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Abstract

A key feature of the Japanese business cycles over the 1980–2007 period is that the fluctuation of total hours worked leads the fluctuation of output. A canonical real business cycle model cannot account for this fact. This paper uses the business cycle accounting method introduced by Chari, Kehoe and McGrattan (2007) and shows that labor market distortions are important in accounting for the this feature of the Japanese labor supply fluctuation. I further discuss fundamental economic shocks that manifest themselves as labor wedges and assess their impacts on labor fluctuation.

Keywords: Business Cycle Accounting; Japanese Labor Market

JEL classification: E13, E32

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1 Introduction

A key feature of the Japanese business cycles over the 1980-2007 period is that the fluctuation of total hours worked leads the fluctuation of output. A canonical real business cycle model cannot account for this fact. This paper uses the business cycle accounting method introduced by Chari, Kehoe and McGrattan (2007) and shows that labor market distortions are important in accounting for the this feature of the Japanese labor supply fluctuation. I further discuss fundamental economic shocks that manifest themselves as labor wedges and assess their impacts on labor fluctuation.

Braun, Okada and Sudou (2005) assess the cyclical features of the Japanese economy over the 1960-2000 period and find that hours worked per worker leads business cycles. They show that it is difficult to account for this fact using a variation of the real business cycle model and conjecture that there was some distortion in the labor market that is independent from productivity shocks. Using the business cycle accounting method, this paper shows that their conjecture is indeed correct, and the usual suspects for labor market distortion, fiscal and monetary disturbances, seem to be useful in accounting for the labor market distortions in Japan.

The model directly follows that of Chari, Kehoe McGrattan (2007) which consists of the representative household, firm, and government. The government creates distortions in markets by charging labor and investment taxes and purchasing goods, which are all assumed to be exogenously determined. The firms face exogenous shocks to the production process. Following the terminology in the literature, These exogenous variables are called labor wedges, investment wedges, government wedges, and efficiency wedges. Wedges are computed as residuals in the equilibrium conditions using the data of output, consumption, labor supply and investment. Finally, the model is simulated using the computed wedges.

Several studies use the business cycle accounting method to analyze the medium term business cycle fluctuations in the Japanese economy. Kobayashi and Inaba (2006) use a deterministic version of the business cycle accounting model and show that efficiency and labor wedges are important in accounting for the lost decade. Chakraborty (2009) shows that efficiency and investment wedges are important in accounting for the boom in the 1980s while labor wedges are important in accounting for the recession during the 1990s. Otsu and Pyo (2009) show that the positive contemporaneous correlation between efficiency and investment wedges may have amplified the effect of financial frictions especially during the boom in the 1980s. While these studies all use linear detrending methods to focus on the medium term business cycle fluctuations, I focus on the HP filtered high frequency fluctuation of the Japanese economy and show that labor wedges are important in accounting for the lead in labor supply.

The model itself does not specify the ultimate source of each wedge. In fact, many different shocks can manifest themselves as labor wedges. For instance, labor income taxes, money growth shocks in a cash in advance constraint model and interest rate shocks in a labor working capital model can all be mapped into a prototype business cycle accounting model with labor wedges. I compare the time series of these usual suspects to the computed labor wedges and find that none of these seem to account for the fluctuation in labor wedges.

The remaining of the paper is organized as follows. In section 2, the data is presented. In section 3, the model is described. In section 4, the quantitative results are shown. Section 5 concludes the paper.

2 Data

Traditionally the real business cycle literature focuses on the standard deviation, contemporaneous and lagged correlation of the Hodrick-Prescott filtered key macroeconomic variables such as output, consumption, investment and labor supply. In this section, I present the data facts following this tradition.

The source of the data is the SNA data offered by the cabinet office ESRI website except for those stated in the text. In order to convert the national income and products account into data suitable to economic theory, I have made some conventional adjustments. Consumption is defined as the consumption expenditure on nondurables and services and the imputed flow of services from consumer durables. Investment is defined as the gross capital formation and the expenditure on household durables. Since I assume Japan to be a closed economy, net exports are considered as a residual in the resource constraint. Government expenditure is considered as a waste in resources. Output is defined as gross domestic product plus the imputed service flow from consumer durables. Capital stock is defined as private corporate capital stock plus consumer durables. Labor supply is defined as the number of workers times the number of hours worked per workers.

The time series of data are all divided by the adult population and filtered with the Hodrick-Prescott filter. Table 1 shows the standard deviation of each variable and the correlation of each variable to output. Not only the contemporaneous correlation, but also the correlation with leads and lags are reported. The business cycle facts are somewhat similar to those computed for the U.S. economy reported in Cooley and Hansen (1995). In terms of volatility, consumption, government purchases, capital stock, and labor are less volatile than output while investment is far more volatile than output. In terms of contemporaneous correlation, all variables are procyclical except for government purchases, which is acyclical. Furthermore, the correlation of labor with output is lower than those of consumption and investment with output, respectively. In terms of leads and lags, capital is lagging output and labor is leading output. The key difference between Japan and the U.S. is that in Japan the fluctuation of labor supply leads the fluctuation of output. This fact is interesting since a standard real business cycle model with productivity shocks predicts a very high contemporaneous correlation between output and labor supply.

3 Business Cycle Accounting Model

The business cycle accounting model a la Chari, Kehoe and McGrattan (2007) is based on a standard neoclassical closed economy model which consists of a representative firm, household and the government. The firm produces a final good from capital and labor using a constant returns to scale production technology which faces exogenous disturbances in production efficiency. The infinitely-lived representative household gains utility from consumption and disutility from leisure. The household owns capital stock and labor endowment and decides how much to consume, invest and work. The government imposes distortionary labor income and investment taxes on the household, spends on government purchases, and rebates the remaining to the household via lump-sum transfers. Labor income and investment taxes, government purchases and production efficiency are computed as "wedges" in equilibrium conditions and are taken as exogenous. The detailed description is as follows.

3.1 Firm

The firm produces a single storable good with a Cobb-Douglas production function,

$$Y_t = z_t K_t^{\theta} (\Gamma_t l_t)^{1-\theta} \tag{1}$$

where Y_t is output, z_t is TFP, K_t is capital stock, l_t is labor, θ is the income share of capital and Γ_t is the labor augmented technical progress. Labor is computed as

$$l_t = h_t \times e_t$$

where h_t is the index of average weekly hours worked per worker and e_t is the number of workers employed per the number of the adult population. The index h_t is a number between zero and one computed as the average weekly hours worked per worker divided by the maximum possible hours available[1].We assume that the labor augmenting technical progress grows at a constant rate γ such that $\Gamma_t = (1+\gamma)\Gamma_{t-1}$. In a standard neoclassical growth model, all variables are known to grow at the rate of labor augmenting technical progress along the the balanced growth path. Therefore, I detrend all growing variables with Γ_t so that all variables are stationary. The detrended variables are denoted by small class letters.

The firm maximizes its profit defined by the value of production net of costs of hiring labor and renting capital stock from the household. That is,

$$\max \pi_t = y_t - w_t l_t - r_t k_t$$

where w_t is the real wage and r_t is the real capital rental rate.

3.2 Household

The lifetime utility for the representative household depends on consumption c_t and labor l_t:

$$\max U = E_0 \sum_{t=0}^{\infty} \beta^t u(c_t, l_t), \tag{2}$$

where $\beta (0 < \beta < 1)$ is the subjective discount rate. For the periodical preference function, $u(\bullet)$, I assume Cobb-Douglas preferences:

$$u(c_t, l_t) = \Psi \log(c_t) + (1-\Psi)\log(1-l_t),$$

which are commonly used in the macroeconomic literature[2].

The representative household maximizes the lifetime utility (2) subject

[1] I assume that the maximum hours available for work is $14*7$ hours taking into account sleeping and other activities necessary to maintain minimum standards of living.

[2] This is a special case of a general form

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

to the budget constraint

$$(1-\tau_t^l)w_t l_t + r_t k_t + \tau_t = c_t + (1+\tau_t^x)x_t$$

and the capital law of motion

$$(1+\gamma)(1+n)k_{t+1} = x_t + (1-\delta)k_t \tag{3}$$

where n is the population growth rate which I assume to be constant, x_t is investment, τ_t^l and τ_t^x are gross labor income and investment tax rates, τ_t is the government transfer and δ is the depreciation rate of capital stock. Labor income taxes depress labor supply while investment taxes depress investment respectively through substitution effects[3].

3.3 Government

The government collects distortionary taxes, spends on exogenous government purchases g_t and rebates the remaining to the household using lump-sum transfer. Thus, the government budget constraint is

$$\tau_t + g_t = \tau_t^l w_t l_t + \tau_t^x x_t. \tag{4}$$

Note that the transfer can be negative in which case the government collects lump-sum taxes from the household. Increases in government purchases

with $\sigma = 1$. In the small open economy literature, GHH preferences a la Greenwood, Hercowitz and Huffman (1988)

$$u = \frac{(c_t - \chi l_t^\nu)^{1-\sigma}}{1-\sigma}$$

are commonly used. Otsu (2007b) applies the business cycle accounting method to a small open economy using GHH preferences.

[3]An increase in labor taxes encourages the household to substitute away from labor towards leisure. An increase in investment tax encourages the household to substitute away from investment toward consumption. Any kind of shocks that manifest themselves as labor and investment taxes have the same effects.

causes a pure negative income effect on the household through negative transfers.

3.4 Competitive Equilibrium

The competitive equilibrium is, $\left\{c_t, l_t, k_{t+1}, y_t, x_t, \tau_t, w_t, r_t, g_t, \tau_t^l, \tau_t^x, z_t\right\}_{t=0}^{\infty}$ such that;

1. Households optimize given $\left\{w_t, r_t, \tau_t, \tau_t^l, \tau_t^x\right\}$ and k_0.
2. Firm optimizes given $\{w_t, r_t, z_t\}$.
3. Markets clear and the government budget constraint (4) holds.
4. The resource constraint holds:
$$y_t = c_t + x_t + g_t. \tag{5}$$
5. Shocks follow the process
$$s_t = P_{0(4\times1)} + P_{(4\times4)} s_{t-1} + \varepsilon_t, \varepsilon_t \sim N(0_{(4\times1)}, Q_{(4\times4)}) \tag{6}$$
where $s_t = \left(\ln g_t, \tau_t^l, \tau_t^x, \ln z_t\right)'$ and $\varepsilon_t = (\varepsilon_{gt}, \varepsilon_{lt}, \varepsilon_{xt}, \varepsilon_{zt})'$.

The household and firm optimality leads to the capital Euler equation

$$(1+n)(1+\gamma)U_{ct}(1+\tau_t^x) = \beta E_t \left[U_{ct+1}\left(\theta \frac{y_{t+1}}{k_{t+1}} + (1-\delta)(1+\tau_{t+1}^x)\right)\right] \tag{7}$$

and the labor first order condition

$$\frac{1-\Psi}{\Psi} \frac{c_t}{1-l_t} = (1-\tau_t^l)(1-\theta)\frac{y_t}{l_t}. \tag{8}$$

4 Quantitative Analysis

The quantitative analysis is carried out in three steps. First we obtain the parameter values by calibration and estimation. Then we solve for linear decision rules of the endogenous variables. Then we back out the shocks using data and these decision rules. Finally we plug the shocks one by one into the decision rules and compare their impacts on the economy.

4.1 Parameters

This section describes the procedure of how we obtained the values of the parameters. The parameter values are listed in Table 2.

The income share of capital θ is computed directly from data using the definition

$$\theta = \frac{\text{capital income} + \text{flow income from consumer durables}}{\text{GNP} + \text{flow income from consumer durables}}.$$

Population growth rate n is computed directly from data of the population of people older than fifteen years old.

The growth rate of labor augmenting technical progress is computed from the trend growth rate of Solow residuals estimated with ordinary least squares. The log of Solow residuals are defined as

$$\ln SR_t = \ln \Gamma_t^{1-\theta} + \ln z_t = \ln \Gamma_0 + (1-\theta)t\ln(1+\gamma) + \ln z_t \tag{9}$$

from (1) and is directly computable using data of output, capital and labor. Thus, we can estimate γ from a regression of Solow residuals on a linear trend t and a constant:

$$\ln SR_t = a + bt + u_t. \tag{10}$$

That is, from (9) and (10), $\gamma \approx \ln(1+\gamma) = \frac{b}{1-\theta}$.

Other structure parameters are obtained using calibration. Calibration is a technique to compute parameter values from data using steady state equations. First, from (3), the depreciation rate δ is computed as

$$\delta = 1 + \frac{x}{k} - (1+n)(1+\gamma).$$

Then from (7), the discount factor β is computed as

$$\beta = \frac{(1+n)(1+\gamma)}{\theta\frac{y}{k} + 1 - \delta}$$

where we assume that investment taxes are zero in the steady state. Also, from (8), the utility parameter Ψ is computed as

$$\frac{1-\Psi}{\Psi} = (1-\theta)\frac{y}{l}\frac{1-l}{c}$$

where we assume that labor income taxes are zero in steady state.

Finally, the parameters in the shock process (6) are estimated using Bayesian estimation. The reason we use Bayesian estimation is because investment taxes are not directly observable. We define it as a latent variable and estimate the whole shock process. We use data of output, consumption, labor and investment in order to estimate the model with four shocks. The estimated values are

$$P = \begin{vmatrix} 0.80 & 0.18 & 0.34 & 0.03 \\ 0.04 & 0.97 & -0.15 & -0.05 \\ 0.02 & -0.00 & 0.95 & -0.03 \\ 0.02 & 0.00 & 0.03 & 0.95 \end{vmatrix}$$

$$Q = \begin{vmatrix} 0.42 & 0.13 & -0.00 & 0.09 \\ 0.13 & 0.16 & -0.03 & 0.08 \\ -0.00 & -0.03 & 0.20 & -0.05 \\ 0.09 & 0.08 & -0.05 & 0.07 \end{vmatrix} \times 1.00E-03.$$

4.2 Computing Wedges

Given all parameters values, the model can be solved quantitatively. I use the solution method à la Uhlig (1999) to solve for linear decision rules. Having obtained the decision rules, I compute the unobserved exogenous variables τ_t^x using data of $\left\{\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t, \widetilde{x}_t\right\}$, the values of $\left\{\widetilde{g}_t, \tau_t^l, \tau_t^x, \widetilde{z}_t\right\}$ can be computed from the linear decision rules

$$\left(\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t, \widetilde{x}_t, \widetilde{k}_{t+1}\right)' = DR_{(\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t, \widetilde{x}_t, \widetilde{k}_{t+1})} \left\{\widetilde{k}_t, \widetilde{g}_t, \tau_t^l, \tau_t^x, \widetilde{z}_t\right\}'$$

where variables with hats indicate the log deviation of them from their steady state values while DR is a matrix containing the corresponding linear decision rule coefficients. In specific, the procedure of computing wedges is as follows:

1. Compute linear decision rules
2. Assume $\widetilde{k}_0 = 0$.
3. Given $\widetilde{k}_0$, compute $\left\{\widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_0$ from $(\widetilde{y}, \widetilde{c}, \widetilde{l}, \widetilde{x})_0' = DR_{(\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t, \widetilde{x}_t)} \left\{\widetilde{k}, \widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_0'$
4. Given $\left\{\widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_0$, compute $\widetilde{k}_1$ from $\widetilde{k}_1 = DR'_{(\widetilde{k}_{t+1})} \left\{\widetilde{k}, \widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_0'$
5. Given $\widetilde{k}_1$, compute $\left\{\widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_1$ from $\left\{\widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_1 = DR'_{(\widetilde{y}_t, \widetilde{c}_t, \widetilde{l}_t, \widetilde{x}_t)} \left\{\widetilde{k}, \widetilde{g}, \tau^l, \tau^x, \widetilde{z}\right\}_1'$ and so on.

4.3 Simulation

Simulation is done by plugging in the computed wedges into the linear decision rules. The business cycle accounting literature focuses on the medium term fluctuations of key variables such as output, consumption, investment and labor supply during recession periods in several countries[4]. While the simulation procedure is the same as these studies, I focus on the impact of each wedges on high frequency cyclical comovements of these variables in Japan.

Figure 3 shows the cyclical features of the HP filtered simulation results using each wedges one by one. The results show that efficiency wedges are important in accounting for the output fluctuation, investment wedges are important in accounting for fluctuation in investment,and labor wedges are important in accounting for the fluctuation in labor whereas both labor and efficiency wedges are important in accounting for the fluctuation in consumption.

Table 3 shows the results of the simulation with only efficiency wedges. This is almost equivalent to a standard real business cycle model since efficiency wedges are equivalent to productivity shocks[5]. There are several important discrepancies between the results and the data. First, the persistence of output and investment are too low. Second the contemporaneous correlations between output and consumption as well as labor are too high. Finally, the model cannot account for the lead in labor.

Table 4 shows the results with both efficiency and labor wedges. The results show that all three discrepancies mentioned above are improved. The persistence of output and investment increased, the contemporaneous correlations between output and consumption and labor both are closer to the data, and the model can reproduce the lead in labor. Therefore, we conclude that labor wedges are important in accounting for the output and labor correlation pattern in Japan. The fact that labor wedges are important in

[4]Chari, Kehoe and McGrattan (2007) focuses on the US great depression and its 1981 recession. Erasmus (2007) focuses on the Canadian economy. Chakraborty (2009) and Kobayashia and Inaba (2006) focus on the Japanese bubble economy and its lost decade. Otsu and Pyo (2009) focus on the Japanese and Korean recessions in the 1990s.

[5]Although in this simulation efficiency wedges affect the expectation on the future values of other wedges.

accounting for the lead in labor supply is consistent with the conjecture of Braun, Esteban-Pretel, Okada and Sudou (2006). The remaining question is, what is the fundamental source of labor wedges.

4.4 The Role of Investment Wedges and Adjustment Costs

One controversial result of Chari, Kehoe and McGrattan (2007) is that investment wedges are not important in accounting for the Great depression and the 80s recession in the U.S. Christiano and Davis (2006) point out that introducing capital adjustment costs increase the importance of investment wedges in accounting for business cycles. In this section, I will show how investment adjustment costs affect the benchmark results.

There are several ways to introduce adjustment cost in investment. In this paper, I will assume that shifting the investment to capital ratio above or below the steady state level causes a cost Φ_t to resources which is proportionate to the current level of capital stock. That is,

$$y_t = c_t + x_t + g_t + \Phi_t k_t.$$

For the functional form of investment adjustment cost, I simply assume that

$$\Phi_t = \frac{\phi}{2}\left(\frac{x_t}{k_t} - d\right)^2$$

where $d = (1+n)(1+\gamma) - (1-\delta)$ so that adjustment cost is equal to zero at the steady state.

As Christiano and Davis (2006) pointed out, introducing investment adjustment cost increases the importance of investment wedges in accounting for the fluctuation of output. Table 5 presents the effect of each wedges on output for both the models with and without the investment adjustment cost. For both cases, I report the correlation of simulated output with data and the standard deviation of simulated output relative to that of data. The results show that both the correlation and standard deviation of the simulated output with only investment wedges rise when the investment adjustment cost is introduced. Especially, the correlation of simulated output and data increases more than threefold.

Another interesting results is that the standard deviation of simulated output with only efficiency wedges falls significantly when investment adjustment cost is included. This is because labor falls in response to a rise in efficiency when the model has investment adjustment costs. A standard real business cycle model predicts procyclical labor, whereas structural VAR models predict countercyclical labor supply. The results of the simulation with efficiency wedges and investment adjustment cost reported in Table 6 imply that even within a real business cycle model, high investment adjustment cost can lead to countercyclical labor supply.

A simple explanation of why labor becomes countercyclical can be made using the capital Euler equation with only efficiency wedges:

$$u_{ct}\Gamma = \beta E_t \left[u_{ct+1} \left(\theta z_{t+1} k_{t+1}^{\theta-1} l_{t+1}^{1-\theta} + 1 - \delta + \Phi_{t+1} - \Phi'_{t+1} \right) \right].$$

For simplicity, assume that with an extremely high adjustment cost parameter ϕ capital stock is always at the steady state level and adjustment costs are zero. When efficiency wedges are high, the expected efficiency wedges are high as well due to persistence. In order to smooth the marginal utilities of consumption across time, the expected marginal product of capital must remain constant. Since capital stock must remain constant by assumption, when expected efficiency wedges are high expected labor supply should be low. Thus, current labor supply should be low as well.

5 Sources of Labor Wedges in Japan

As shown in Chari, Kehoe and McGrattan (2007), there are several fundamental sources of labor wedges. In this section, I show that labor income taxes, money growth shocks and real interest rate shocks can be mapped into the prototype model with labor wedges. I assess whether these monetary and fiscal variables can account for the fluctuation pattern of the labor wedges in Japan.

5.1 Labor Income Tax

Braun (1994) and McGrattan (1994) show that fluctuations in labor income taxes were important in accounting for the postwar US business cycle fluctuations. Since the model defines labor income tax as the source of labor market distortions, it is worthwhile investigating whether this can be the main source of labor wedges.

McDaniel (2006) computes labor income tax for OECD countries including Japan. I plot the HP filtered annual labor income taxes along with the labor wedges in Figure 4. Unfortunately, this labor tax data is only available in the annual frequency so I compare them with the annual average of the labor wedges. The figure shows that the fluctuation of the annual labor wedges are highly correlated to the fluctuation of labor taxes. Especially the sudden rises in 1996 and 2001 are highly correlated. However, since labor income taxes only change once a year, they cannot explain the quarterly fluctuations of labor wedges. Therefore, although they do account for a lot of the annual fluctuation of labor wedges, they cannot account for the quarterly lead of hours worked.

5.2 Money Growth Shocks

Chari, Kehoe and McGrattan (2007) show that a sticky wage model due to labor unions a la Cole and Ohanian (2002) can be mapped into a prototype model with labor wedges. That is, given sticky wages, a temporary increase in the price level will cause a drop in real wages, which can be interpreted as an increase in labor wedges. They provide a mapping from the sticky wage model to the prototype model with labor wedges.

A cash in advance model such as Cooley and Hansen (1989) also has the same feature that money growth shocks cause labor wedges. With a cash in advance constraint, the consumer holds cash because he cannot use the current labor income in order to purchase consumption goods. Since labor income cannot be used to buy cash goods in the current period, money growth shocks affect the effective price of labor relative to consumption. Therefore, money growth shocks create labor wedges in the form of inflation tax. The following shows the mapping from the cash in advance model and the prototype model with labor wedges.

The consumer's budget constraint with money without wedges is

$$w_t l_t + r_t k_t + m_t/p_t + \tau_t = c_t + x_t + m_{t+1}/p_t. \tag{11}$$

Assume that the consumer holds money due to a standard cash in advance constraint

$$m_t/p_t \geq c_t \tag{12}$$

where m_t is the money supply and p_t is the price of consumption goods relative to money. The amount of cash he holds to purchase goods in the current period is predetermined during the previous period. The labor first order condition will be

$$\frac{1-\Psi}{\Psi}\frac{c_t}{1-l_t} = \frac{\lambda_t}{\lambda_t + \mu_t} w_t$$

where λ and μ are the Lagrange multipliers on the constraints (11) and (12), respectively. If $\frac{\lambda_t}{\lambda_t+\mu_t} = (1-\tau_{lt})$ the cash in advance model is observationally equivalent to the prototype model with labor wedges.

Figure 5 plots the labor wedges and money growth computed from the growth rate of M1. Money growth is highly correlated to labor wedges during the 1980s. However, they become less correlated during the 1990s and 2000s. The correlation coefficients are listed in Table 7.

5.2.1 Interest Rate Shocks

Following Christiano and Eichenbaum (1992), assume that the firm has to borrow cash in order to pay for the wage bill. Since the borrowing cost is included in the labor cost, shocks to the borrowing rate can be interpreted as labor wedges.

For simplicity, assume that the firm borrows in the beginning of the period and pays back at the end of the same period after the produced final goods are sold in the market. The firm's problem will change accordingly as follows.

$$\max \pi_t = y_t - (1 + i_t)w_t l_t - r_t k_t$$

where i is the real interest payment the firm has to make. The firm's first order condition for labor will be

$$w_t = \frac{1}{1 + i_t}(1 - \theta)\frac{y_t}{l_t}.$$

Therefore, if $\frac{1}{1+i_t} = (1-\tau_{lt})$ the labor working capital model is observationally equivalent to the prototype model with labor wedges.

Figure 5 plots the labor wedges an the fluctuation of the nominal interest rate computed as the three month average call rate. The call rate is positively correlated to labor wedges during the 1990s. After 2001, the nominal interest rate does not fluctuate because it was maintained at the almost zero level for several years. The correlation coefficients between labor wedges and the nominal interest rate is listed in Table 7.

6 Conclusion

This paper shows that the fluctuations in labor wedges are important in accounting for the lead in labor of the Japanese business cycles. Fiscal and monetary variables such as labor income tax, money growth and interest rates seem to play some role in creating labor wedges. While labor income taxes cannot account for quarterly fluctuations of labor wedges due to its low frequency fluctuation nature, monetary variables seem to be promising candidates to account for the quarterly fluctuation in labor wedges. Further investigation is needed to quantitatively account for the impacts of these variables on Japanese labor supply. Furthermore, the systematic lead of labor indicates a possible connection between labor wedges and productivity. Pursuit of possible explanations of this is left for future research.

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A Tables and Figures

Table 1. Business Cycle Features of the Japanese Economy

	$std(\%)$	Correlation of Output with						
x		$x(-3)$	$x(-2)$	$x(-1)$	$x(0)$	$x(1)$	$x(2)$	$x(3)$
Output	1.06	0.46	0.61	0.79	1.00	0.79	0.61	0.46
Consumption	0.60	0.15	0.11	0.18	0.38	0.28	0.29	0.36
Investment	2.87	0.58	0.67	0.80	0.89	0.72	0.54	0.35
Labor	0.74	0.36	0.47	0.55	0.45	0.40	0.24	0.12
Government	2.68	−0.14	0.05	0.18	0.35	0.28	0.20	0.17

Table 2. Parameter Values

θ	0.388
δ	0.022
β	0.987
Ψ	0.228
γ	0.0035
n	0.0019
l	0.253
c/y	0.534
y/k	0.104

Table 3. Business Cycle Accounting Result with Efficiency Wedges

	$std(\%)$	Correlation of Output with						
v		$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$
Output	1.25	0.34	0.47	0.57	1.00	0.57	0.47	0.34
Consumption	0.63	0.22	0.36	0.50	0.92	0.64	0.59	0.51
Investment	3.57	0.37	0.49	0.58	0.99	0.53	0.41	0.27
Labor	0.53	0.41	0.50	057	0.94	0.44	0.30	0.15

Table 4. Business Cycle Accounting Result with Efficiency and Labor Wedges

	$std(\%)$	Correlation of Output with						
v		$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$
Output	0.98	0.43	0.51	0.67	1.00	0.67	0.51	0.43
Consumption	0.49	0.25	0.35	0.54	0.81	0.67	0.59	0.58
Investment	2.95	0.46	0.52	0.66	0.98	0.62	0.44	0.35
Labor	0.64	0.30	0.29	0.33	0.28	0.13	-0.01	-0.04

Table 5. The Effect of each Wedges on Output

		g	τ^l	τ^x	z
No Φ	$corr(y^{model}, y^{data})$	0.55	-0.37	0.23	0.90
	$std(y^{model})/std(y^{data})$	0.12	0.48	0.24	1.17
With Φ	$corr(y^{model}, y^{data})$	0.54	-0.37	0.86	0.90
	$std(y^{model})/std(y^{data})$	0.26	0.37	0.35	0.77

Table 6. Business Cycle Accounting Result with Efficiency Wedges
and Investment Adjustment Cost

	$std(\%)$	Correlation of Output with						
v		$v(-3)$	$v(-2)$	$v(-1)$	$v(0)$	$v(1)$	$v(2)$	$v(3)$
Output	0.82	0.33	0.46	0.57	1.00	0.57	0.46	0.33
Consumption	1.04	0.33	0.46	0.57	1.00	0.57	0.46	0.33
Investment	0.99	0.33	0.46	0.57	1.00	0.57	0.46	0.33
Labor	0.17	-0.33	-0.46	-0.57	-1.00	-0.57	-0.46	-0.33

Table 7. Correlation of Labor Wedges with

	M1growth	Call Rate
1980-2007	0.16	0.03
1980-1989	0.44	-0.19
1990-1999	0.06	0.27
2000-2007	0.10	-0.04

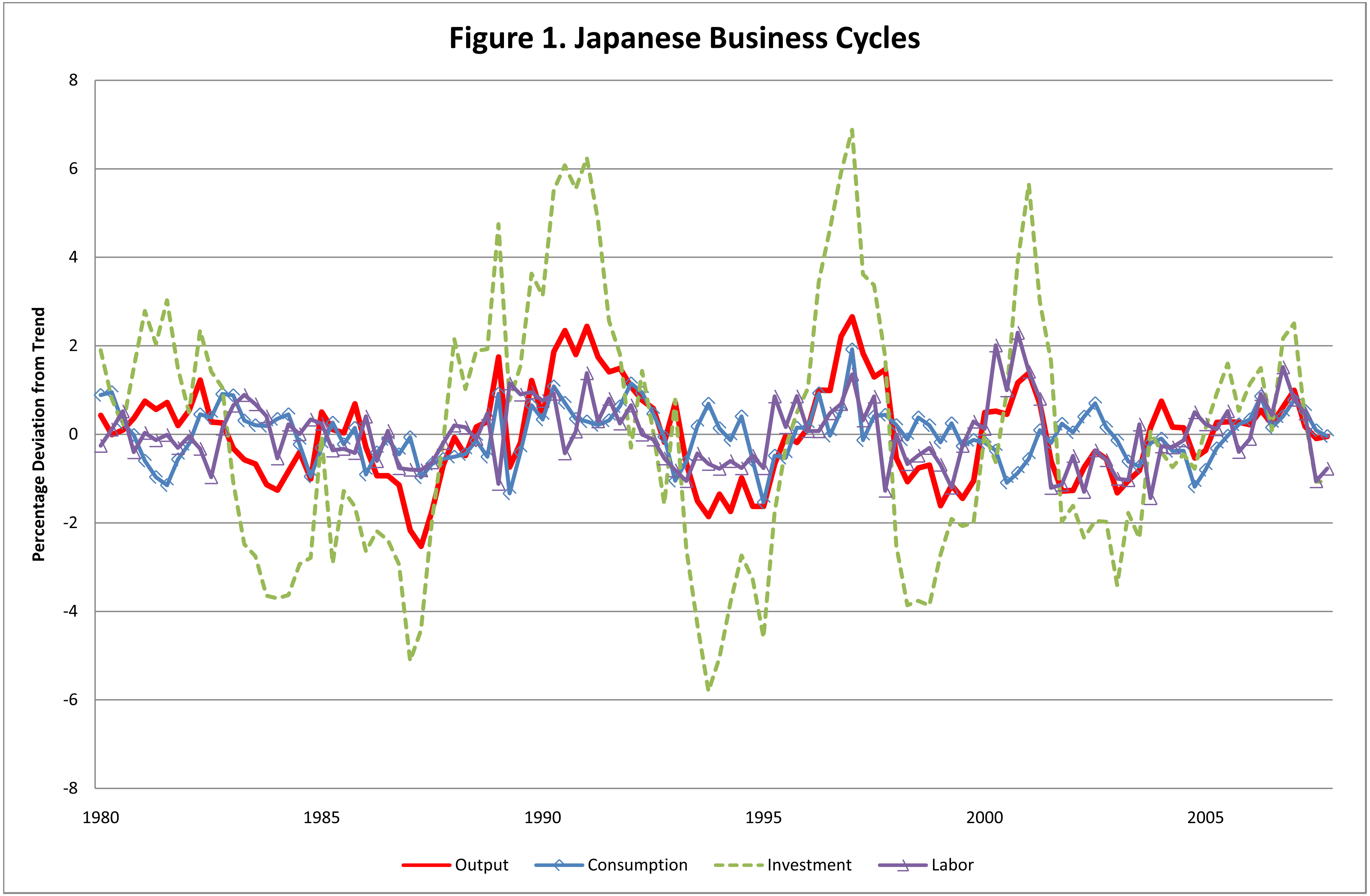


Figure 1. Japanese Business Cycles
Percentage Deviation from Trend
8
6
4
2
0
-2
-4
-6
-8
1980
1985
1990
1995
2000
2005
Output
Consumption
Investment
Labor

Figure 2. Wedges

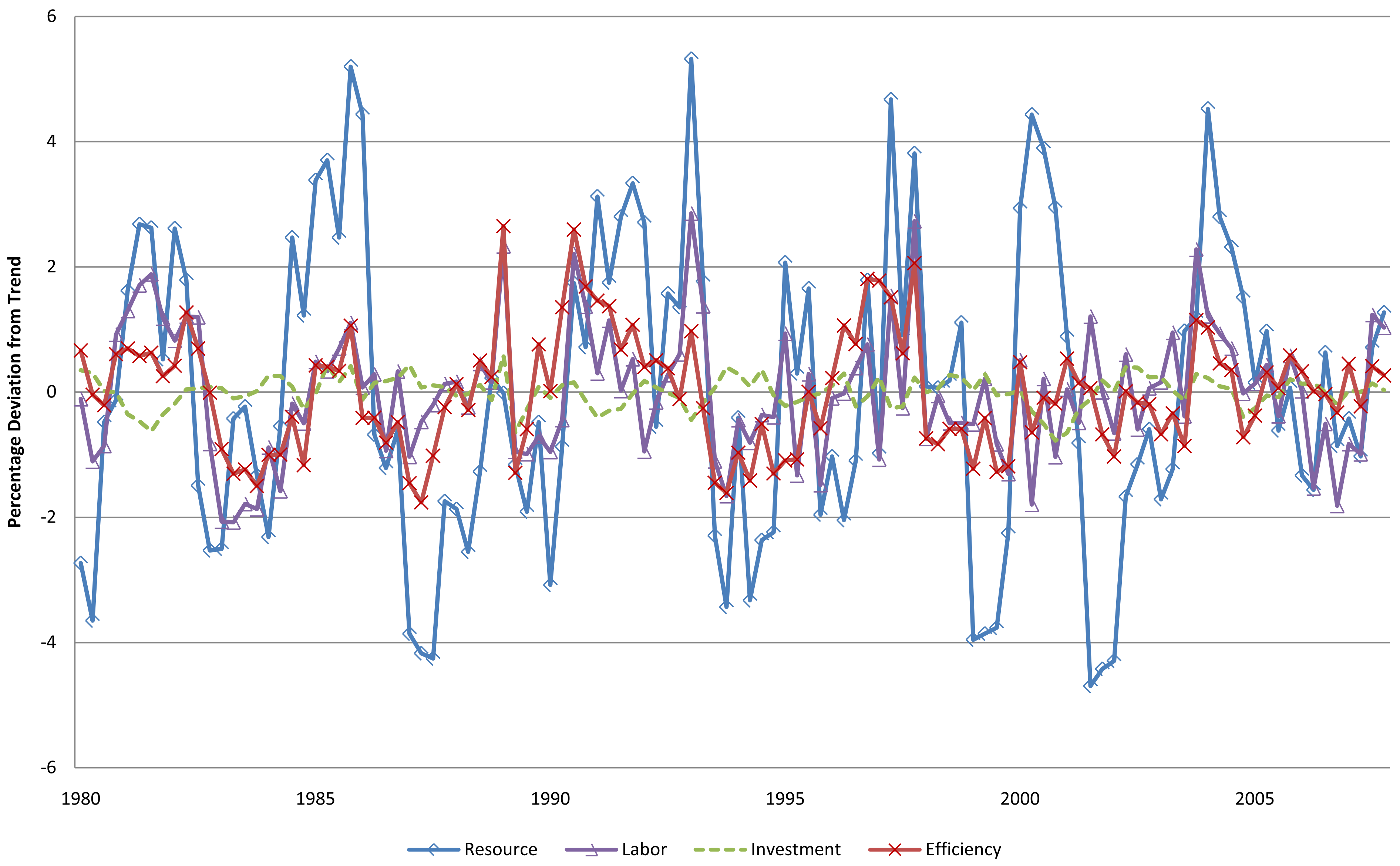
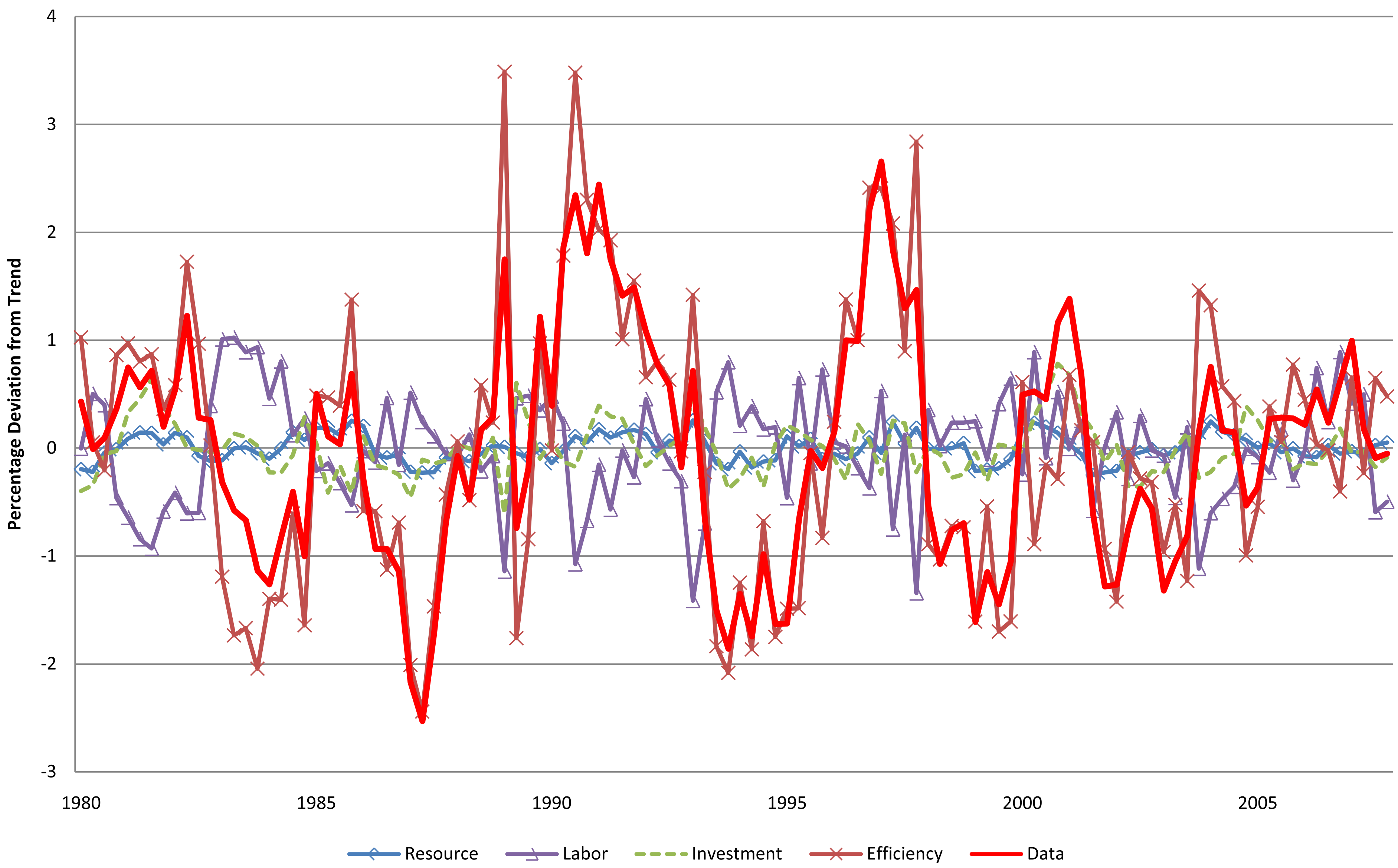


Figure 3. Simulated Output



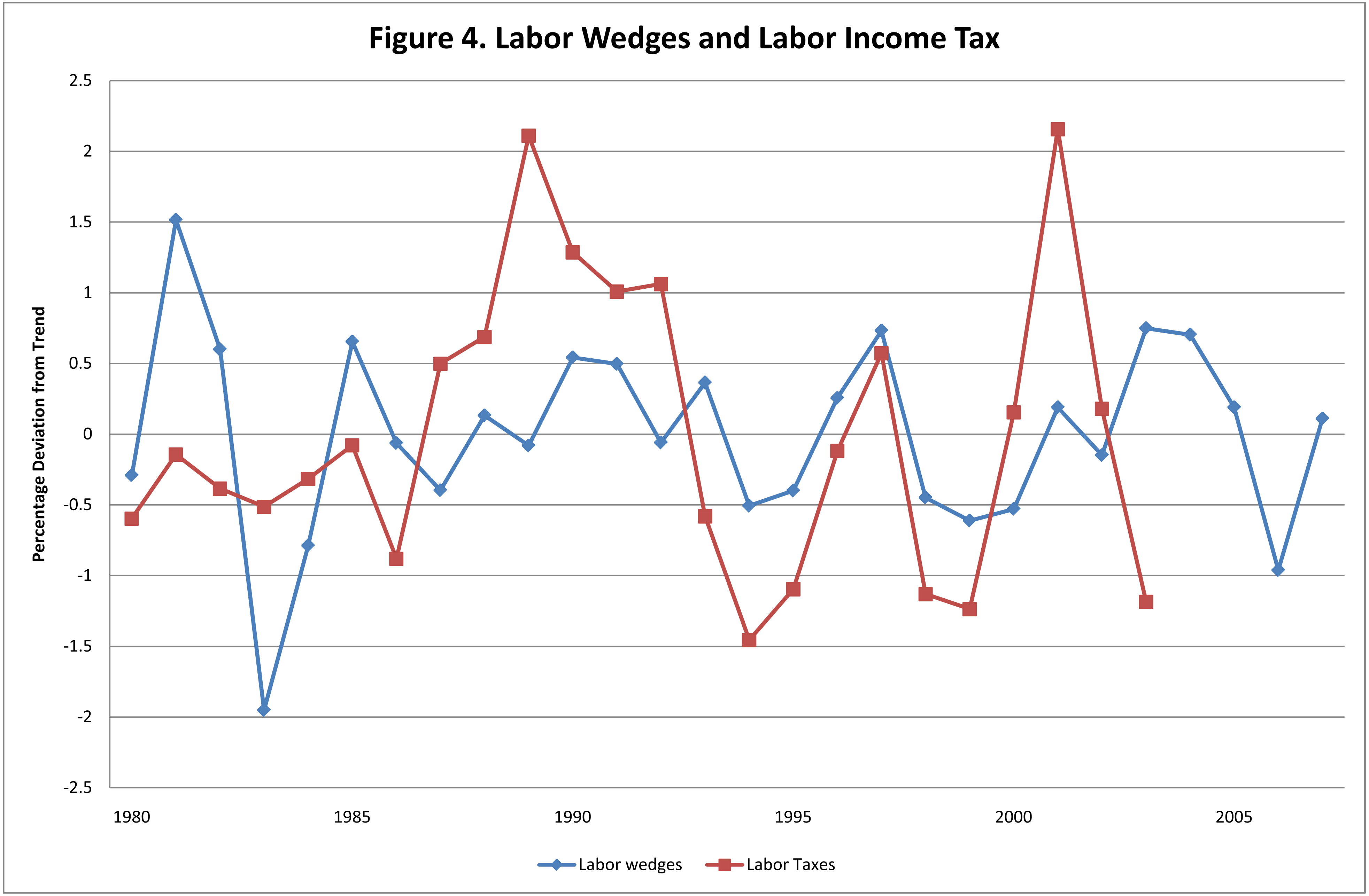


Figure 4. Labor Wedges and Labor Income Tax
Percentage Deviation from Trend
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
1980
1985
1990
1995
2000
2005
Labor wedges
Labor Taxes

Figure 5. Labor Wedges and Monetary Variables