Business cycle accounting for the Japanese economy*

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Abstract

We conducted business cycle accounting (BCA) using the method developed by Chari, Kehoe, and McGrattan (2002a) on data from the 1980s–1990s in Japan and from the interwar period in Japan and the United States. The contribution of this paper is twofold. First, we find that labor wedges may have been a major contributor to the decade-long recession in the 1990s in Japan. We argue that the deterioration of the labor wedge may have been caused by sticky wages and monetary contraction, and it may have been prolonged by the continuation of asset-price declines through binding collateral constraints. Second, we performed an alternative BCA exercise using the capital wedge instead of the investment wedge to check the robustness of BCA implications for financial frictions. The accounting results with the capital wedge imply that financial frictions may have had a large depressive effect during the 1930s in the United States. This implication is the opposite of that from the original BCA findings.

Keywords: Business cycle accounting; Japanese economy; capital wedge; Great Depression.

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1 Introduction

A popular analytical framework for business cycle research, which was pioneered by Kydland and Prescott (1982), is to quantitatively model the economy as a dynamic general equilibrium. The standard method in this literature is to model market distortions and shocks in a neoclassical growth model, calibrate parameters, and simulate the equilibrium outcome by numerical calculations. The performance of a dynamic equilibrium model is judged by the closeness of the simulated outcome to the actual data.

Recently, a "dual" method for the above standard approach was proposed and applied in an analysis of the Great Depression by Mulligan (2002) and Chari, Kehoe, and McGrattan (2002a, 2004). In the dual method, it is assumed that the economy is described as a standard neoclassical growth model with time-varying productivity, labor taxes, investment taxes, and government consumption. These wedges, called *efficiency*, *labor*, *investment*, and *government wedges*, are measured so that the outcome of the model is exactly equal to the actual data. Therefore, in this dual approach the distortions are measured so that the model replicates the data exactly. In the standard approach, by contrast, the researcher predetermines plausible distortions and simulates the outcome, which is usually different from the actual data.

The dual approach, which was named "business cycle accounting (BCA)" by Chari et al., has several useful features. First, the calculations are quite easy to make, since the wedges are directly calculated from the equilibrium conditions, which necessitate data for only one or two consecutive years and few assumptions on the future equilibrium path (see also the propositions in Mulligan [2002]). Second, BCA is a useful method for guiding researchers in developing relevant models. This is because, as Chari et al. (2004) show, a large class of quantitative business cycle models is equivalent to a prototype growth model with wedges. Since the BCA procedure shows which wedges are most crucial in actual business fluctuations, researchers can judge their business cycle models by whether they can reproduce relevant wedges.

The BCA method seems to provide particularly useful insight into the recent recession in Japan. In the policy and academic debate over the persistent recession in Japan during the 1990s, people have proposed different causes of the recession: for example, insufficient fiscal stimulation, financial frictions caused by the severe nonperforming loan problem, deflation caused by a contractionary monetary policy, and productivity declines caused by structural problems. When we try to infer which is the most promising among these explanations, it is useful to see which wedges are the main contributors to the recession by applying BCA.

For this paper, we conducted business cycle accounting using data from the 1980s–1990s, and the 1920s in Japan. Since in both periods the Japanese economy suffered from deflationary recessions subsequent to asset-price collapses, BCA results for both periods are useful to infer the causes of the recent recession in Japan. Interesting implications are given by comparing our results with other explanations, especially those of Hayashi and Prescott (2002). Hayashi and Prescott show that time-varying productivity, i.e., the efficiency wedge, can explain most of the output fluctuations during the 1990s. Our results show that the labor wedge may have been even more crucial in producing the recession. The BCA exercise shows that the labor wedge began to deteriorate in the early 1980s. We elaborate on the implications of this result and show that the deterioration in the 1980s may be a misspecification of a technological change in which the aggregate labor share changes: A modified BCA exercise in which we assume variable labor share shows that the labor wedge began to deteriorate in the early 1990s, when the asset-price bubble burst. We also examine why the labor wedge continued to deteriorate: While the deterioration during the early 1990s may be explained by sticky wages and a deflationary shock, the deterioration from 1995 onward points to other factors; one candidate may be that the continuation of asset-price declines worsened the labor wedge by making collateral constraints more severe.

We also conducted a different version of the BCA method, which is basically the same as the dual method proposed by Mulligan (2002). In the original business cycle accounting proposed by Chari et al. (2002a), friction in financial markets is assumed to manifest itself as the investment wedge, which is an imaginary tax on investment. Mulligan (2002) introduces the capital wedge, which is an imaginary tax on dividends from capital holdings. In order to justify the assumption that financial friction may manifest itself as a capital wedge in the Mulligan-type BCA, we show that a model with financial frictions proposed by Carlstrom and Fuerst (1998) is equivalent to the prototype growth model with a capital wedge. We then examine whether different versions of BCA produce different implications for the role of financial frictions using the data from the 1980s–1990s in Japan and from the Great Depression in the United States. The accounting results show that the capital wedge might have had a large depressive economic effect in the latter case. This result is the opposite of the BCA result for the Great Depression by Chari et al. They suggest that models of financial frictions are not a promising explanation for the Great Depression, since their BCA result shows that the investment wedge had no depressing effect. Our results with the capital wedge imply that financial frictions may have had considerable effects in the Great Depression in the United States, and that models with financial frictions may capture an important aspect of reality.

This paper is not the first to apply the BCA method to the Japanese economy. Chakraborty (2004) conducted BCA for the 1980s and the 1990s in Japan, and she found that the investment wedge played a major role in the performance of the Japanese economy in the 1990s. This result is somewhat different from our result in Section 3.1, which is that the investment wedge did not have a crucial effect. This difference between her results and ours seems to be caused by a combination of differences in data constructions, data sources, and simulation methods: For example, government investment and net exports are categorized differently; The steady state values of wedges are assumed to be those in 1980 in her simulation, while they are assumed to be the values in 2002 in ours; and she simulates a log-linearlized model, while we simulate a full nonlinear model without linearizing it.

The organization of the paper is as follows. Section 2 describes the general method of business cycle accounting, which is basically the same as that in Chari et al. (2002a, 2004) but includes a simplification, i.e., an assumption of perfect foresight, and some modifications in exposition. Section 3 reports the BCA results for the 1980s–1990s and the 1920s in Japan. Section 4 describes the new method of BCA with the capital wedge and presents the results of the new BCA for the Great Depression in the United States. Section 5 provides some concluding remarks.

2 Framework of business cycle accounting

In this section we briefly describe the method of BCA, following Chari, Kehoe, and McGrattan (2004).

2.1 Prototype growth model

In the BCA framework, it is assumed that an economy is described as the following standard neoclassical growth model with time-varying wedges: the *efficiency wedge* A_t, the *labor wedge* $1-\tau_{lt}$, the *investment wedge* $1/(1+\tau_{xt})$, and the *government wedge* g_t. The representative consumer solves

$$\max_{c_t, k_{t+1}, l_t} E_0[\sum_{t=0}^{\infty} \beta^t U(c_t, l_t) N_t]$$

subject to

$$c_t + (1+\tau_{xt}) \left\{ \frac{N_{t+1}}{N_t} k_{t+1} - k_t \right\} = (1-\tau_{lt}) w_t l_t + r_t k_t + T_t,$$

where c_t denotes consumption, l_t labor, k_t capital stock, w_t the wage rate, r_t the rental rate on capital, N_t population, β the discount factor, and T_t lump-sum taxes. All quantities written in lower case letters denote per-capita quantities. The functional form of the utility function is given by $U(c,l) = \ln c + \phi \ln(1-l)$, where the unit of labor is set so that the total time endowment for one year is normalized to one. The firm solves

$$\max A_t \gamma^t F(k_t, l_t) - \{r_t + (1+\tau_{xt})\delta\} k_t - w_t l_t,$$

where δ is the depreciation rate of capital and γ^t is the long-term trend rate of technical progress, which is assumed to be a constant. The functional form of the production function is given by $F(k,l) = k^\alpha l^{1-\alpha}$. The resource constraint is

$$c_t + x_t + g_t = y_t, \tag{1}$$

where x_t is investment and y_t is per-capita output. The law of motion for capital stock is

$$\frac{N_{t+1}}{N_t}k_{t+1} = (1-\delta)k_t + x_t. \tag{2}$$

The equilibrium is summarized by the resource constraint (1), the law of motion for capital (2), the production function,

$$y_t = A_t \gamma^t F(k_t, l_t), \tag{3}$$

and the first-order conditions,

$$-\frac{U_{lt}}{U_{ct}} = (1-\tau_{lt})A_t\gamma^t F_{lt}, \tag{4}$$

$$(1+\tau_{xt})U_{ct} = \beta E_t U_{ct+1}\{A_{t+1}\gamma^{t+1}F_{kt+1} + (1+\tau_{xt+1})(1-\delta)\}, \tag{5}$$

where U_{ct}, U_{lt}, F_{lt} and F_{kt} denote the derivatives of the utility function and the production function with respect to their arguments.

Chari, Kehoe, and McGrattan (2004) show that various quantitative business cycle models are equivalent to the above prototype economy with wedges: A model with input-financing frictions is equivalent to the prototype growth model with an efficiency wedge; a sticky-wage economy or one with powerful labor unions is equivalent to the prototype economy with labor wedges; and an economy with financial friction of the type proposed by Carlstrom and Fuerst (1997) is equivalent to the prototype economy with an investment wedge.

2.2 Accounting procedure

The values for the parameters of preferences and technology are given in a standard way, as in quantitative business cycle literature. Then we calculate wedges from the data using equilibrium conditions (1), (3), (4), and (5). We then feed the values of the measured wedges back into the prototype growth model, one at a time and in combinations, to assess what portion of the output movements can be attributed to each wedge separately and in combinations. By construction, all four wedges account for all of the observed movements in output. In this sense, this procedure proposed by Chari et al. (2002a, 2004) is an accounting procedure.

An important simplification in this paper from the original version by Chari et al. (2004) is that we assume perfect foresight in the prototype economy so that all wedges are given deterministically from (1), (3), (4), and

$$(1+\tau_{xt})U_{ct} = \beta U_{ct+1}\{A_{t+1}\gamma^{t+1}F_{kt+1} + (1+\tau_{xt+1})(1-\delta)\}, \tag{6}$$

instead of (5). The assumption of perfect foresight enables us to avoid complicated arguments and calculations concerning the stochastic process of wedges, which Chari et al. (2004) discuss in detail. Since the perfect foresight version in Chari et al. (2002a) provides identical implications for the Great Depression as the stochastic version in Chari et al. (2004), we adopt this simplification in this paper.

Measuring realized wedges We take the government wedge g_t directly from the data. To obtain the values of the other wedges, we use the data for y_t, l_t, x_t, g_t, and N_t, together with a series on k_t constructed from x_t by (2). The efficiency wedge and the labor wedge are directly calculated from (3) and (4).

To solve (6), we need to posit a strict assumption on the values of the wedges for the time period after the target period of business cycle accounting. Denoting the target period of BCA by $t = 0, 1, 2, \cdots, T$, we assume that $A_t = A^* = A_T$, $g_t/y_t = (g/y)^* = g_T/y_T$, and $\tau_{lt} = \tau_l^* = \tau_{lT}$ for $t \geq T+1$. The growth rate of the population is assumed to be constant for $t \geq T+1$. We also assume that τ_{xt} is an unknown constant τ_x^* for $t \geq T$. Under these assumptions, given that k_{T+1} is constructed from the data x_t ($t \leq T$), we pick a value for τ_x^* and calculate the equilibrium path of $\{c_t, k_t\}$ ($t \geq T+1$) which converges to the balanced growth path with constant wedges. Since the equilibrium path of c_t (and k_t) is uniquely determined for a given value of τ_x^*, we can choose the "true" value of τ_x^* such that $\tau_{xT} = \tau_{xT+1} = \tau_x^*$ and the initial consumption $c_{T+1}(\tau_x^*)$ satisfy (6) at $t = T$, given c_T and k_{T+1}. Once $\tau_x^* = \tau_{xT}$ is determined by this method, τ_{xt} for $t = 0, 1, 2, \cdots, T-1$, are obtained by solving (6) backward.

Decomposition To see the effect of the measured wedges on movements in macroeconomic variables from the initial date $t = 0$, we decompose the movements as follows. Define $s_t = (A_t, \tau_{lt}, \tau_{xt}, (g_t/y_t))$. First, we construct the benchmark equilibrium by solving the prototype model with constant wedges. The values of the benchmark wedges are determined as the initial values at $t = 0$, or the averages of the values of the wedges for some period prior to the target period. Therefore, we solve the model assuming that s_t is a constant vector for $0 \leq t \leq T$ and $s_t = s^* = (A^*, \tau_l^*, \tau_x^*, (g/y)^*)$ for $t \geq T + 1$. The derived sequences: y_t^b, c_t^b, x_t^b, and l_t^b are taken as the benchmark case. In order to determine the effect of one wedge, we solve the prototype model, given that the one wedge takes the measured value and the other wedges stay at the benchmark values. We then compare the derived sequences of macroeconomic variables with those of the benchmark case. For example, to see the effect of the efficiency wedge, we solve the model, given that $s_t = (A_t, \tau_{l-}, \tau_{x-}, (g_-/y_-))$ for $0 \leq t \leq T$, where τ_{l-}, τ_{x-}, (g_-/y_-) are the benchmark wedges, and $s_t = s^*$ for $t \geq T + 1$. If the derived output is below the benchmark, we say that the efficiency wedge had a depressing effect.

A similar method is used to determine the effect of two wedges in combination: We solve the prototype model, given that the two wedges take the measured values and the other wedges stay at the benchmark values.

One caveat for our decomposition procedure is that we assume in all cases that $s_t = s^*$ for $t \geq T + 1$. This is because we want to compare equilibrium paths which converge to the same balanced growth path with the same wedges. Since we measured the realized wedges under the assumption that $s_t = (A_T, \tau_{lT}, \tau_{xT}, (g_T/y_T))$ for $t \geq T+1$, we continue to posit the same assumption in the decomposition.[1]

[1] An alternative method may be to assume that wedges go back to the initial values at $t = T + 1$, and to assume $s_t = (A_0, \tau_{l0}, \tau_{x0}, g_0)$ for $t \geq T + 1$ for all cases. There are, however, two difficulties with this method. In conducting BCA for business fluctuations in one decade, it may not be plausible to assume that people will believe that the wedges for the next year will jump back to their initial values of ten years ago. A second problem is that the value of the investment wedge for $t \geq T + 1$: τ_x^*, which is the solution to (6) under the assumption that the other wedges take the initial values, may not coincide with τ_{x0}.

3 BCA for Japan

Japan experienced persistent deflationary recessions subsequent to asset-price collapses during the 1990s and the 1920s. In the late 1980s the Japanese economy experienced an unprecedented stock market and real estate boom, which came to be called the "bubble economy." At the beginning of the 1990s, both stock and land prices collapsed, leaving huge amounts of nonperforming loans. Soon afterward, a persistent recession took hold, leading to nationwide bank panics in 1997–99, and to subsequent deflation. This deflation continues in 2005. After World War I, on the other hand, Japan experienced an investment boom in military and heavy industries, and the stock market collapsed in 1920. A deflationary recession continued during the 1920s, and led to the first nationwide bank panics in Japanese history in 1927. A deflationary policy in 1929–1931 aimed at restoring a fixed exchange rate worsened the recession, which forced Japan to leave the gold standard again in December 1931. In the early 1930s the Japanese economy staged a strong recovery, which is said to have been enabled by the expansionary fiscal and monetary policies introduced in 1932.

3.1 The 1980s–1990s

The target period of our first accounting exercise is 1981–2002. We constructed the data set following the method of Hayashi and Prescott (2002). The data set is provided in a data appendix (Kobayashi and Inaba [2005]). We assume that $\beta = 0.98$. We set $\alpha = 0.372$ and $\delta = 0.0846$, which are the averages during 1984–89.[2] We also set $g_n = 0$, and $g_z = 0.0209$, where g_n is the population growth rate for $t \geq 2003$, and $(1+g_z)^{1-\alpha} = \gamma$. The trend rate of technical progress $(1 + g_z)$ was set as the average during 1981–2002.

In Figure 1 we display the actual data for output (detrended by $1 + g_z$) and the four measured wedges for 1981–2002: the efficiency wedge A_t, the labor wedge $(1 - \tau_{lt})\phi^{-1}$, the investment wedge $1/(1+\tau_{xt})$, and the government wedge g_t. All variables are plotted

[2] We set these values following Hayashi and Prescott for convenience of comparison.

as indices set at 100 in 1981.

Figure 1. Output and the four measured wedges in the 1980s–1990s

The detrended output declined in 1992–95, recovered in 1996 and 1997, but fell again during the financial crisis of 1998–99. The government wedge surged since 1992, just after the asset-price collapses, then fell in the contractionary policy in 1997, and rose again in response to the expansionary fiscal policy following the banking crisis of 1998–99. The investment wedge improved from the value of 1981, almost throughout the target period. The labor wedge continued to deteriorate from 1984 onward. The efficiency wedge surged during the "bubble economy" of the late 1980s and fell after the asset-price collapses in 1989–91.

The decomposition results for output are shown in Figure 2. (The decomposition results for consumption, labor, and investment are not reported in this paper, but can be obtained from the authors upon request.) In our decomposition exercise for the 1980s–1990s, we assumed the values of the benchmark wedges as follows: A, τ_l, τ_x, and (g/y) are the averages for the 1984–89 period.[3]

In Figure 2, we display the separate contributions of each wedge. We plot the actual output, the benchmark case, and the simulated outputs due to each of the four wedges. We plot the benchmark as a horizontal line at 100 and the other outputs as deviations from the benchmark. If output due to a wedge is below (above) the benchmark case, we judge that the wedge had a depressing (expanding) effect on output. Figure 2 has several interesting features. First, the government wedge had an expanding effect on the economy almost throughout the 1990s. The effect of the government wedge is worth noting, since there is a popular view that insufficient fiscal expansion during the 1990s prolonged the recession. Our accounting result shows that there were possibly no depressing effects from fiscal policy during the 1990s.

The investment wedge had a slightly negative effect during the bubble period of the late 1980s, 1991–2, and 1996–7. This result for the investment wedge seems to imply

[3]We also conducted the BCA exercise taking the values of all benchmark wedges as those of the start year (1981). The results were qualitatively the same.

investment frictions were not a significant cause of the persistent recession during the 1990s. This seems consistent with the view of those academic economists who argue that financial problems may not have been the culprit for the lost decade of Japan (see, for example, Hayashi and Prescott [2002] and Andolfatto [2003]).

The output due to the efficiency wedge roughly replicates actual output, while the discrepancy widened during the 1990s. Note that the efficiency wedge had a large "expanding" effect until the financial crisis of 1998–99, since the detrended productivity remained higher than the 1984–89 average.

The labor wedge had a large depressing effect on output during 1989–2002. As we see in Figure 3, this effect explains the wider discrepancy between the output due to the efficiency wedge and the data. But we need to be careful in interpreting this result: If we change the benchmark wedges, the time period in which the labor wedge had a depressing effect changes. If we set the benchmark wedges at the values of 1983, the labor wedge began to depress output in 1985.

In Figure 3, we show the combined effects of two and three wedges, respectively, on output. To compare these results with Hayashi and Prescott (2002) is interesting. In their accounting exercise, Hayashi and Prescott found that output due to the efficiency and government wedges could replicate the observed output on the premise that τ_{xt} is constant for all t and τ_{lt} improved from 1993 onward.[4] Our result seems inconsistent with theirs, since the combined contribution of the efficiency and government wedges shows a large deviation from the actual output. Figure 3 demonstrates that the combined effect of the efficiency, government, and labor wedges more closely replicates the data.

Two factors may explain the difference between the Hayashi-Prescott result and ours. First, the data sources are different: Hayashi and Prescott used the national accounts data of the 1968 standard (1968 SNA [System of National Accounts]), while we used that

[4]Hayashi and Prescott formalize the reduction of the workweek length (average hours worked per week), a change in the Japanese labor policy, as follows: The workweek length h was exogenously set at 44 hours until 1992, and h becomes an endogenous variable for the representative consumer from 1993 onward. This formulation apparently implies the improvement of the labor wedge from 1993 onward, since an exogenous constraint on labor supply is lifted off in 1993.

of the 1993 standard (1993 SNA). Among many differences between the data in the 1968 SNA and those in the 1993 SNA, the difference in capital stock seems most problematic. The capital stock in the 1993 SNA is quite different from that in the 1968 SNA, mainly because it includes computer software. As a result, the growth rate of capital stock in the 1990s is lower in the 1993 SNA than in the 1968 SNA. This difference may result in higher growth of productivity in our accounting exercise. The second factor is the treatment of the labor and investment wedges: Hayashi and Prescott assumed that the labor wedge improved by an exogenous change in the labor policy and the investment wedge remained constant. The negative effect due to change in the labor wedge may be attributed to the efficiency or government wedge in their accounting exercise because of this assumption.

Figures 2. Decomposition of output with just one wedge

Figure 3. Combined effect of two and three wedges on output

When did the labor wedge begin to deteriorate? While our BCA results imply that the labor wedge is a crucial factor that explains the output declines during the 1990s, the labor wedge itself began to deteriorate long before the recession started. Figure 1 shows that the labor wedge, calculated from (4), began to deteriorate in 1984. There are two different interpretations for this. The first is that the deterioration of the labor wedge represents a structural change in the economy, which may be unrelated to the recession in the 1990s: The labor wedge may represent a declining trend in the Japanese economy, while a temporary surge in productivity could have brought about a short period of boom in the late 1980s. The other interpretation is that the deterioration of the measured labor wedge in the 1980s is a result of a measurement error: If there was a change in production technology, in which the labor share $(1-\alpha)$ decreases, the labor wedge declines, since we assumed a constant α when we measured the labor wedge. The national account statistics show that the actual labor share changed considerably during the 1980s and the 1990s. We calculated the modified labor wedge on the premise that the labor share $(1-\alpha)$ changes year-by-year and is directly given from the national accounts data. Both the original and the modified labor wedges are shown in Figure 4. The upper panel shows the labor wedges in 1960–2000, measured from data of 1968 SNA, and the lower panel shows them in 1981–2002, measured from 1993 SNA. Both panels show that the modified labor wedge was roughly stable or had a slightly improving trend during the 1980s, and then sharply deteriorated after the asset-price collapses in 1989–91.

Figure 4. The modified labor wedge

Thus, this figure implies that the deterioration of the labor wedge is closely related to the asset-price collapses or the onset of the recession, if we assume that the change in the labor share is caused by a technological change in the aggregate production function. Figure 5 shows the output decomposition in the modified BCA, in which we used the modified labor wedge and the variable labor share. As expected, the labor wedge began to exert a depressing effect on output only since 1990. Moreover, the efficiency wedge began to depress the economy in 1993, when the bank distress in Japan became apparent. Contrary to the original BCA results, the finding that the labor wedge began to depress the output only since the 1990s is robust against changes in the benchmark wedges.

Figure 5. Output decomposition with variable labor share

Figure 6 shows the combined effects of two and three wedges, respectively, on the output in the modified BCA. The combined effect of the efficiency and government wedges closely replicates the data during the 1980s, but a discrepancy emerged and widened since the recession in the 90s started. The figure reinforces the implications of Figure 3 that the deterioration of the labor wedge was crucial to explain the 1990s in Japan.

Figure 6. Combined effect of two and three wedges on output in the case of variable labor share

Our decomposition results for the 1980s and 1990s in Japan imply that the deterioration of the labor wedge was a crucial factor in the protracted recession of the 1990s, while the cause of the labor-wedge deterioration may or may not be directly associated with the onset of the recession. If we modify the measurement of the labor wedge by assuming that a technological change alters the labor share, the deterioration of labor wedge began as the recession started.

Why did the labor wedge deteriorate? Chari et al. (2004) show theoretically that sticky wages, together with monetary contraction, may worsen the labor wedge. The Bank of Japan conducted a very contractionary monetary policy during 1989–91, but it began monetary easing in response to the recession and maintained a very expansionary stance during the latter half of the 1990s. Thus it can be said that a contractionary monetary shock hit the economy only in 1989–91. A rise in real wages may have been caused by the stickiness of nominal wages, together with the disinflation, which was possibly due to a contractionary monetary shock.[5] As shown in Figure 7, real wages (detrended), which are defined as output (detrended) divided by the labor input times labor share, continued to rise until 1994. The rise in real wages seem consistent with Chari et al. (2004)'s story, and may explain the deterioration of the labor wedge during the early 1990s. But the fact that the labor wedge continued to deteriorate in the latter half of the 1990s cannot be explained by sticky wages and a monetary shock, since as shown in Figure 7 the real wage (detrended) declined from 1995 onward and there was no contractionary monetary policy during that period.

Figure 7. Real wage in Japan (detrended).

One candidate for the explanation of the 1995–2002 period is that the contiunation of asset-price declines together with binding collateral constraints may have worsened the labor wedge. Let us describe casually and briefly a model for such a story. To introduce the collateral constraint most simply, we consider the following economy, in which the representative consumer owns a_t units of land, which generates stochastic dividends d_t.

[5] Alternatively, we can conjecture that the disinflation in the early 1990s may have been natural consequences of the onset of the recession. A demand shortage may have been brought about by some exogenous shocks, and it may have caused the disinflation through sticky prices, as predicted by the dynamic new Keynesian models.

The total supply of land is normalized to one. The consumer solves

$$\max_{c_t, i_t, l_t, a_{t+1}} E_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t, l_t) N_t \right]$$

subject to

$$\begin{cases} c_t + i_t + q_t\{a_{t+1} - a_t\} = w_t l_t + r_t k_t + d_t a_t - T_t, \\ c_t + i_t \leq \theta q_t a_t, \\ k_{t+1} = (1-\delta)k_t + i_t, \end{cases}$$

where q_t is the real asset price and the second equation is the collateral constraint, in which θ $(0 < \theta < 1)$ is the collateral ratio. The representative firm solves

$$\max_{k_t, l_t} A_t k_t^{\alpha} l_t^{1-\alpha} - r_t k_t - w_t l_t.$$

The resource constraints for this economy are $c_t + i_t = A_t k_t^{\alpha} l_t^{1-\alpha} + d_t - T_t$ and $a_t = 1$. Recall that the labor wedge $(1 - \tau_{lt})$ is defined as

$$1 - \tau_{lt} = \frac{\lambda_t}{\lambda_t + \mu_t},$$

where λ_t and μ_t are the Lagrange multipliers for the budget constraint and the collateral constraint, respectively. This expression implies that if the collateral constraint binds severely so that μ_t becomes large, the labor wedge deteriorates. The labor wedge is also written as

$$1 - \tau_{lt} = \frac{\phi c_t}{1 - l_t} \left\{ (1-\alpha) A_t \left(\frac{k_t}{l_t} \right)^{\alpha} \right\}^{-1}, \tag{7}$$

where we assume that $U(c_t, l_t) = \ln c_t + \phi \ln(1 - l_t)$. Suppose that the government sets $T_t = d_t$. In this case, the collateral constraint and the resource constraint imply that

$$c_t + i_t = q_t \theta = A_t k_t^{\alpha} l_t^{1-\alpha}. \tag{8}$$

The following casual comparative statics, in which we assume that k_t is fixed exogenously, imply that the labor wedge actually declines as q_t declines: The first equality of (8) implies that c_t is (weakly) increasing in q_t, and the second equality implies that l_t is strongly increasing in q_t, since k_t is fixed in our casual comparative statics; These observations and equation (7) imply that $1 - \tau_{lt}$ is strongly increasing in q_t. Suppose that the expectations for future dividends d_t worsen every year because people suffer from (possibly irrational) pessimism. The asset price q_t then declines and the labor wedge continues to deteriorate in this model economy.[6]

Figure 8 shows the market values of land owned by households and nonfinancial corporations during 1980–2003 in Japan. Figure 9 shows the sum of private consumption and investment (i.e., $c_t + i_t$) for the same period. These figures indicate that at least from 1995 onward, the labor wedge deterioration may have been caused by the decline in land values and binding collateral constraints.[7] The story that the collateral constraints bound severely in the 1990s may be supported by microeconomic empirical research that estimates the investment function and shows that corporate investment declined in the early 1990s due to land price declines (see Ogawa and Kitasaka [1998]).

Figure 8. Market value of land owned by households and nonfinancial corporations

Figure 9. Private consumption and investment (detrended)

3.2 The 1920s

The target period of our accounting exercise for the 1920s is 1920–35. The data sources are shown in the Appendix. For the accounting procedure for the 1920s, we set $\beta = 0.98$. The other parameters were set as the averages of the 1920–35 period: $\alpha = 0.363$, $\delta = 0.0719$, $g_n = 0.0141$, and $g_z = 0.0362$. First, we report the output and the wedges in Figure 10. Output declined throughout the 1920s and picked up after Japan left the gold standard again in December 1931.[8] The efficiency wedge remained below its initial value throughout the 1920s, but rapidly recovered after 1932. The government wedge was

[6]It is easy to see that the investment wedge also deteriorates as q_t declines. This is not consistent with the BCA results, in which the investment wedge does not deteriorate. To explain the result concerning the investment wedge, we need to modify the model such that the investment expenditure is not subject to the collateral constraint.

[7]In the Japanese economy, land and corporate stocks were considered as collateralizable assets for bank credit. It is easily confirmed by data that the total value of land and stocks owned by households and nonfinancial corporations has also continued to decline since the beginning of the 1990s.

[8]Japan rejoined the gold standard on January 11, 1930.

above its initial value throughout the target period and increased markedly after Japan embarked on a military venture in China in 1931. The behavior of the investment wedge in this period was quite different from that of the 1990s. Although in both periods the Japanese economy suffered from nonperforming loans and banking crises, the investment wedge worsened in the 1920s and was stable in the 1990s.[9] The labor wedge stayed high in the early 1920s but fell below the initial value in the late 1920s. Neither the labor nor the investment wedges recovered at all after the drastic change of economic regime, i.e., the abandonment of the gold standard and the start of fiscal and monetary expansion.

Figure 10. Output and the four measured wedges in the 1920s

The decomposition result for output is shown in Figure 11. We set the benchmark wedges at their initial values as of 1920.

This figure shows that the efficiency and investment wedges had a significant negative impact on the economy during the recession of the 1920s, while the labor wedge contributed to this slowdown at the end of the 1920s. The investment wedge implies that financial frictions (e.g., bank distress) may have played a major role in the recession. The government wedge boosted the economy during the period. In the recovery phase after 1932, the sole contributor to the spectacular recovery was the efficiency wedge. The negative effects of the labor and investment wedges grew and the positive effects of the government wedge diminished in this recovery period.

One theoretical challenge that this decomposition result raises is why the abandonment of gold standard and the subsequent fiscal and monetary stimulation were associated with a spectacular recovery of productivity but sparked no recovery in the labor and investment wedges.

Figure 11. Decomposition of output with just one wedge

[9]The difference in the investment wedge between these two periods may be due to institutional differences in financial regulations. One major difference in regulations is that no deposit insurance system existed in the 1920s, and there were no government guarantees for depositors. Deposit insurance existed in the 1990s, and a blanket depositor guarantee was introduced in 1995.

4 BCA with the capital wedge

Financial frictions are assumed to manifest themselves as the investment wedge in the original business cycle accounting proposed by Chari, Kehoe, and McGrattan (2002a, 2004). Mulligan (2002) assumes alternatively that there is a capital wedge, which is induced by an imaginary tax on dividends from capital, rather than an investment wedge. Chari et al. (2004) conclude that there is no need to postulate the capital wedge as long as one assumes there is an investment wedge, since the capital wedge "is only slightly different from that induced by a tax on investment." It is easy to establish the theoretical equivalence between the investment and capital wedges. We show, however, that the implications from an accounting exercise in which BCA is conducted with the capital wedge are quite different from the original BCA. This result may imply that BCA is quite sensitive to identifying assumptions for wedges.

4.1 Equivalence result

The prototype growth model is the same as in the original BCA, except for the budget constraint for the representative consumer:

$$c_t + \frac{N_{t+1}}{N_t}k_{t+1} - k_t = (1-\tau_{lt})w_t l_t + (1-\tau_{kt})r_t k_t + T_t,$$

where $(1-\tau_{kt})$ is the *capital wedge*, and the firm's problem:

$$\max A_t \gamma^t F(k_t, l_t) - w_t l_t - (r_t + \delta)k_t.$$

Assuming perfect foresight, the equilibrium is summarized by the resource constraint (1), the law of motion for capital (2), the production function (3), and the first-order conditions (4) and

$$U_{ct} = \beta U_{ct+1}\{(1-\tau_{kt+1})A_{t+1}\gamma^{t+1}F_{kt+1} + 1 - \delta + \delta\tau_{kt+1}\}. \tag{9}$$

If we change the specification of the prototype model such that the imaginary capital tax is paid not by the consumer but by the firm, the last term of (9), i.e., $\delta\tau_{kt+1}$ disappears. But this modification does not have a major effect on the accounting exercise in the next subsection. Note that as Mulligan (2002) emphasizes, the capital wedge can be calculated using the data for only t and $t+1$. This simplicity in calculation contrasts sharply with the measurement of the investment wedge in the original BCA, since we need to know or assume the entire future path of the economy in order to obtain the value of τ_{xt} from (5).[10]

To show the equivalence between BCA with the investment wedge and that with the capital wedge, it is convenient to rewrite the prototype models with net investments instead of gross investments.[11] In the rewritten model for BCA with the investment wedge, the representative consumer maximizes the discounted present value of the utility flow subject to

$$c_t + (1+\tau_{xt})\left\{\frac{N_{t+1}}{N_t}k_{t+1} - (1-\delta)k_t\right\} = (1-\tau_{lt})w_t l_t + \tilde{r}_t k_t + T_t,$$

while the representative firm solves

$$\max A_t \gamma^t F(k_t, l_t) - \tilde{r}_t k_t - w_t l_t.$$

In the rewritten model for BCA with the capital wedge, the representative consumer maximizes the same objective function subject to

$$c_t + \frac{N_{t+1}}{N_t}k_{t+1} - (1-\delta)k_t = (1-\tau_{lt})w_t l_t + (1-\tau_{kt})\tilde{r}_t k_t + T_t,$$

while the firm solve the same problem as above. These two growth models are equivalent, since the intertemporal budget constraint for the consumer is identical for both cases:

$$\sum_{t=0}^{\infty} q_t c_t \leq \sum_{t=0}^{\infty} q_t\{(1-\tau_{lt})w_t l_t + T_t\} + q_{-1}k_0,$$

where $q_t = \prod_{i=0}^{t} \frac{(1+\tau_{xi})N_{i+1}}{\{\tilde{r}_i + (1-\delta)(1+\tau_{xi})\}N_i}$ for $t \geq 0$ and $q_{-1} = \tilde{r}_0 + (1-\delta)(1+\tau_{x0})$ in the model with the investment wedge, and $q_t = \prod_{i=0}^{t} \frac{N_{i+1}}{\{(1-\tau_{ki})\tilde{r}_i + 1 - \delta\}N_i}$ for $t \geq 0$ and $q_{-1} = (1-\tau_{k0})\tilde{r}_0 + 1 - \delta$ in the model with the capital wedge. This equivalence implies that an economy with financial friction of the type proposed by Carlstrom and Fuerst (1997) is also equivalent to the prototype economy with a capital wedge.

[10] In the following accounting exercise, however, we also need to assume that τ_{kt} takes a constant value, τ_k^* for $t \geq T+1$, and to find τ_k^* by the same shooting method that we use to find the value of τ_x^*.

[11] We thank Tomoyuki Nakajima for pointing out this equivalence result.

4.2 Accounting results for the Great Depression in the United States

We conducted BCA with the capital wedge on the 1981–2002 period in Japan and on the 1929–1939 period in the United States. The data sources are shown in the Appendix. The decomposition results for output in Japan, which are not reported in this paper, show that the efficiency, labor, and the government wedges had the same effects on output as in the BCA with the investment wedge. The result for the capital wedge is not robust: The capital wedge had an expanding effect in some cases and a depressing effect in other cases; the effect changes if we change the benchmark wedges from the averages over 1984–89 to the values of 1983; and it also changes if we change the specification of the model such that the last term of (9), i.e., $\delta\tau_{kt+1}$ disappears. The instability of the result is in contrast with the result of the original BCA, in which the investment wedge had an expansionary effect for all benchmarks.

An interesting result appeared in the accounting exercise for the Great Depression. Figures 12 and 13 show the decomposition results for output in the 1929–1939 period in the United States. The BCA results with the investment wedge are shown in Figure 12, and those with the capital wedge are shown in Figure 13.

Parameters and the benchmark wedges were determined in the same way as in the BCA for Japan. We set $\beta = 0.97$ and $\alpha = 0.34$, which are taken from Chari et al. (2002b). The other parameters were set as the averages during 1923–28: $\delta = 0.0267$, $g_n = 0.0188$, and $g_z = 0.0233$.[12] The values of the benchmark wedges were also set as the averages during 1923–28, except for the benchmark efficiency, which was set as the initial value in 1929.

In calculating the decomposition results, we imposed the nonnegativity condition for investment: $x_t \geq 0$. Otherwise, x_t takes a negative value in some cases.[13]

The upper panel of Figure 12 shows the output due to one wedge and the lower panel

[12] To check the robustness of our results, we also performed BCA with the capital wedge using a larger depreciation rate: $\delta = 0.06$, which is the value used in Chari, Kehoe, and McGrattan (2002a, 2004). The results are qualitatively similar to those in Figure 13.

[13] In the BCA exercises for Japan, we need not impose the nonnegativity condition for investment, since it always takes a positive value.

shows the combined effect of the efficiency, labor, and government wedges. The upper and lower panels of Figure 13 show the corresponding results for BCA with the capital wedge. Figure 12 indicates that almost throughout the period, the investment wedge had a considerable expansionary effect on the economy, while Figure 13 shows that over the years from 1929 to 1932, the capital wedge had a severe depressing effect, and it continued to have a negative effect in 1935–39.[14] The result for the investment wedge is consistent with the results by Chari, Kehoe, and McGrattan (2002a, 2004). They reported that the investment wedge had a positive effect on the economy throughout the target period and concluded that investment friction was not a promising explanation for the Great Depression. Our result for BCA with the capital wedge indicates the opposite. The lower panel of Figure 13 implies that if there had been no capital wedge, the depression should have been milder in 1929–1932 and the recovery quicker in 1935–1939. In this accounting exercise, part of the output movement attributed to the efficiency wedge in the original BCA seems, in fact, to be attributable to the negative effect of the capital wedge.

Figure 12. Decomposition with the investment wedge: Output in the Great Depression

Figure 13. Decomposition with the capital wedge: Output in the Great Depression

Therefore, it can be said that the original BCA and the new BCA in this section have quite different implications for the role of financial frictions in depression episodes: The original BCA implies that financial frictions were insignificant, while the new BCA implies that they may have had a depressing effect on the economy in the case of the US Great Depression. The guidance to theoretical researchers differs as well: The original BCA implies that models with financial friction of the sort developed by Carlstrom and Fuerst (1997) are not promising as explanations for the Great Depression, while the new BCA implies that financial friction models may reflect some important aspects of the depression episode.

[14] We also performed the modified BCA with the capital wedge, in which the firms pay a capital tax and the last term of (9), i.e., $\delta\tau_{kt+1}$, disappears. The result is virtually identical to Figure 13.

This result may indicate that the measured values of the investment and capital wedges are too sensitive to identifying assumptions: In both the original and new BCA exercises, we assumed that the investment (or capital) wedge remain constant from year T onward, where T is the last year of the target period of the BCA exercise. This assumption may be too restrictive and make the measurement of the intertemporal Euler equations unreliable. In other words, the current BCA method may not be useful in assessing the effect of financial frictions in the depression episodes.

5 Concluding remarks

We conducted business cycle accounting on data from the 1980s–1990s and the 1920s in Japan. Our results show that the labor wedge, in addition to the efficiency wedge, had a large depressing effect on the economy during the 1990s and the early 2000s. This implies that any theory attempting to explain the recession in Japan needs to include market distortions which manifest themselves as the labor wedge. Sticky wages, together with contractionary monetary policy, are one candidate which may explain the early 1990s successfully, but this seems inconsistent with the labor wedge during the period from 1995 onward. The continuation of asset-price declines, together with binding collateral constraints, may be a good candidate for explanation of the labor wedge in 1995–2002.

Our accounting results for the other deflationary episode in Japan, the 1920s, raise another theoretical challenge. The Japanese economy experienced a strong recovery after Japan abandoned the gold standard. Since our results show that this recovery was solely due to the marked increase in the efficiency wedge, economic theory needs to be able to explain why the abandonment of the gold standard and subsequent fiscal and monetary expansion led to the rise in the efficiency wedge but not to improvement in the labor and the investment wedges.

We also conducted another BCA exercise, in which we introduced the capital wedge instead of the investment wedge. Our results show that the capital wedge had a large depressing effect in the 1929–39 period in the United States. On the other hand, the original BCA indicated that the investment wedge had no depressing effect during the

Great Depression. These findings are contradictory, since the investment and capital wedges are regarded in the literature to represent the same kind of distortions in the financial sector.

Reconciling the conflicting implications of the investment wedge and the capital wedge in financial frictions is an important topic for future research.

6 Appendix

In this appendix we briefly describe the data sources and data construction method. The complete data set and the details of the data construction method are provided in Kobayashi and Inaba (2005), which is appended to this paper.

The 1980s–1990s in Japan The data sources and the data construction method are the same as in Hayashi and Prescott (2002). The difference is that we used the 1993 SNA for the national accounts data, while Hayashi and Prescott used the 1968 SNA.

The 1920s in Japan All data except for labor and population are taken from Ohkawa, Takamatsu, and Yamamoto (1974) and Ohkawa et al. (1966). Labor and population data are taken from Umemura et al. (1988), the Bank of Japan (1966), and various volumes of *Nippon Teikoku tokei nenkan* [Annual statistics of the Empire of Japan], published by the Statistics Department of the Bank of Japan. The value of the capital share is calibrated as the 1920–35 average of (1 - labor share). The data sources are Ohkawa, Takamatsu, and Yamamoto (1974); Minami and Ono (1978); and Hayami (1975). The value of the depreciation rate is calibrated as the 1920–35 average of the ratio of depreciation to capital stock. The data sources are Ohkawa, Takamatsu, and Yamamoto (1974) and Ohkawa et al. (1966).

The 1930s in the United States All data except for population are taken from the National Income and Product Accounts, which are available at the website of the Bureau of Economic Analysis, and Kendrick (1961). Population data are taken from the Bureau of the Census (1975). The value of the depreciation rate is calibrated as the 1920–35 average of the ratio of depreciation to capital stock. Depreciation data are taken from Table A-III of Kendrick (1961). The capital stock data are from Table A-XV of Kendrick (1961).

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Figure 1. Output and the four measured wedges in the 1990s

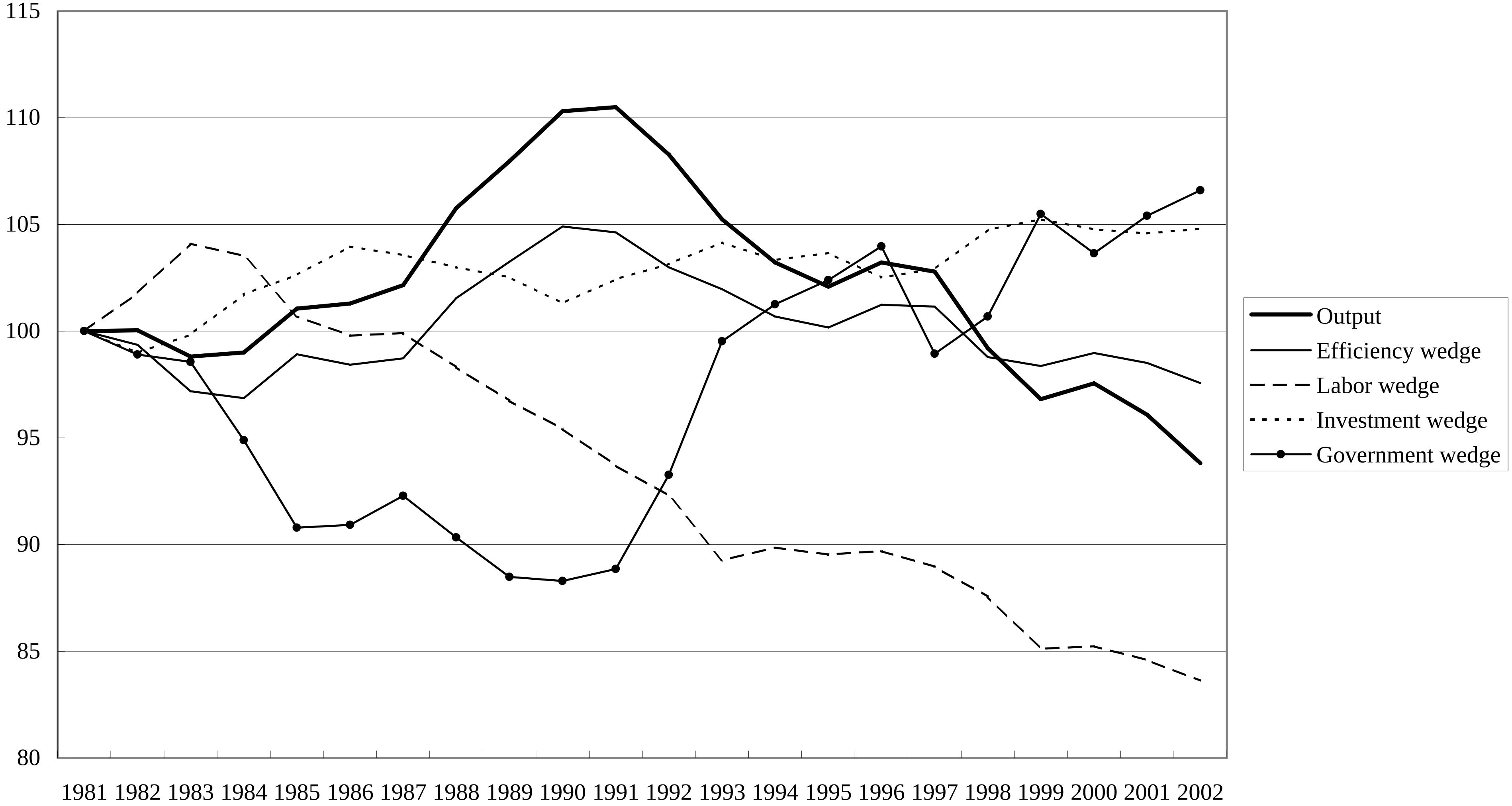


Figure 2. Decomposition of output with just one wedge

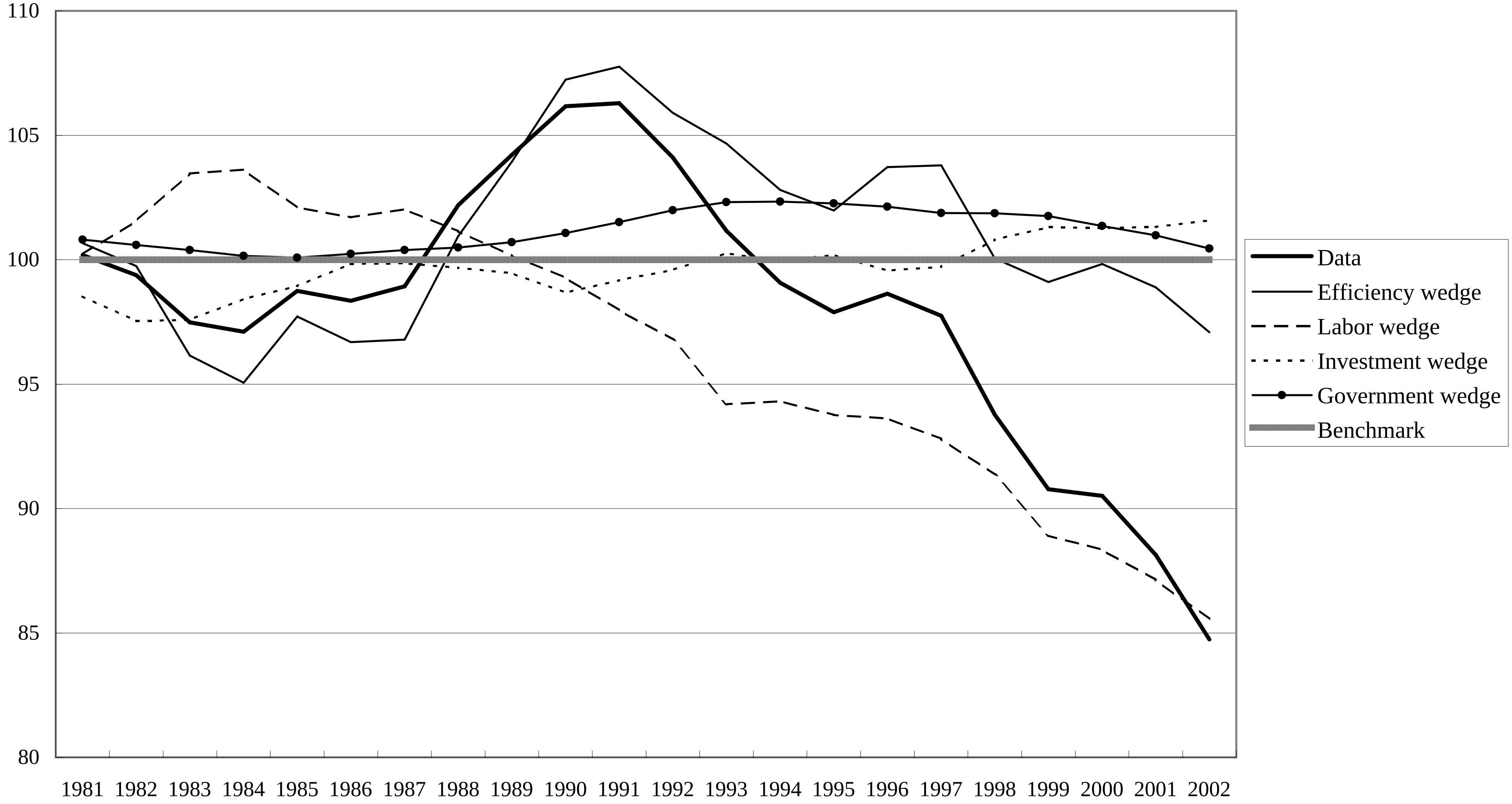


Figure 3. Combined effect of two and three wedges on output

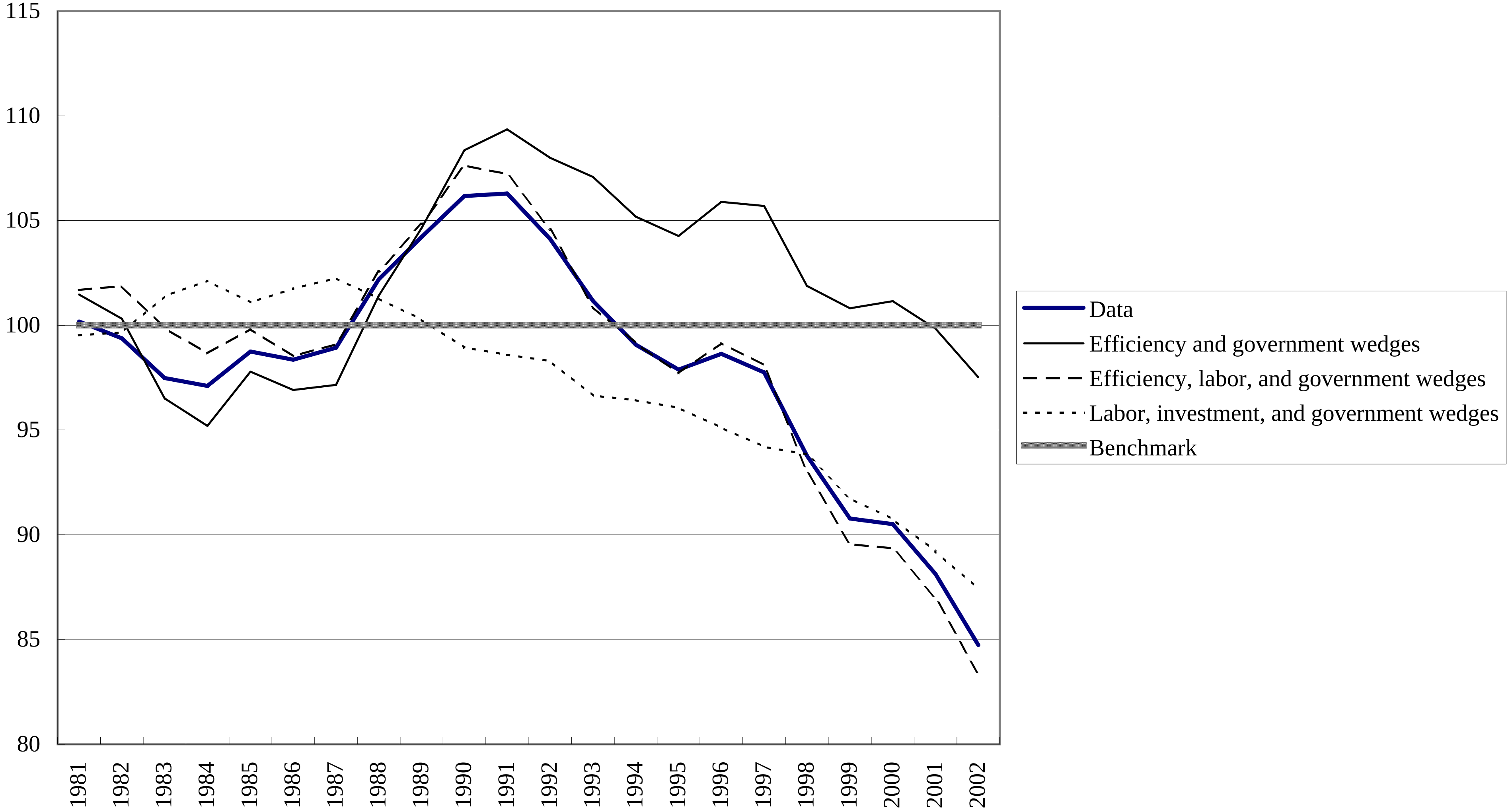
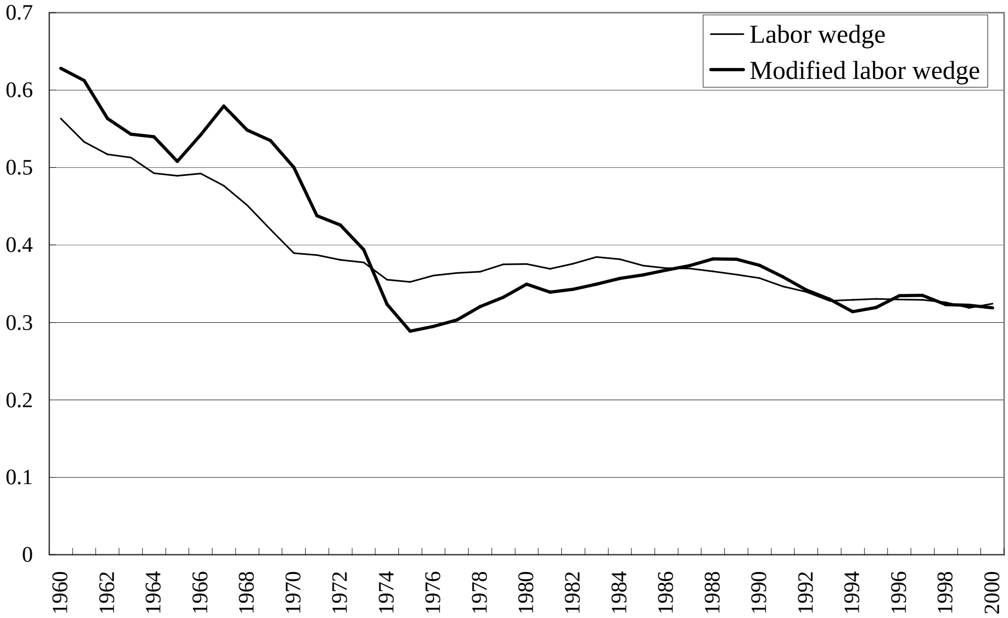


Figure 4. The modified labor wedge

Labor wedges measured from data of 1968 SNA



Labor wedges measured from data of 1993 SNA

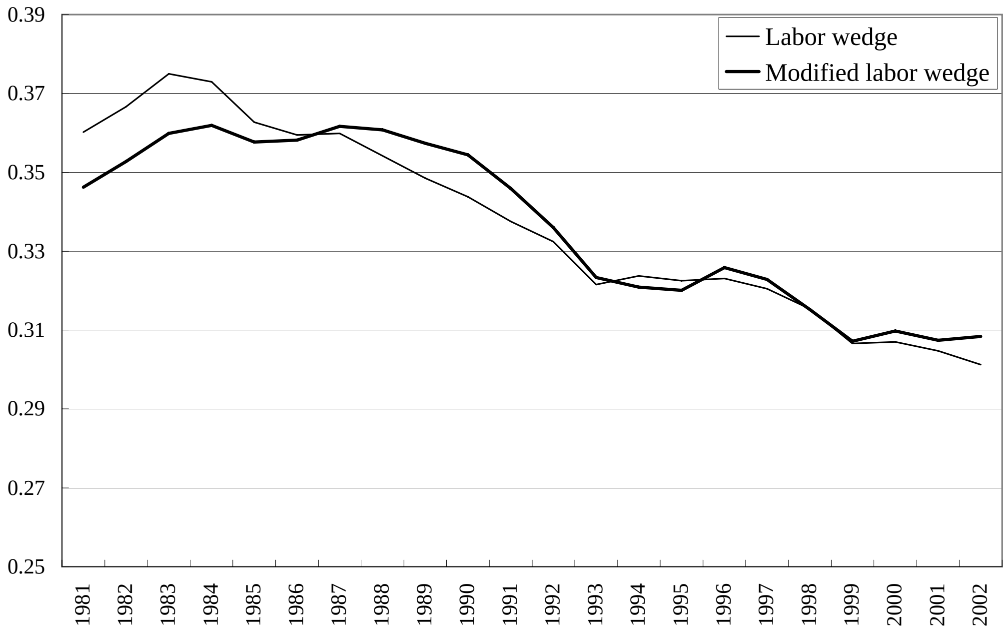


Figure 5. Output decomposition with variable labor share

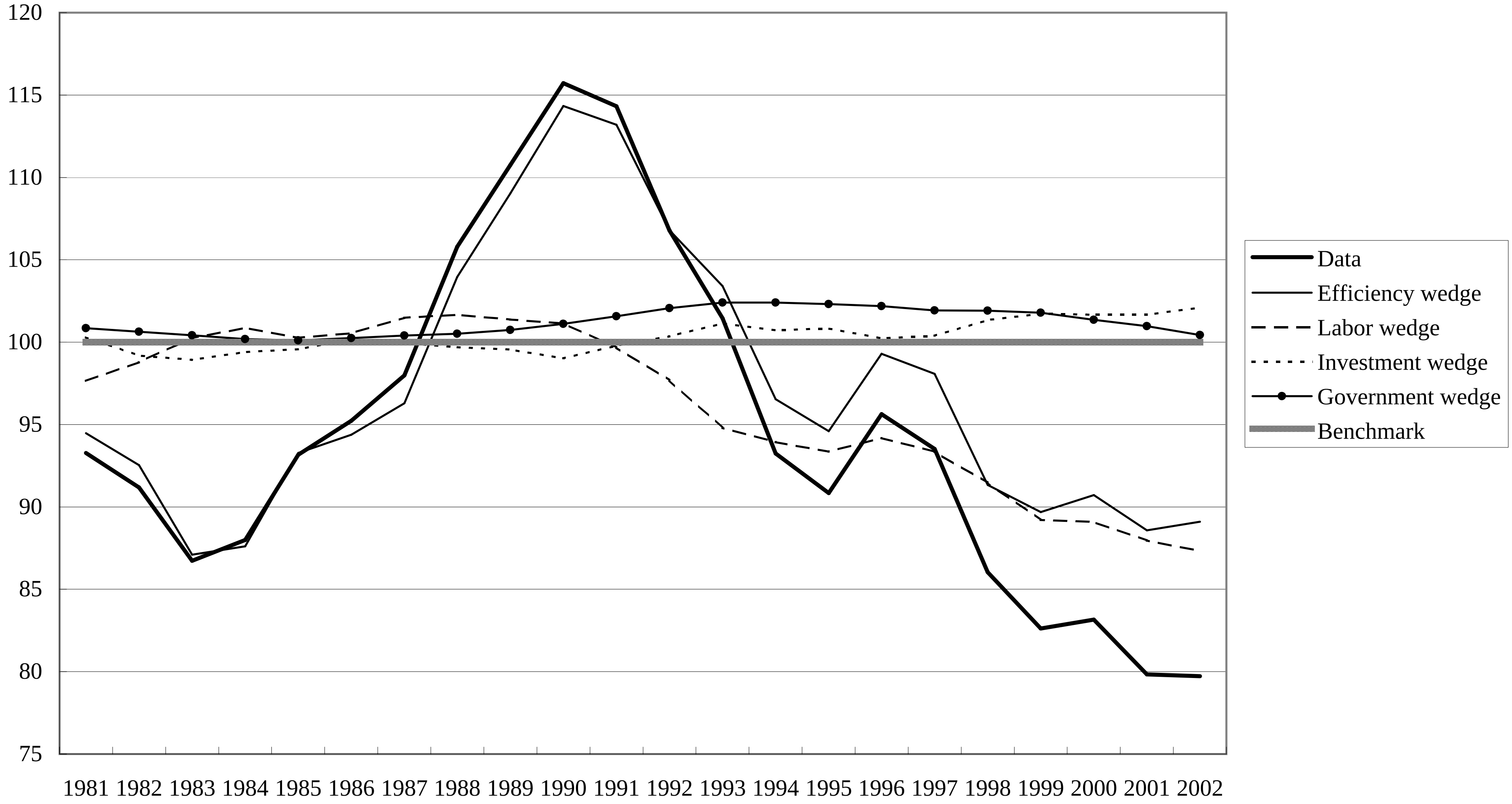


Figure 6. Combined effect of two or three wedges in the case of variable labor share

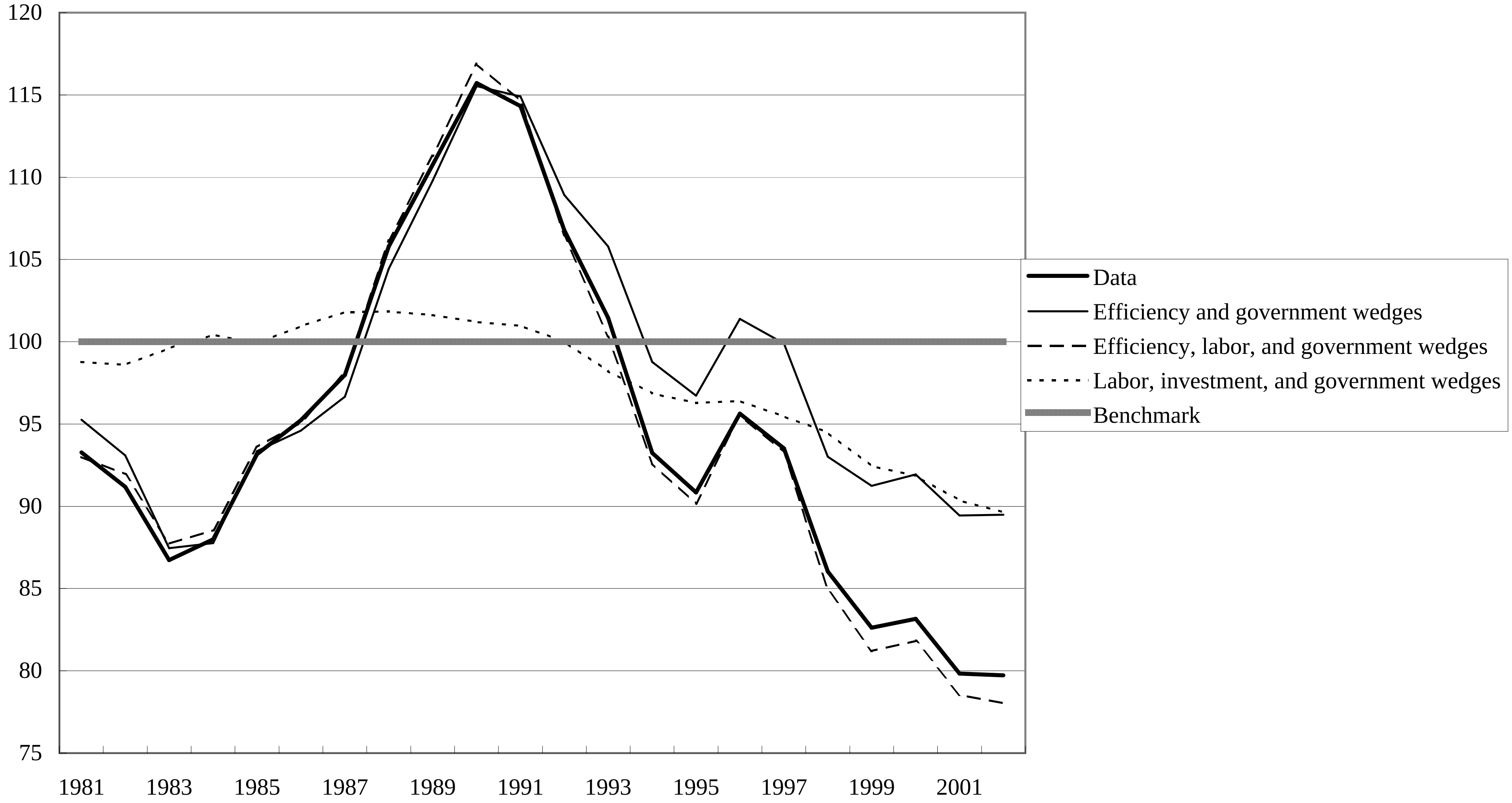
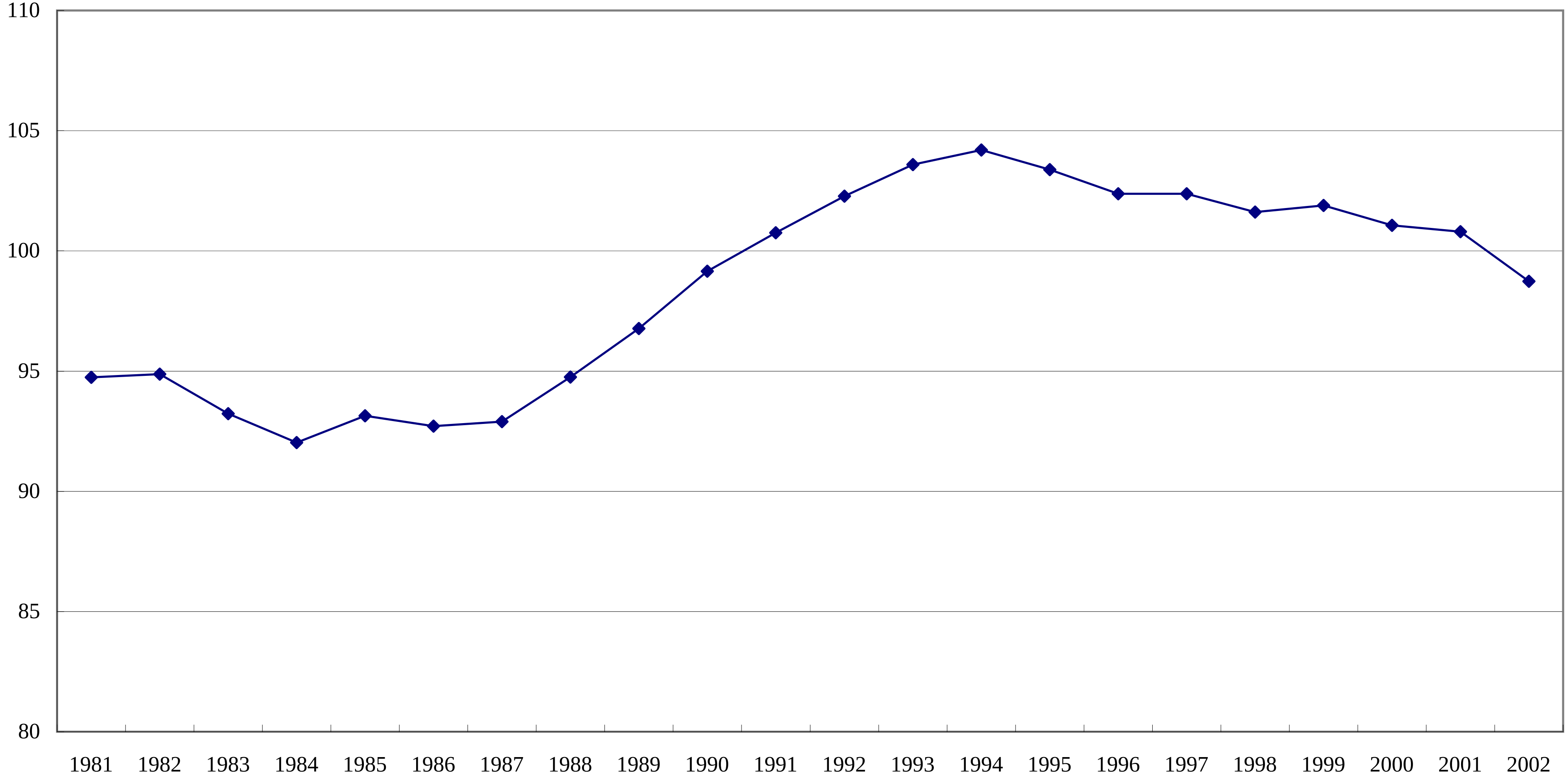
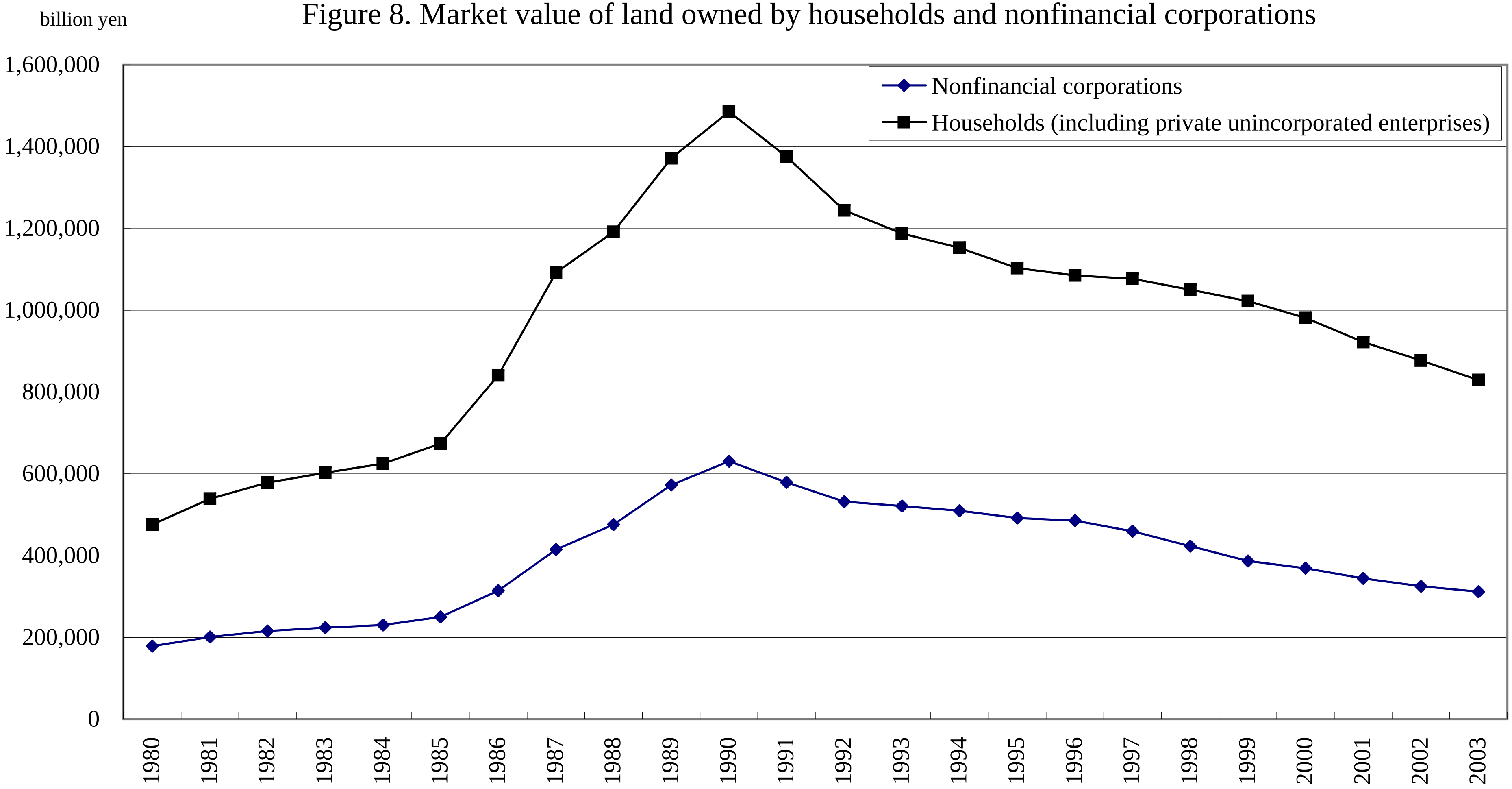


Figure 7. Real wage in Japan (detrended).



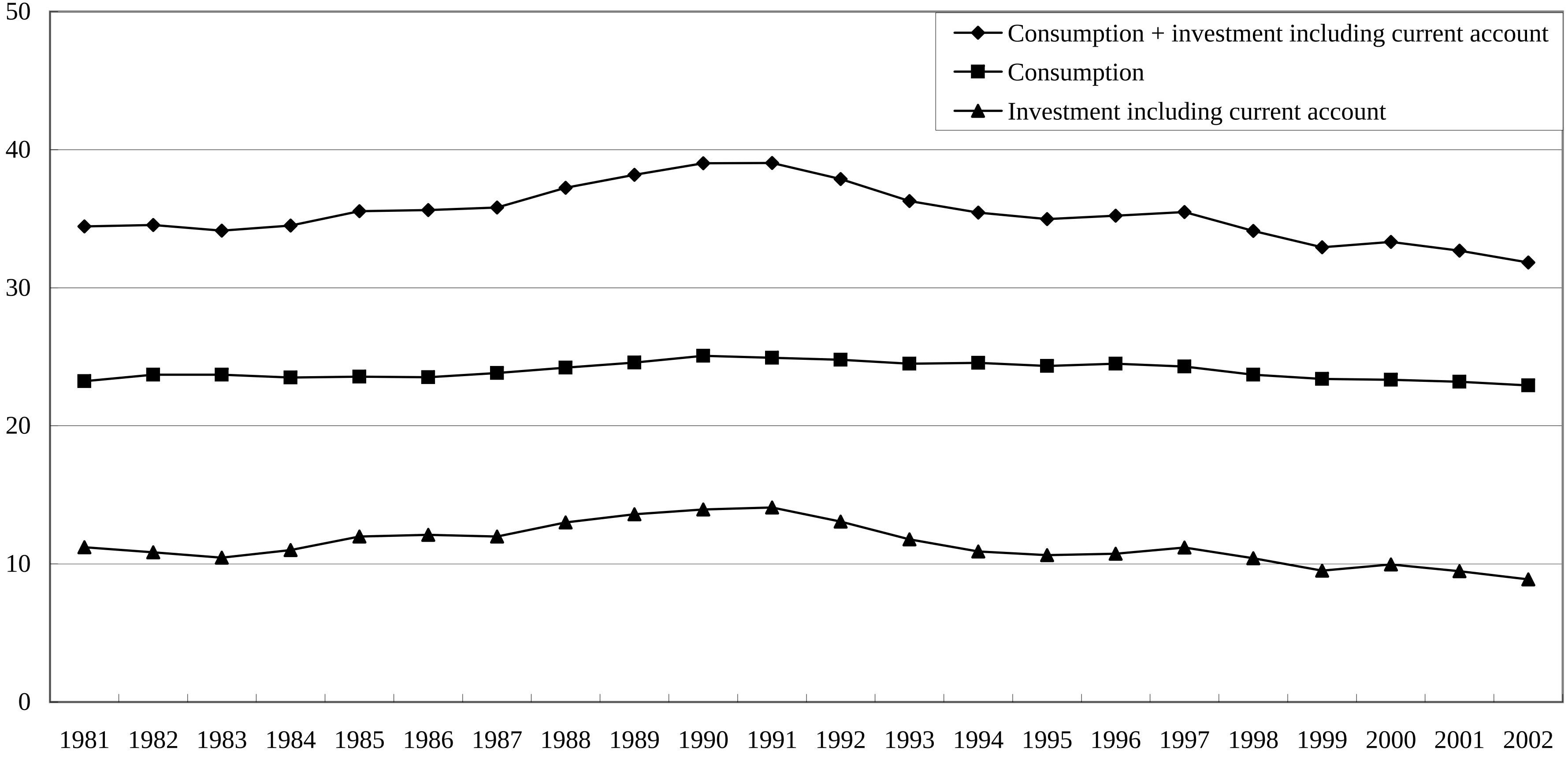
Note: Real wage is detrended by 2.1 percent per year, the average TFP growth rate from 1981 to 2002.

Figure 8. Market value of land owned by households and nonfinancial corporations



Source: Annual Report on National Accounts of 2005, Economic and Social Research Institute, Cabinet Office, Government of Japan .

Figure 9. Private consumption and investment (detrended)



Note: Both data are detrended by 2.1 percent per year, the average TFP growth rate from 1981 to 2002.

Figure 10. Output and the four measured wedges in the 1920s

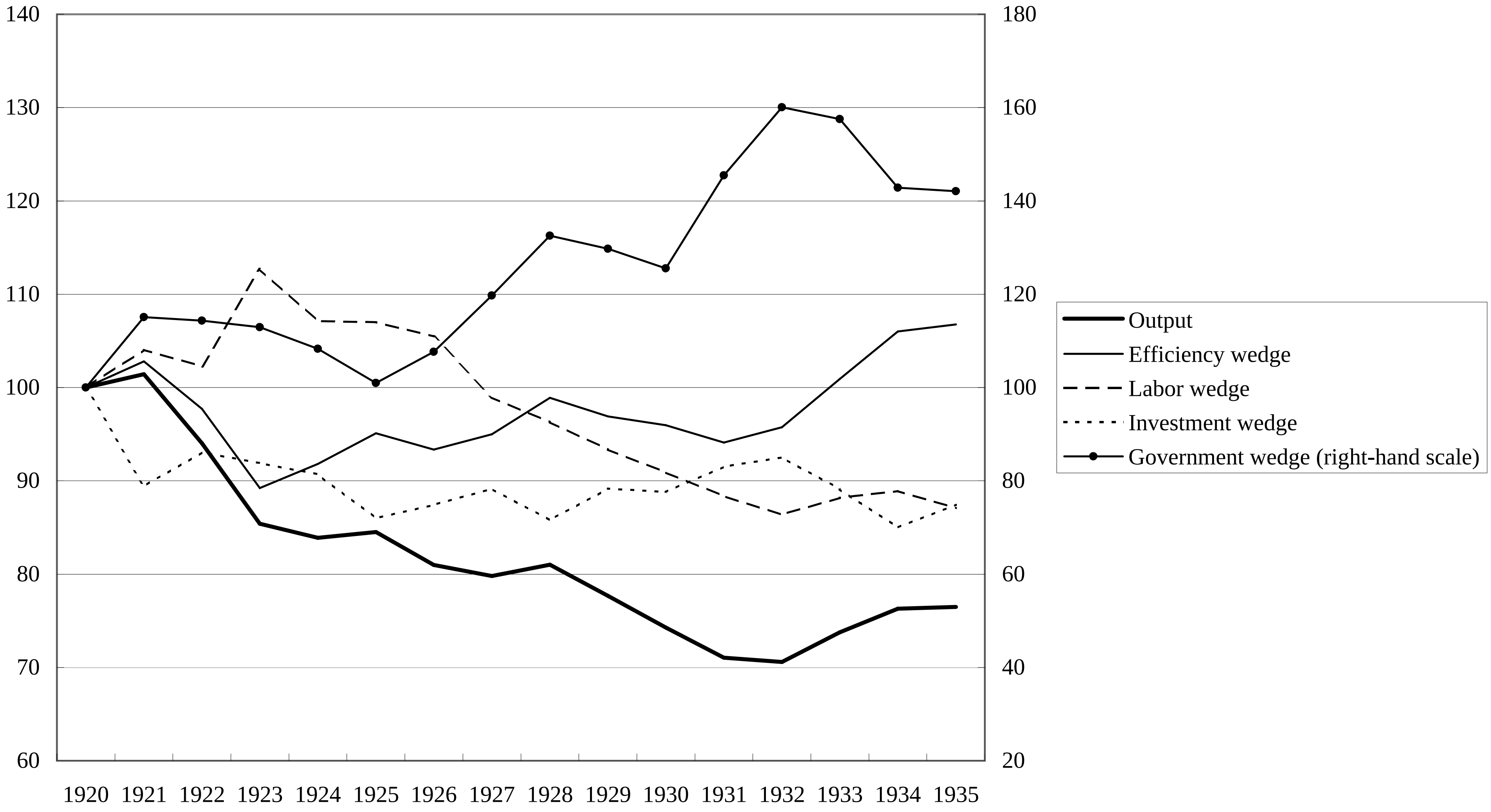


Figure 11. Decomposition of output with just one wedge

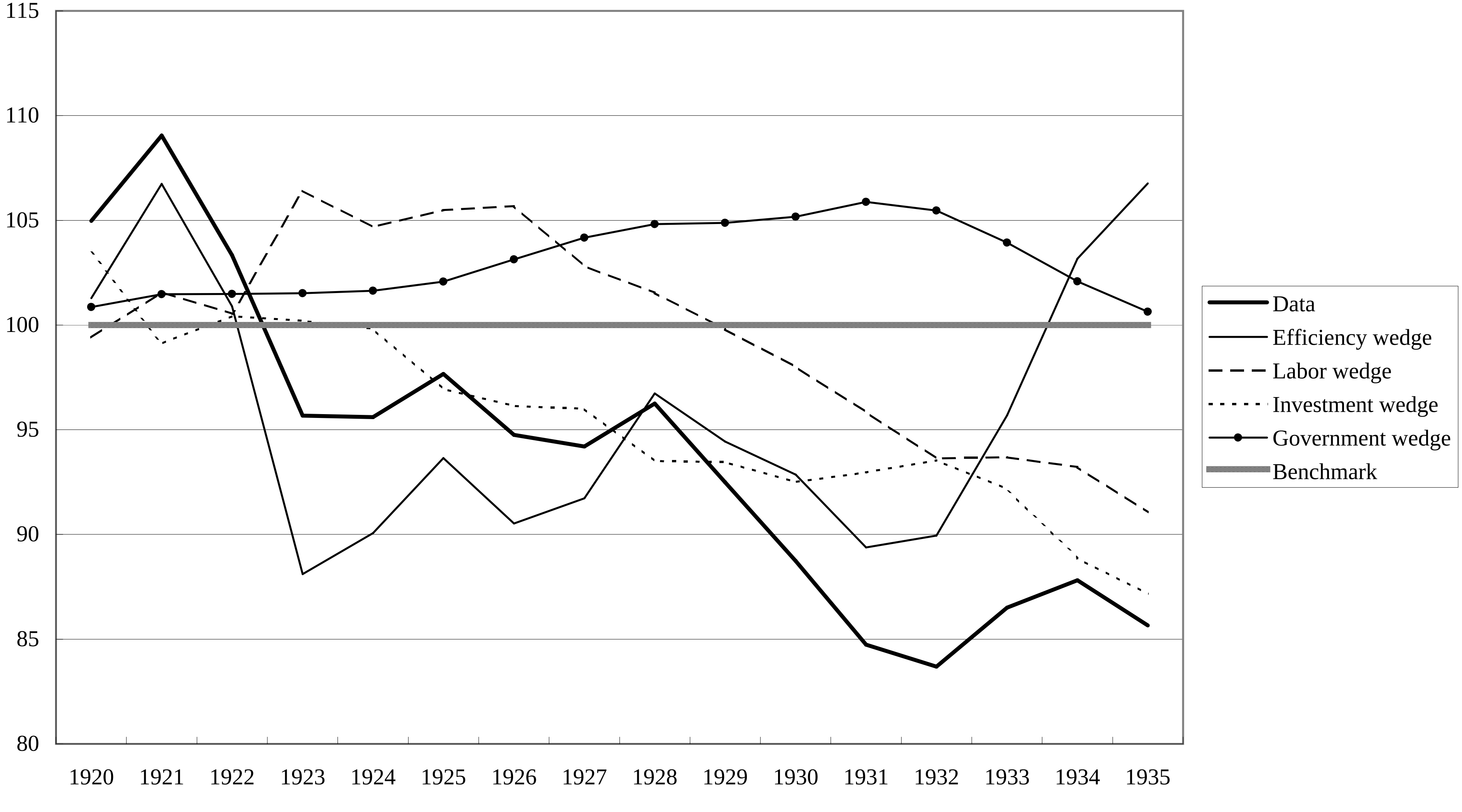
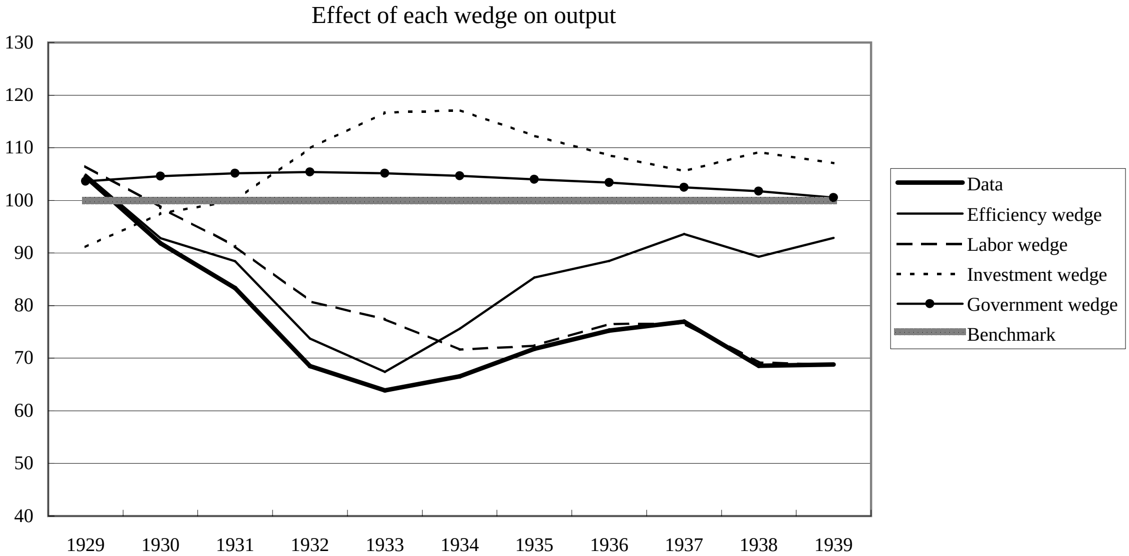


Figure 12. Decomposition with the investment wedge: Output in the Great Depression



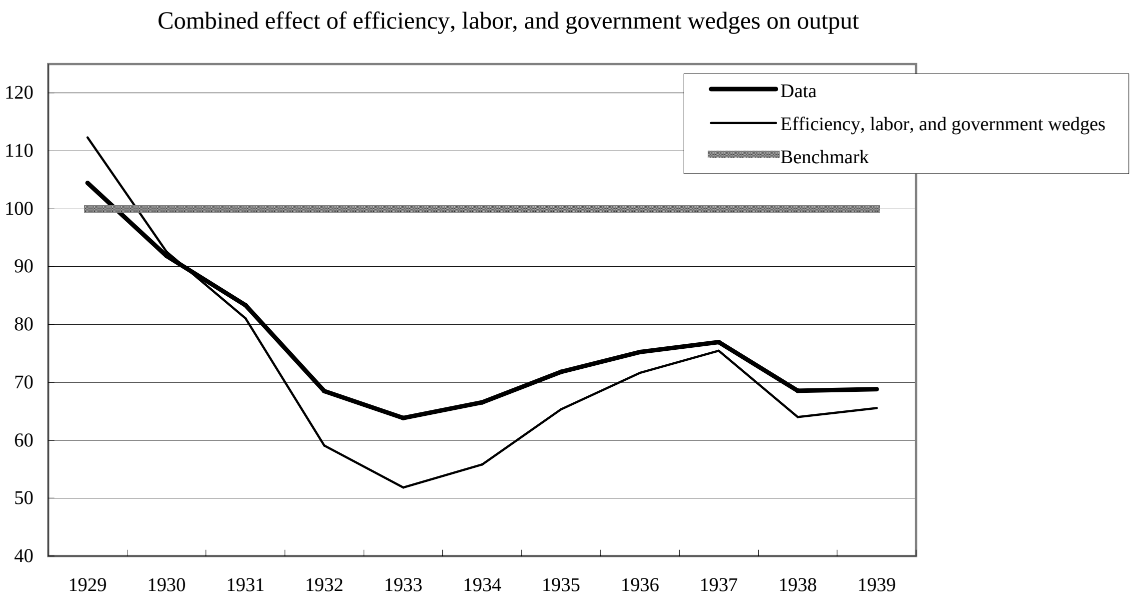
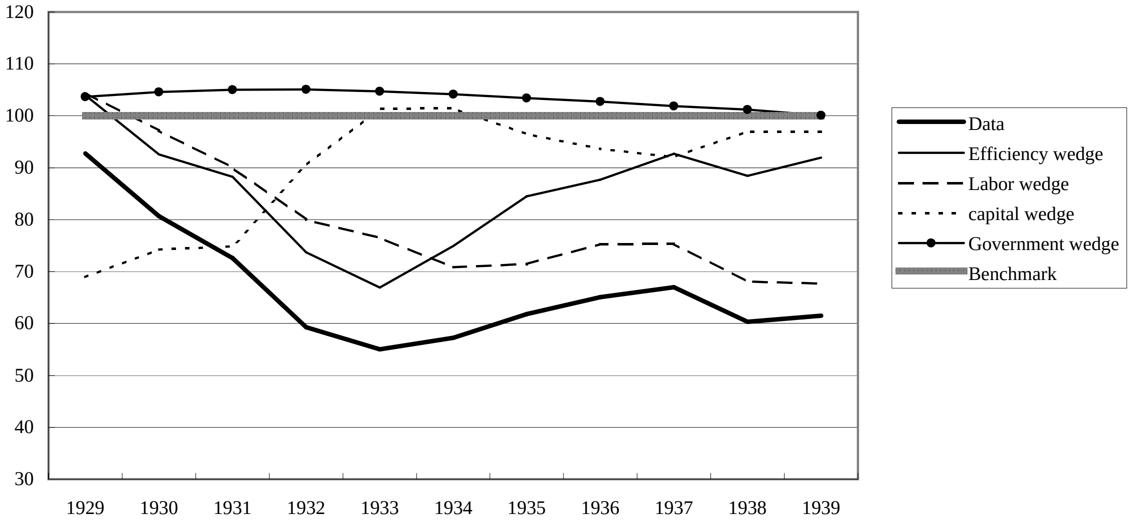


Figure 13. Decomposition with the capital wedge: Output in the Great Depression

Effect of each wedge on output



Combined effect of efficiency, labor, and government wedges on output