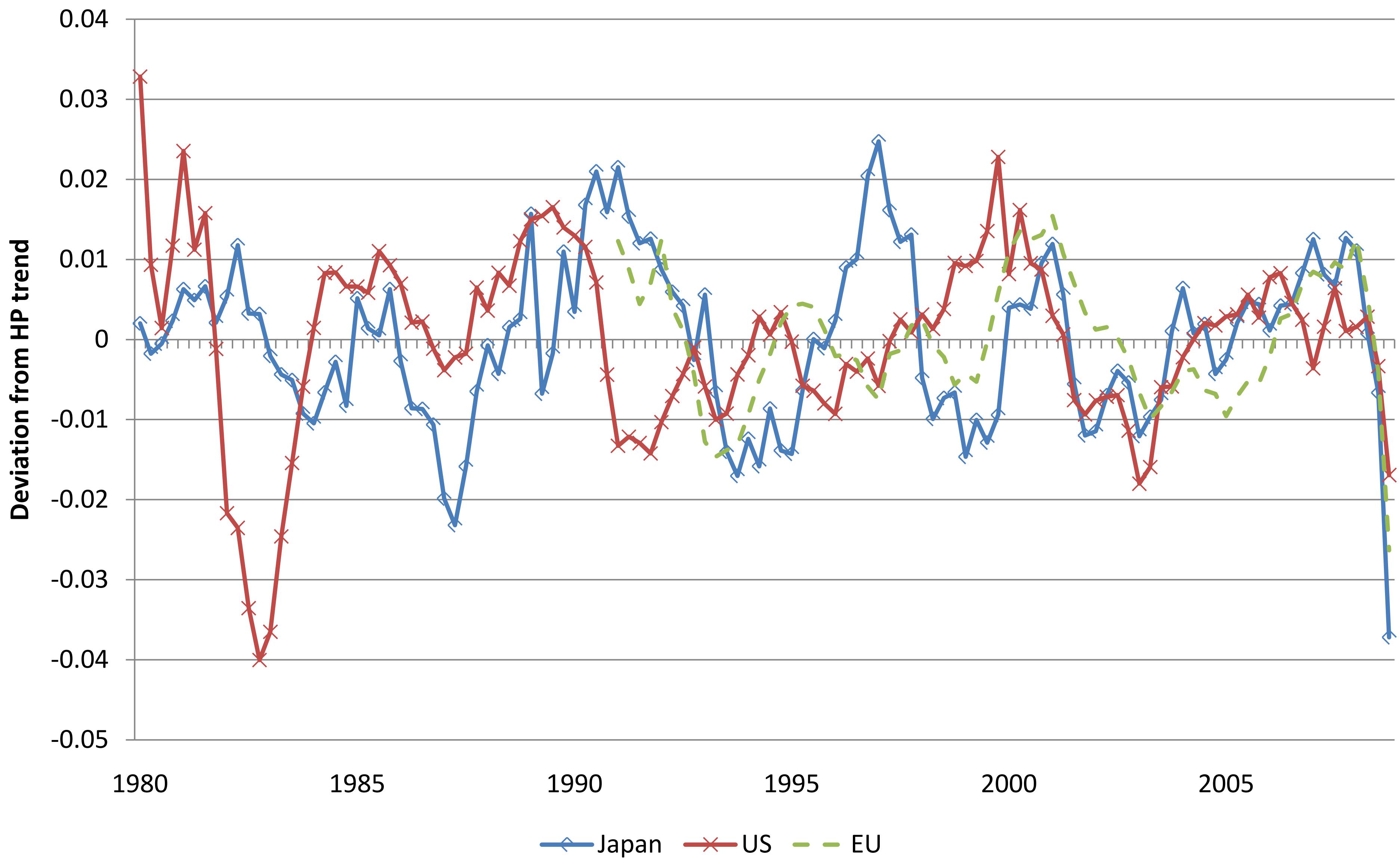


Figure 1b. HP-Detrended Output in Japan and US



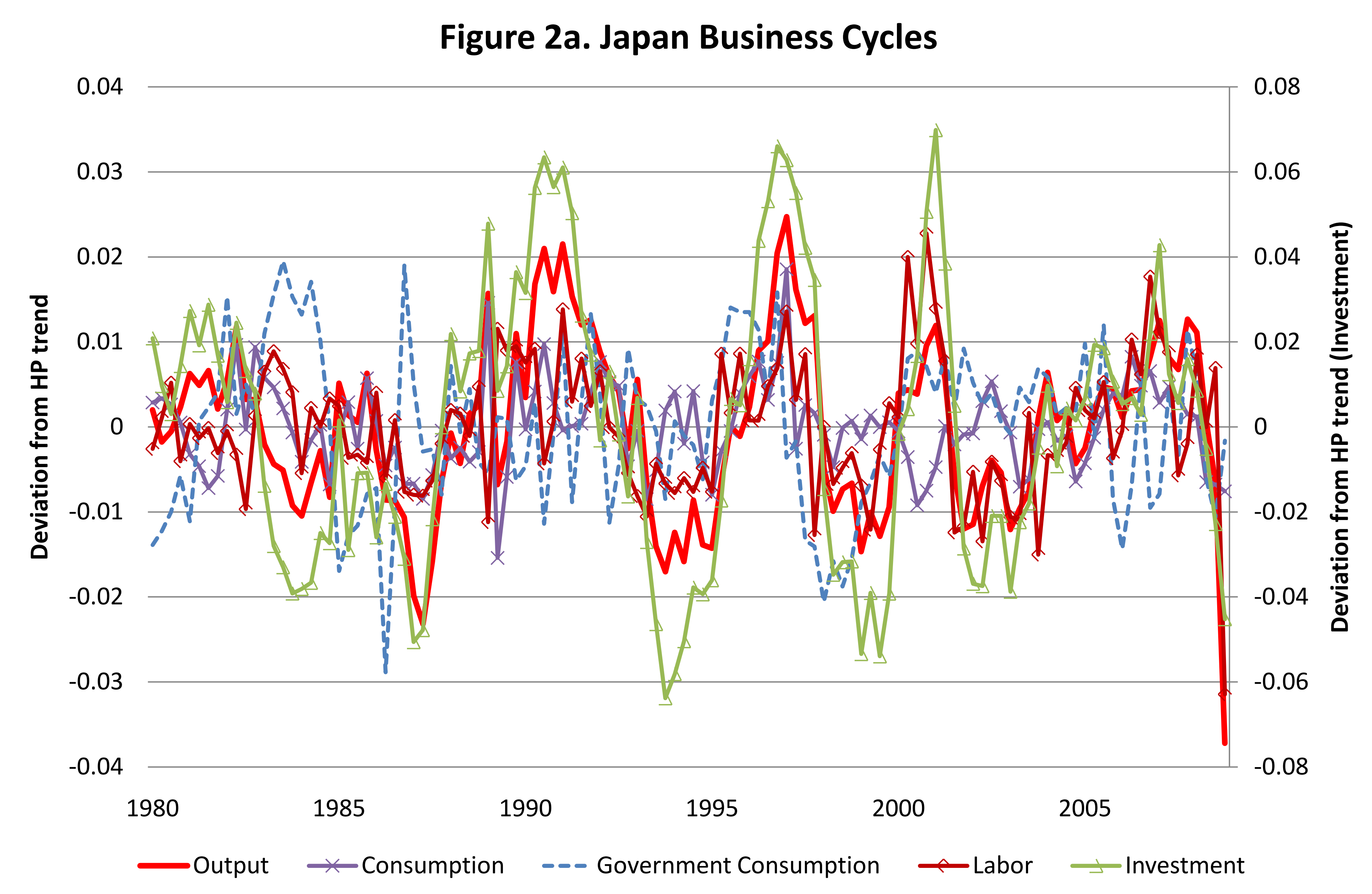
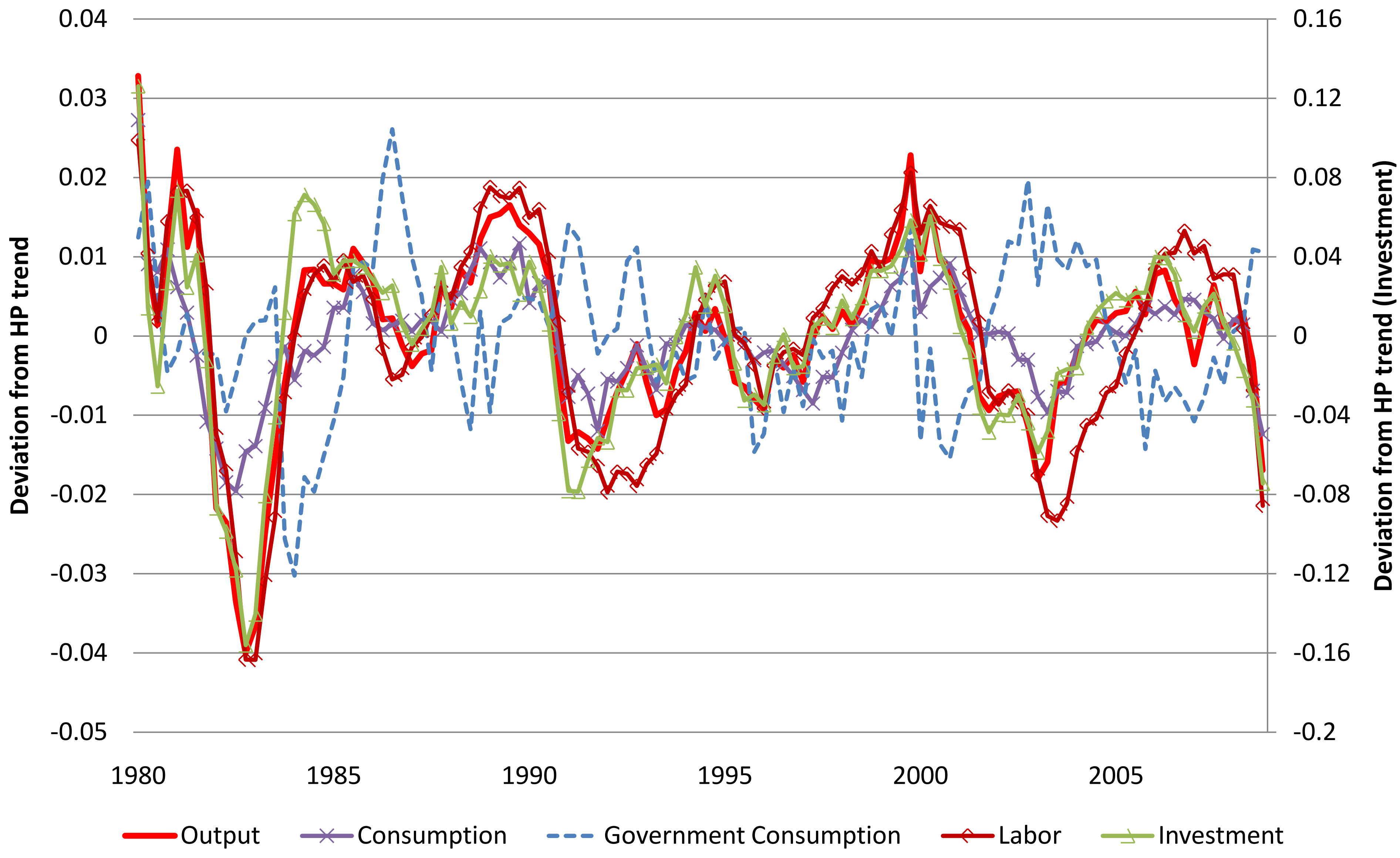


Figure 2a. Japan Business Cycles
Deviation from HP trend
Deviation from HP trend (Investment)
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
1980
1985
1990
1995
2000
2005
Output
Consumption
Government Consumption
Labor
Investment

Figure 2b. US Business Cycles



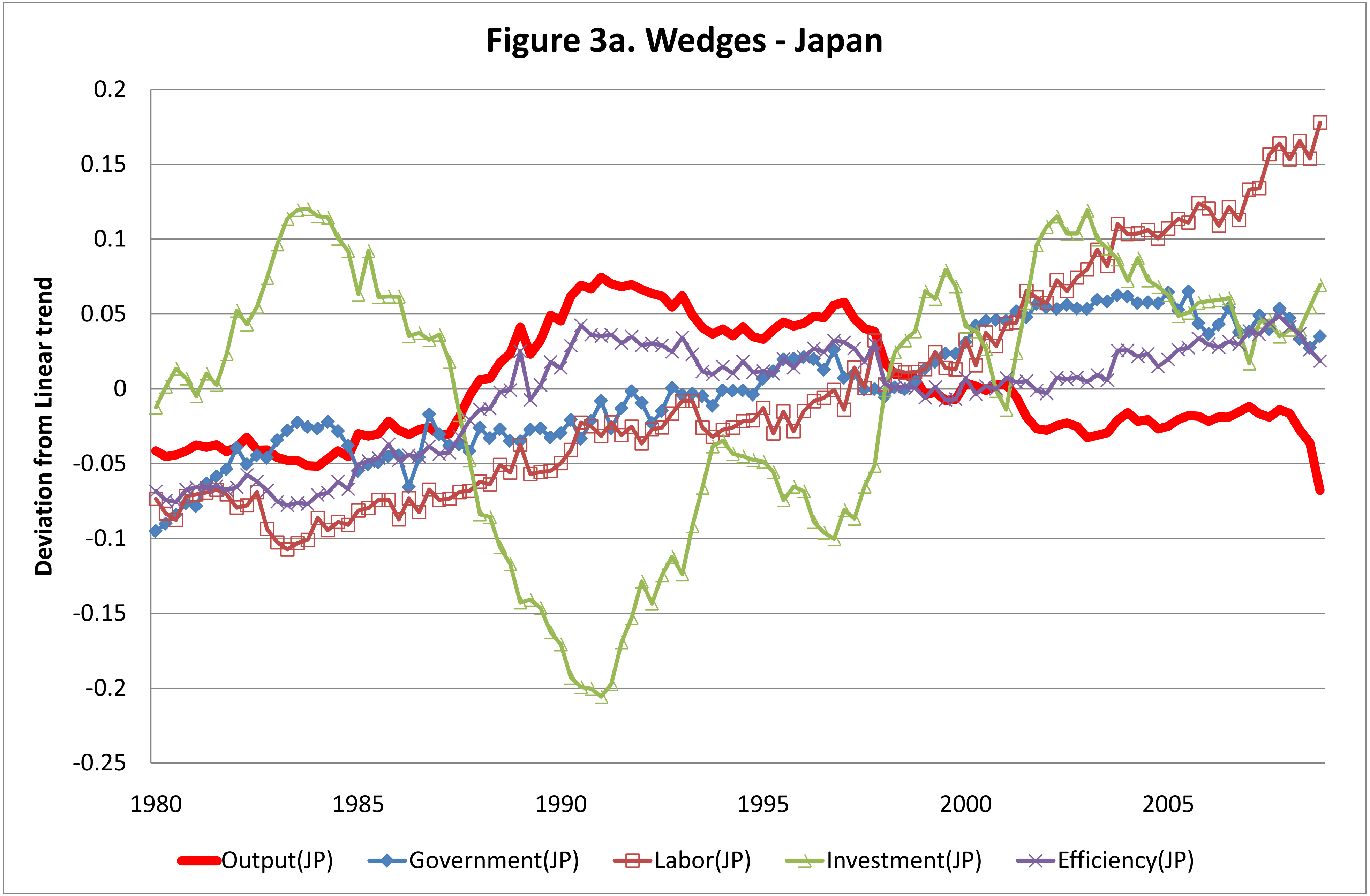


Figure 3a. Wedges - Japan
Deviation from Linear trend
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1980
1985
1990
1995
2000
2005
Output(JP)
Government(JP)
Labor(JP)
Investment(JP)
Efficiency(JP)

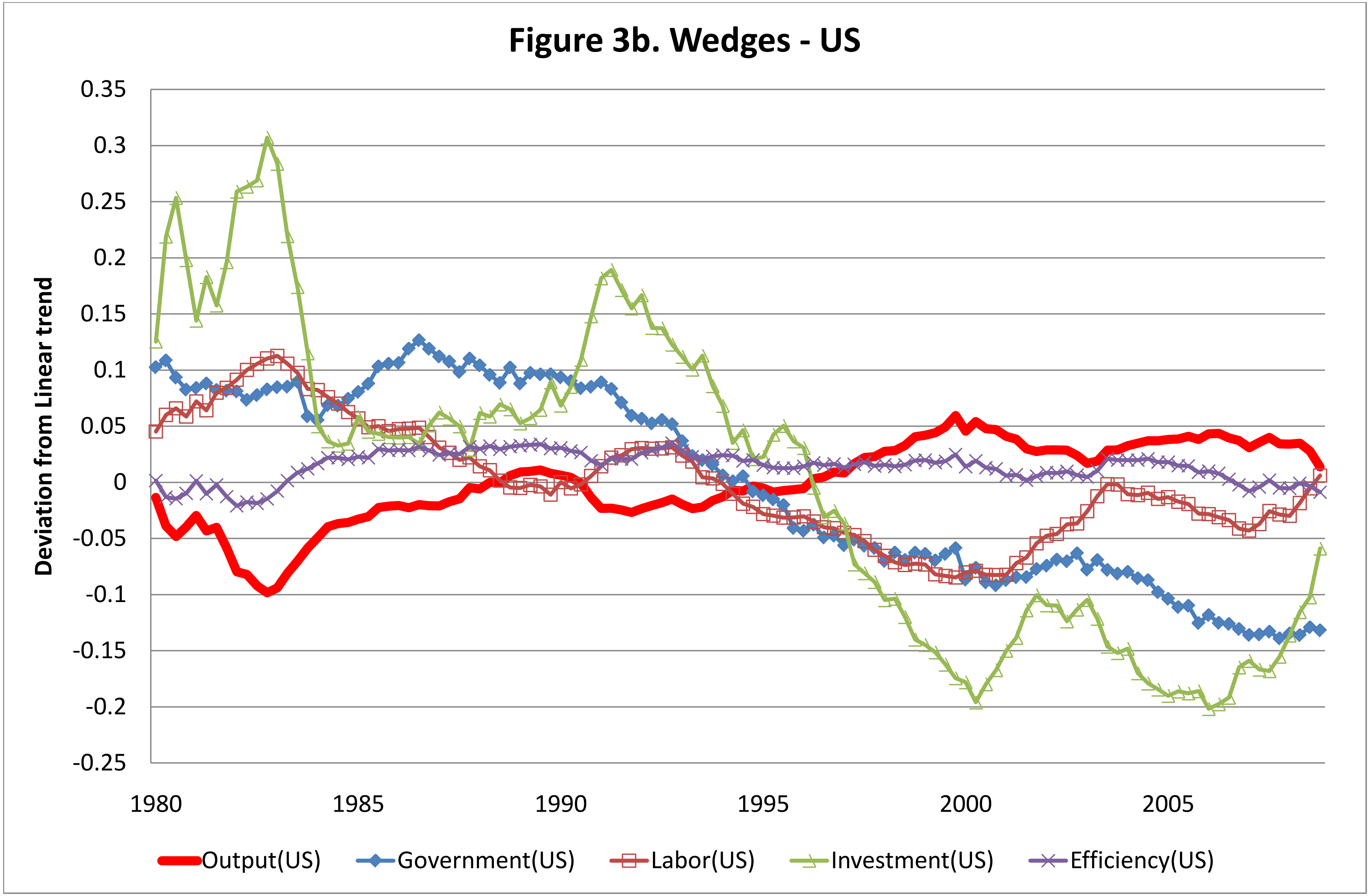
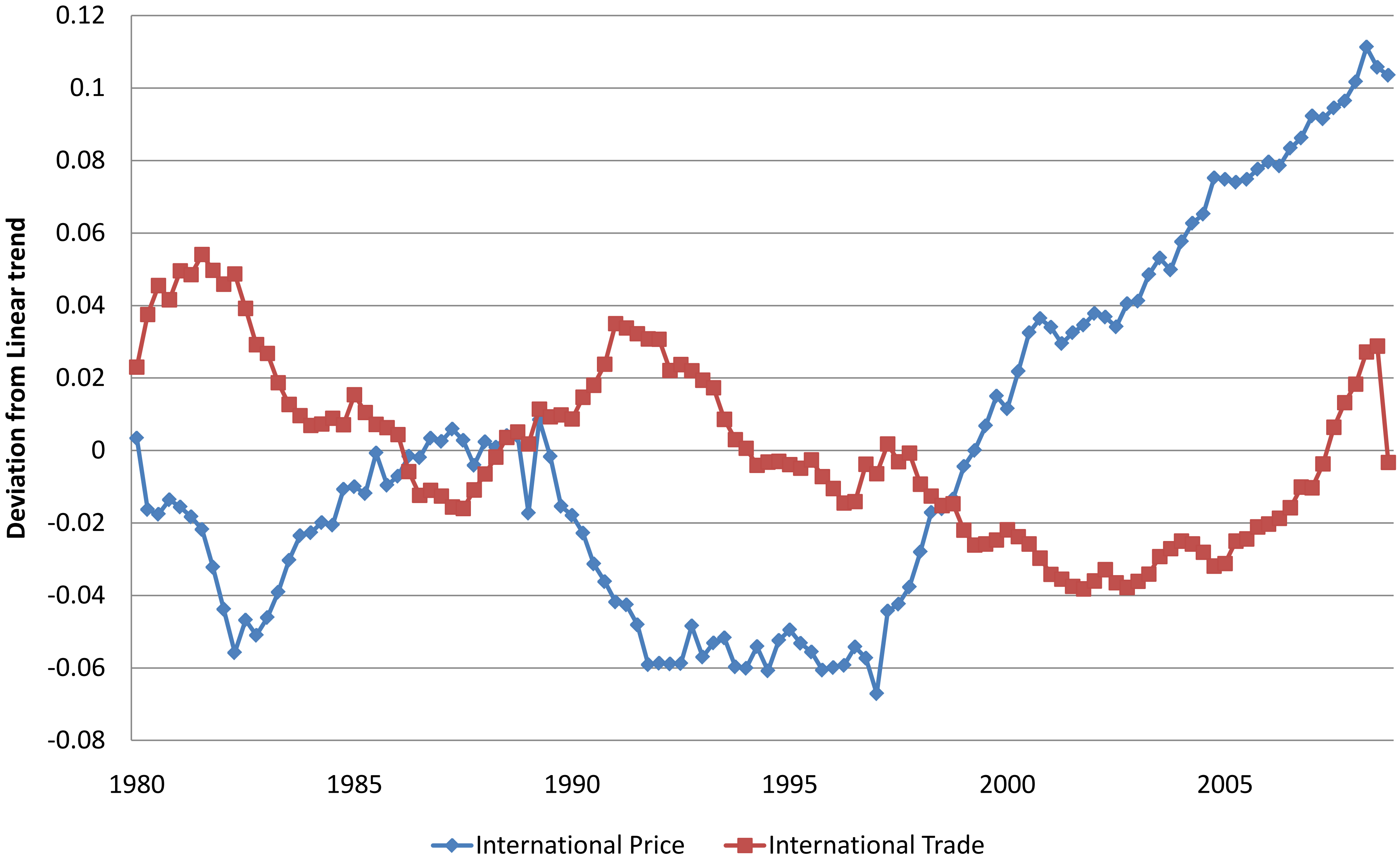


Figure 3b. Wedges - US
Deviation from Linear trend
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1980
1985
1990
1995
2000
2005
Output(US)
Government(US)
Labor(US)
Investment(US)
Efficiency(US)

Figure 3c. Wedges - International



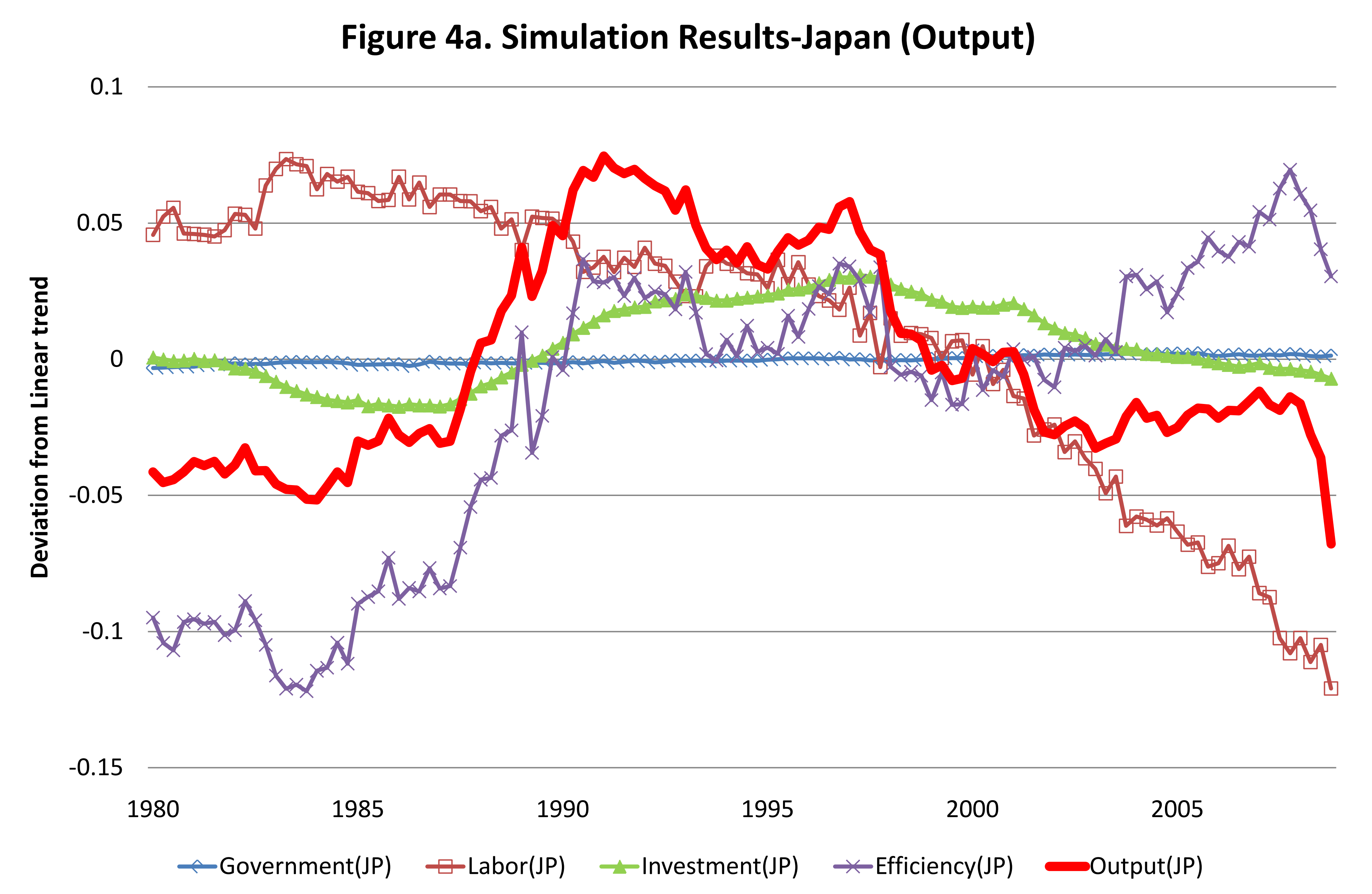
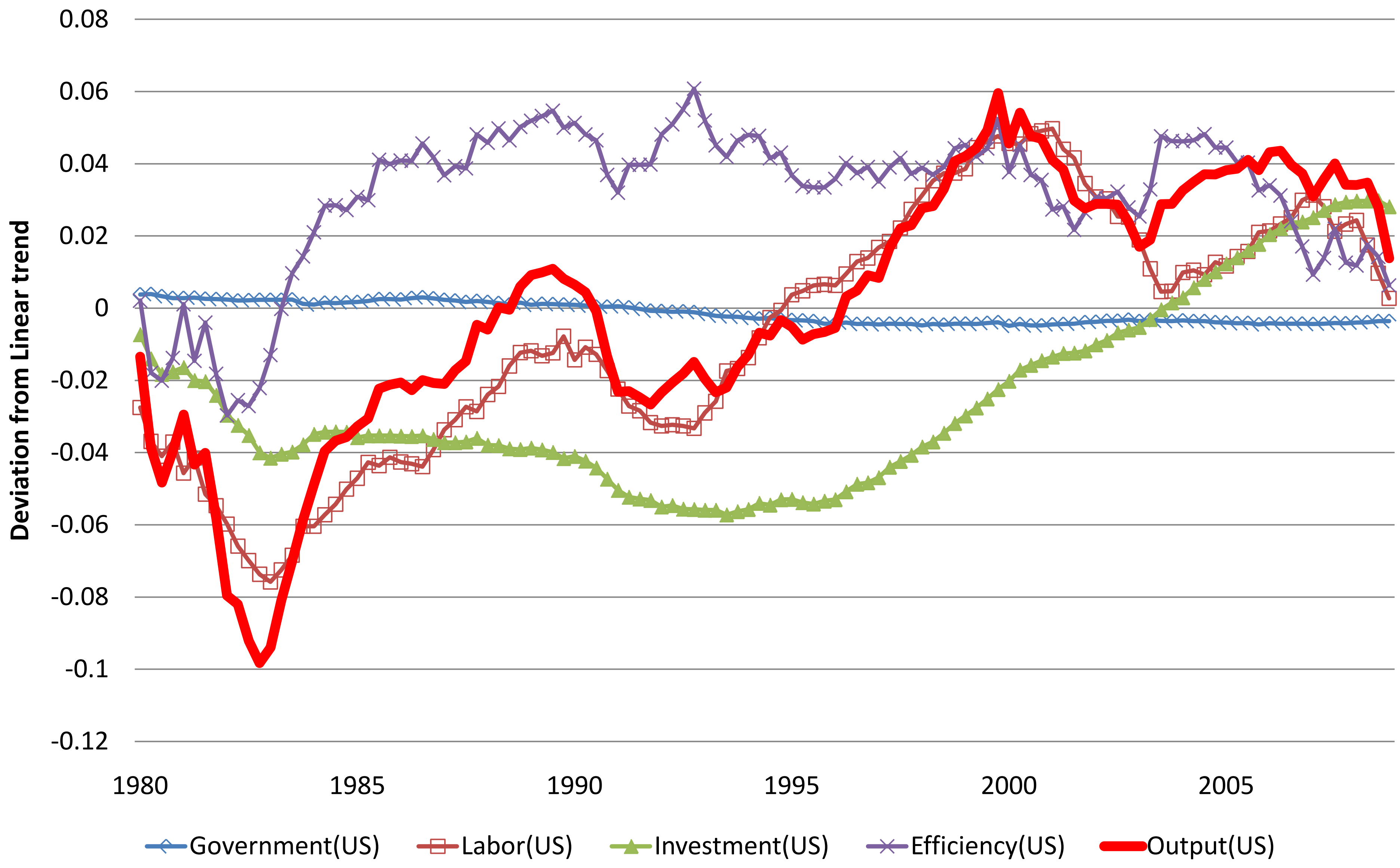


Figure 4a. Simulation Results-Japan (Output)
Deviation from Linear trend
0.1
0.05
0
-0.05
-0.1
-0.15
1980
1985
1990
1995
2000
2005
Government(JP)
Labor(JP)
Investment(JP)
Efficiency(JP)
Output(JP)

Figure 4b. Simulation Results-US (Output)



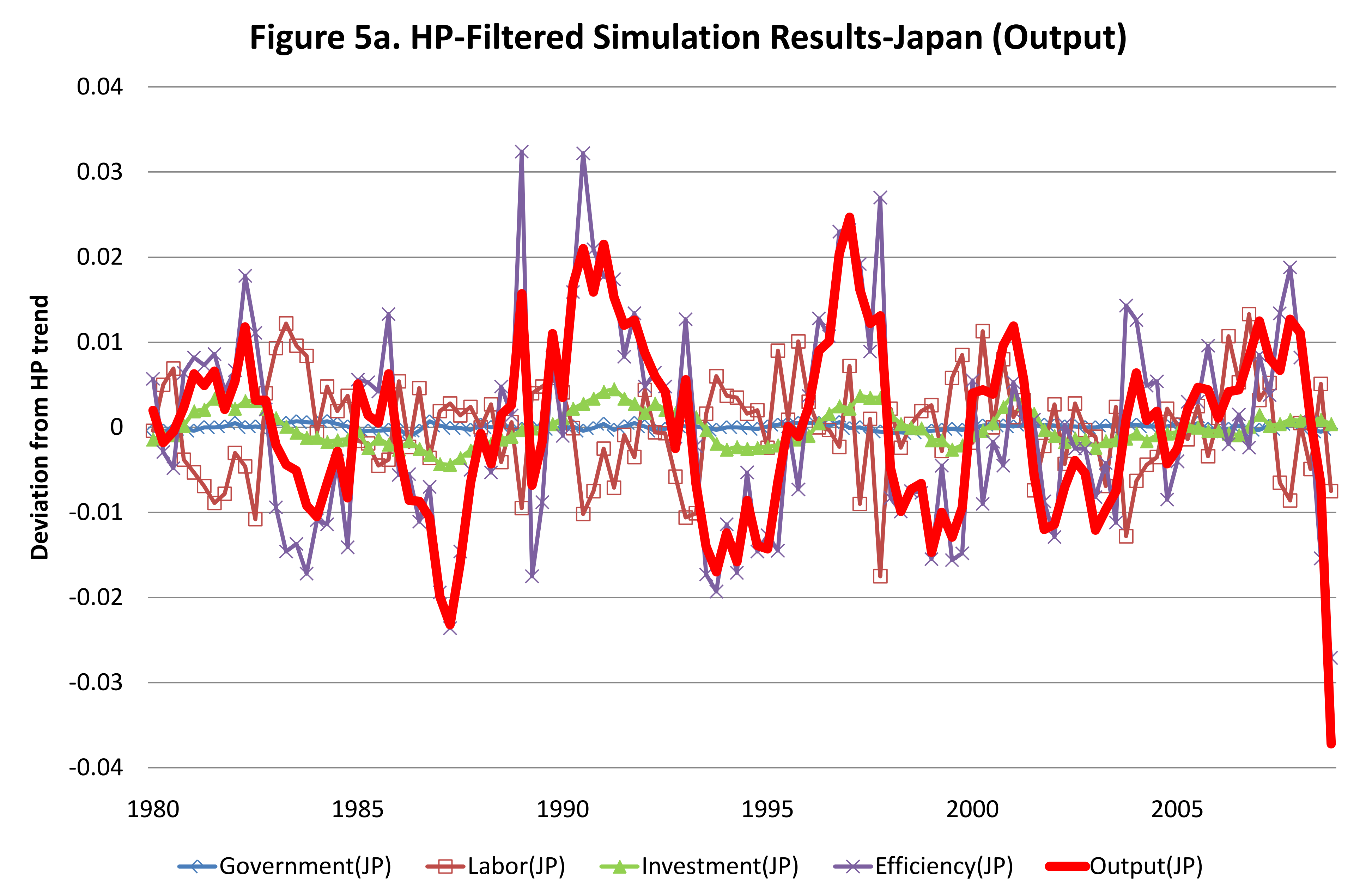


Figure 5a. HP-Filtered Simulation Results-Japan (Output)
Deviation from HP trend
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
1980
1985
1990
1995
2000
2005
Government(JP)
Labor(JP)
Investment(JP)
Efficiency(JP)
Output(JP)

Figure 5b. HP-Filtered Simulation Results-US (Output)

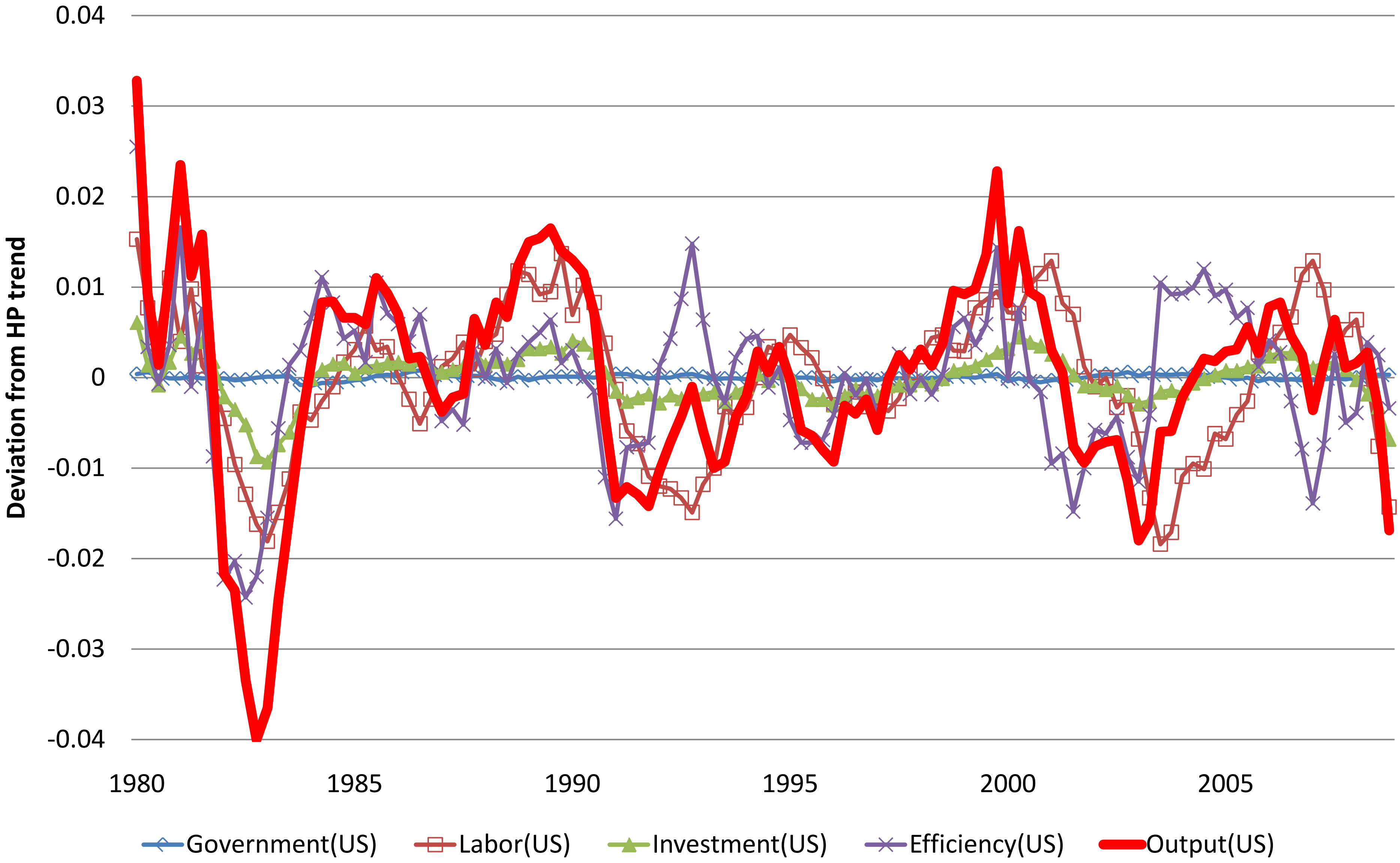


Figure 6. Results from the Global Financial Market Integration Model