Business Cycle Accounting for the Japanese economy*

Keiichiro Kobayashi† and Masaru Inaba‡

May 30, 2005

Abstract

We conducted the business cycle accounting (BCA) developed by Chari, Kehoe, and McGrattan (2002a) on data from the 1990s in Japan and from the interwar period in Japan and the United States. The contribution of this paper is two-fold. First, we find several interesting implications from the accounting for Japan, e.g., labor distortions may have been a major contributor to the decade-long recession in the 1990s in Japan. 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. We show that a model with financial frictions is equivalent to a prototype growth model with the capital wedge. The accounting results with the capital wedge imply that financial frictions might have had a large depressing effect during the 1930s in the United States. This implication is opposite to that from the original BCA findings.

Keywords: Business cycle accounting; 1990s in Japan; 1920s in Japan; capital wedge; Great Depression.

JEL Classifications: E32; E37; O47.

*The views expressed herein are those of the author and not necessarily those of the Research Institute of Economy, Trade and Industry.

†The Research Institute of Economy, Trade and Industry. E-mail: kobayashi-keiichiro@rieti.go.jp

‡University of Tokyo

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 are 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 give 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 problems, 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 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 with 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.

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 check whether different versions of BCA produce different implications for the role of financial frictions using the data from the 1990s in Japan and the Great Depression in the United States. The accounting results show that the capital wedge might have had a depressing economic effect in both cases. This result is opposite to 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 and slightly negative effects in the recent recession in Japan, and that models with financial frictions may capture an important aspect of reality. It may also be said that this finding casts doubt on the robustness of the implications concerning financial frictions of the current version of BCA.

This paper is not the first one to apply the BCA method to the 1990s in Japan. 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 depressing effect. The difference seems, however, to be largely due to a difference in the start year of the accounting exercise: Chakraborty sets the start year at 1980 and we set it at 1990. Her result seems to imply that the investment wedge had a large expansionary effect in the 1980s in Japan.

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 1990s and the 1920s in Japan. Section 4 describes the new method of BCA with the capital wedge and presents the the results of the new BCA for the 1990s in Japan and 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

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

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 trend of technical progress, which is assumed to grow at a constant rate. 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 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 fraction 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 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 average 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 see 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 in 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.

The similar method is used to see 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]

3 BCA for Japan: The 1990s and the 1920s

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 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. After that a persistent recession together with deflation continued, and it lead to nationwide bank panics in 1997–99. The deflation still 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 it lead to the first nationwide bank panics in Japanese history in 1927. A deflationary policy in 1929–1931 aimed at

[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 in this method. In conducting BCA for business fluctuations in one decade, it may not be plausible to assume that people will believe that wedges 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}.

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 startling recovery, which is said to have been enabled by the expansionary fiscal and monetary policies introduced in 1932.

3.1 The 1990s

The target period of our first accounting exercise is 1990–2002. 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 constructed the other parameter values following the same procedure as Hayashi and Prescott: $\alpha = 0.372$, $\delta = 0.0846$, $g_n = 0$, and $g_z = 0.01347$, where g_n is the population growth rate for $t \geq 2003$, and $(1 + g_z)^{1-\alpha} = \gamma$. The trend of technical progress $(1 + g_z)$ was set as the average during 1990–2002.

In Figure 1 we display the actual data for output (detrended by $1 + g_z$) and the four measured wedges for 1990–2002: 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 as indices set at 100 in 1990.

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

The detrended output declined in 1992–95, recovered in 1996 and 1997, but fell again during the financial crisis of 1998–99. During the target period the government and investment wedges improved from the values of 1990, while the labor wedge became significantly worse. The efficiency wedge fell slightly during the early 1990s but improved in and after 1996. This finding that productivity improved in the latter half of the 1990s is consistent with those by Jorgenson and Motohashi (2003) and Kawamoto (2004).

The decomposition results for output, consumption, labor, and investment are shown in Figures 2–5. In our decomposition exercise for the 1990s, we assumed the values of the benchmark wedges as follows: The benchmark efficiency wedge is A_0, which is the value at 1990; and τ_l, τ_x, and (g/y) are the averages of the 1984–89 period.

In these figures, we display the separate contributions of each wedge. In Figure 2, 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 concerned had a depressing (expanding) effect on output. The same method was used for consumption, labor, and investment in Figures 3–5. There are interesting features in Figure 2. First, both the government and the investment wedges had an expanding effect on the economy almost throughout the period. 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 the fiscal policy during that period.

The result for the investment wedge also runs contrary to the conventional view that the persistent recession was caused by investment frictions associated with the nonperforming loan problem. This is 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]).

Both the efficiency and the labor wedges had depressing effects on output. The output due to the efficiency wedge exhibits a milder recession than the actual data, while the output due to the labor wedge closely replicates the actual output.

In Figure 6, we show the combined effects of two and three wedges 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, setting τ_{xt} and τ_{lt} at zero. 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 6 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 account data of the 1968 standard (1968 SNA [System of National Accounts]), while we used that 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 becomes 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 these two wedges were zero. 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.

Our decomposition results seem to imply that any theory attempting to explain the 1990s in Japan needs to account for the negative effect of the labor wedge, in addition to the declines in productivity.

Figures 2–5. Decomposition results with just one wedge

Figure 6. Combined effect of two and three wedges on output

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 7. Output went down throughout the 1920s and picked up after Japan left the gold standard again in December 1931.[2] The efficiency wedge remained under its initial value throughout the 1920s but rapidly recovered after 1932. The government wedge was above its initial value throughout the target period and increased remarkably when Japan

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

embarked on a military venture in China in 1931. The behavior of the investment wedge in this period was quite different from that in the 1990s. Although in both periods the Japanese economy suffered from nonperforming loans and banking crises, the investment wedge worsened in the 1920s and improved in the 1990s.[3] The labor wedge stayed high in the early 1920s but fell under the initial value in the late 1920s. Noticeable is that both the labor and the investment wedges did not recover 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 7. Output and the four measured wedges in the 1920s

The decomposition result for output is shown in Figure 8. (The decomposition results for consumption, labor, and investment are not reported in this paper, but can be obtained from the authors upon request.) 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 in the 1920s, while the labor wedge joined the negative contributors at the end of the 1920s. The government wedge worked to lift the economy up 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 became larger and the positive effects of the government wedge became smaller in this recovery period.

One theoretical challenge that this decomposition result raises is why the abandonment of the 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 8. Decomposition of output with just one wedge

[3]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 blancket 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, instead of aninvestment 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." In this section, however, we show that the implications from an accounting exercise in which BCA is conducted with the capital wedge are quite different from the original BCA.

4.1 Equivalence result

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

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

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 production function (3), and the first-order conditions (4) and

$$U_{ct} = \beta U_{ct+1}\{(1-\tau_{kt+1})A_{t+1}\gamma^{t+1}F_{kt+1} + 1 - \delta + \delta\tau_{kt+1}\}. \tag{7}$$

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).[4]

[4]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^*.

To confirm that BCA with the capital wedge is useful to judge the plausibility of a variety of business cycle models with financial frictions, we establish the following equivalence result. Carlstrom and Fuerst (1998) propose a model with financial frictions. We call this the "CF output model." In it, total output, not only investment, is subject to financial friction of the sort that is modeled by Carlstrom and Fuerst (1997) as investment friction. The equilibrium of the CF output model is characterized by the following equations:

$$
\begin{aligned}
&\tfrac{U_{lt}}{U_{ct}} = \tfrac{1}{p_t}\theta_t F_{lt}, \\
&U_{ct} = E_t \beta U_{ct+1}\{\tfrac{1}{p_{t+1}}\theta_{t+1}F_{kt+1} + 1 - \delta\}, \\
&c_t + e_t + x_t = \theta_t F(k_t, l_t)\{1 - \Psi(\overline{\omega}_t)\mu\}, \\
&k_{t+1} = (1-\delta)k_t + x_t,
\end{aligned}
$$

where θ_t is exogenously given productivity, p_t is an endogenous mark-up, e_t is consumption by entrepreneurs, $\overline{\omega}_t$ is an endogenous cut-off value of debt repayment, and μ is an exogenous parameter for the monitoring cost. There are also equations that determine endogenous variables (see Carlstrom and Fuerst [1998] for details). A proposition similar to Proposition 6 in Chari et al. (2004) is derived directly from the above equations.

Proposition 1 *Consider the prototype economy with* $N_t = 1$, $A_t\gamma^t = \theta_t\{1-\Psi(\overline{\omega}_t)\mu\}$, $1-\tau_{lt} = \frac{1}{(1-\Psi(\overline{\omega}_t)\mu)p_t}$, $1-\tau_{kt} = \frac{\theta_t F_{kt} + \delta p_t}{\{1-\Psi(\overline{\omega}_t)\mu\}p_t\theta_t F_{kt} - \delta p_t}$, *and* $g_t = e_t$. *The aggregate equilibrium allocations for this prototype economy coincide with those of the CF output model.*

In this proposition, we are measuring aggregate consumption by $c_t + e_t$ in the CF output model and by $c_t + g_t$ in the associated prototype economy. This proposition implies that a model economy with financial frictions modeled by Carlstrom and Fuerst (1997, 1998) is equivalent to a version of the prototype growth model with the capital wedge.

4.2 Accounting results

We conducted BCA with the capital wedge on the 1990–2002 period in Japan and on the 1929–1939 period in the United States. The data sources are shown in the Appendix. Figure 9 shows the decomposition result for output in the 1990s in Japan. We see that the capital wedge has a small depressing effect on the economy almost throughout the target period. This result is in contrast with the result of the original BCA, in which the investment wedge had an expansionary effect on the economy. We surmise that a part of the negative effect of the efficiency wedge (and the positive effect of the investment wedge) in the original BCA may be attributed to the capital wedge.

Figure 9. Decomposition with the capital wedge: Output in the 1990s in Japan

The same result turned up in the accounting exercise for the Great Depression. Figures 10 and 11 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 10, and those with the capital wedge are shown in Figure 11.

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 over 1923–28: $\delta = 0.0267$, $g_n = 0.0188$, and $g_z = 0.0233$. The values of the benchmark wedges were also set as the averages over 1923–28, except for the benchmark efficiency, which was set as the initial value at 1929. The data sources are shown in the Appendix.

In calculating the decomposition results, we imposed the nonnegativity condition for investment: $x_t \geq 0$. Otherwise, x_t takes a negative value at some times in some cases.[5]

The upper panel of Figure 10 shows the output due to one wedge and the lower panel shows the combined effect of the efficiency, labor, and government wedges. The upper and lower panels of Figure 11 show the corresponding results for BCA with the capital wedge. Figure 10 indicates that almost throughout the period, the investment wedge had a considerable expansionary effect on the economy, while Figure 11 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. This 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

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

of the Great Depression. Our result for BCA with the capital wedge is opposed to their conclusion. The lower panel of Figure 11 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, just as in the case for Japan, a part of the output movement that is attributed to the efficiency wedge in the original BCA seems to be attributed to the negative effect of the capital wedge.

Figure 10. Decomposition with the investment wedge: Output in the Great Depression

Figure 11. Decomposition with the capital wedge: Output in the Great Depression

Therefore, 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 might have had a depressing effect on the economy, especially in the case of the Great Depression in the United States. The guidance to theoretical researchers is different too: The original BCA implies that models with financial friction of the sort developed by Carlstrom and Fuerst (1997, 1998) are not promising as explanations for the Great Depression or the lost decade of Japan, while the new BCA implies that financial friction models may reflect some important aspects of those episodes.

5 Concluding remarks

We conducted business cycle accounting on data from the 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 subsume market distortions which manifest themselves as the labor wedge.

Our accounting results for the other deflationary episode in Japan, the 1920s, raise another theoretical challenge. The Japanese economy experienced a spectacular recovery after Japan abandoned the gold standard. Since our results show that this recovery was solely due to the startling 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 lead to the rise in the efficiency wedge but not to improvement in the labor and the investment wedges.

We also conducted another BCA excercise, in which we introduced the capital wedge instead of the investment wedge. Our results show that the capital wedge had a small depressing effect in the 1990s in Japan and a large one 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 in either episode. This finding casts a doubt on the robustness of BCA implications concerning financial frictions, since the investment and capital wedges are regarded in the literature to represent the same kind of distortions in financial markets.

Reconciling the conflicting implications of the BCA investment wedge and capital wedge for financial frictions should be considered an important topic for future research.

6 Appendix

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

The 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 openly 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 from Table A-III of Kendrick (1961). The capital stock data are from Table A-XV of Kendrick (1961).

7 References

Andolfatto, D. (2003). "Monetary implications of the Hayashi-Prescott hypothesis for Japan." Bank of Japan *Monetary and Economic Studies* 21 (4): 1–20.

Bank of Japan (1966). *Meiji iko honpo shuyo keizai tokei* [Hundred-year statistics of the Japanese economy].

Bureau of the Census (1975). *Historical statistics of the United States, colonial times to 1970, bicentennial edition.* US Department of Commerce. Washington, DC: US Government Printing Office.

Carlstrom, C. T., and T. S. Fuerst (1997). "Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis." *American Economic Review* 87 (5): 893–910.

—- (1998). "Agency costs and business cycles." *Economic Theory* 12:583–97.

Chakraborty, S. (2004). "Accounting for the 'lost decade' in Japan." Mimeo. University of Minnesota.

Chari, V. V., P. J. Kehoe, and E. R. McGrattan (2002a). "Accounting for the Great Depression." *American Economic Review* 92 (2): 22–27.

—- (2002b). "Technical appendix: Accounting for the Great Depression." Federal Reserve Bank of Minneapolis Research Department Working Paper 619.

—- (2004). "Business cycle accounting." Federal Reserve Bank of Minneapolis Research Department Staff Report 328.

Hayami, Y. (1975). *A century of agricultural growth in Japan.* Tokyo: University of Tokyo Press.

Hayashi, F., and E. C. Prescott (2002). "The 1990s in Japan: A lost decade." *Review of Economic Dynamics* 5 (1): 206–35.

Jorgenson, D. W., and K. Motohashi (2003). "Economic growth of Japan and the United States in the Information Age," RIETI Discussion Paper 03-E-015, Research Institute of Economy, Trade and Industry.

Kawamoto, T. (2004). "What do the purified Solow residuals tell us about Japan's lost decade?" IMES Discussion Paper 2004-E-5, Bank of Japan.

Kendrick, J. (1961). *Productivity trends in the United States.* National Bureau of Economic Research General Series, no. 71. Princeton: Princeton University Press.

Kobayashi, K. and M. Inaba (2005). "Data Appendix: Business cycle accounting for the Japanese economy." mimeo.

Kydland, F. and E. C. Prescott (1982). "Time to build and aggregate fluctuations." *Econometrica*, 50 (6): 1345–70.

Minami, R., and A. Ono (1978). "Estimation of factor income and shares (Youso shotoku to bunpairitsu no suikei)," *Keizai Kenkyu* 29 (2): 143-69.

Mulligan, C. B. (2002). "A dual method of empirically evaluating dynamic competitive equilibrium models with market distortions, applied to the Great Depression and World War II." NBER Working Paper 8775.

Ohkawa, K., N. Takamatsu, and Y. Yamamoto (1974). *Estimates of long-term economic statistics of Japan since 1868: Vol. 1, National income.* Tokyo: Toyo Keizai Shinposha.

Ohkawa, K., S. Ishiwatari, S. Yamada, and H. Ishi (1966). *Estimates of long-term economic statistics of Japan since 1868: Vol. 3, Capital stock.* Tokyo: Toyo Keizai Shinposha.

Umemura, M., K. Akasaka, R. Minami, N. Takamatsu, K. Arai, and S. Ito (1988). *Estimates of long-term economic statistics of Japan since 1868: Vol. 2, Labor forces.* Tokyo: Toyo Keizai Shinposha.

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

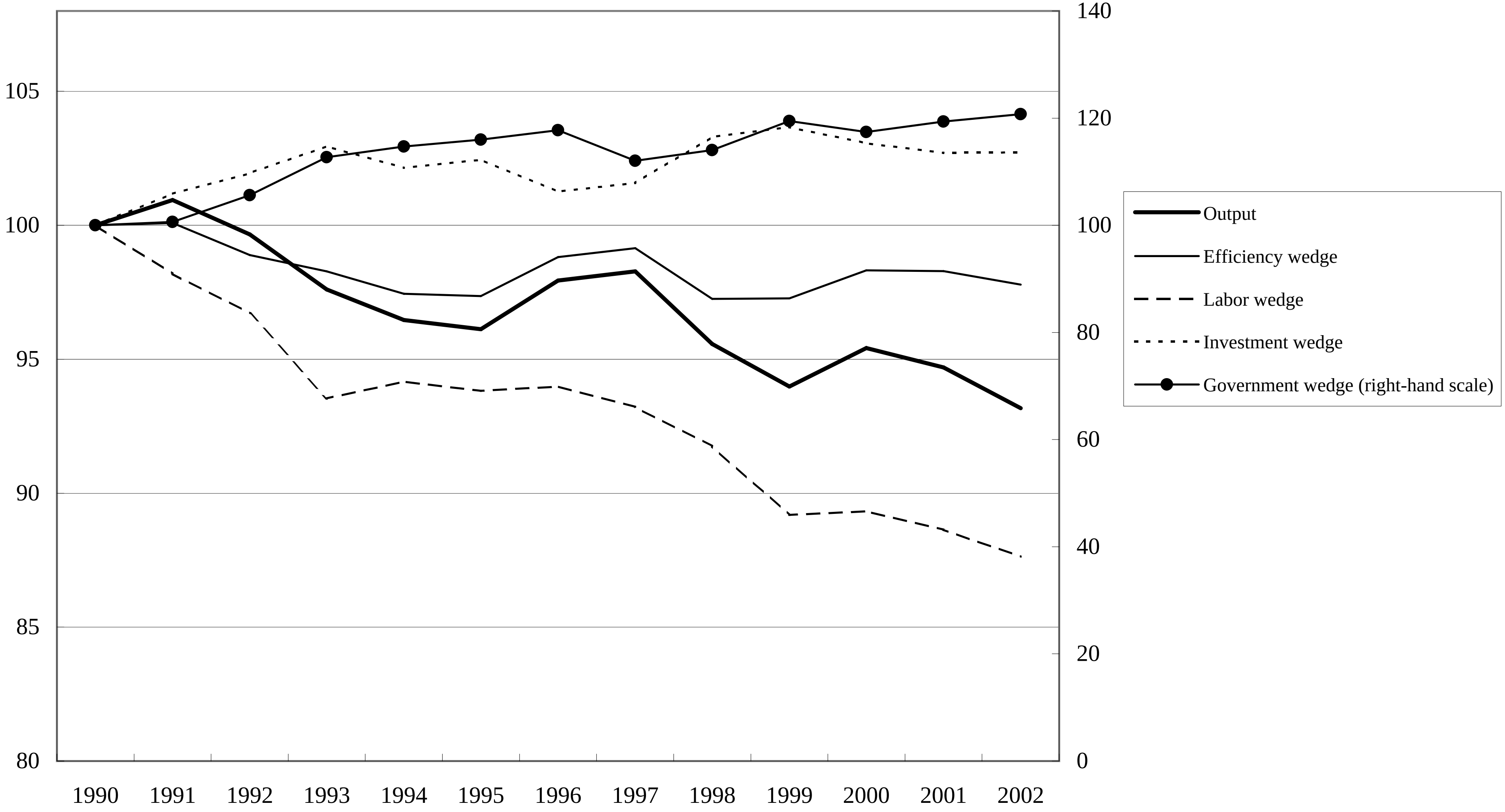


Figure 2. Decomposition result with just one wedge: Output

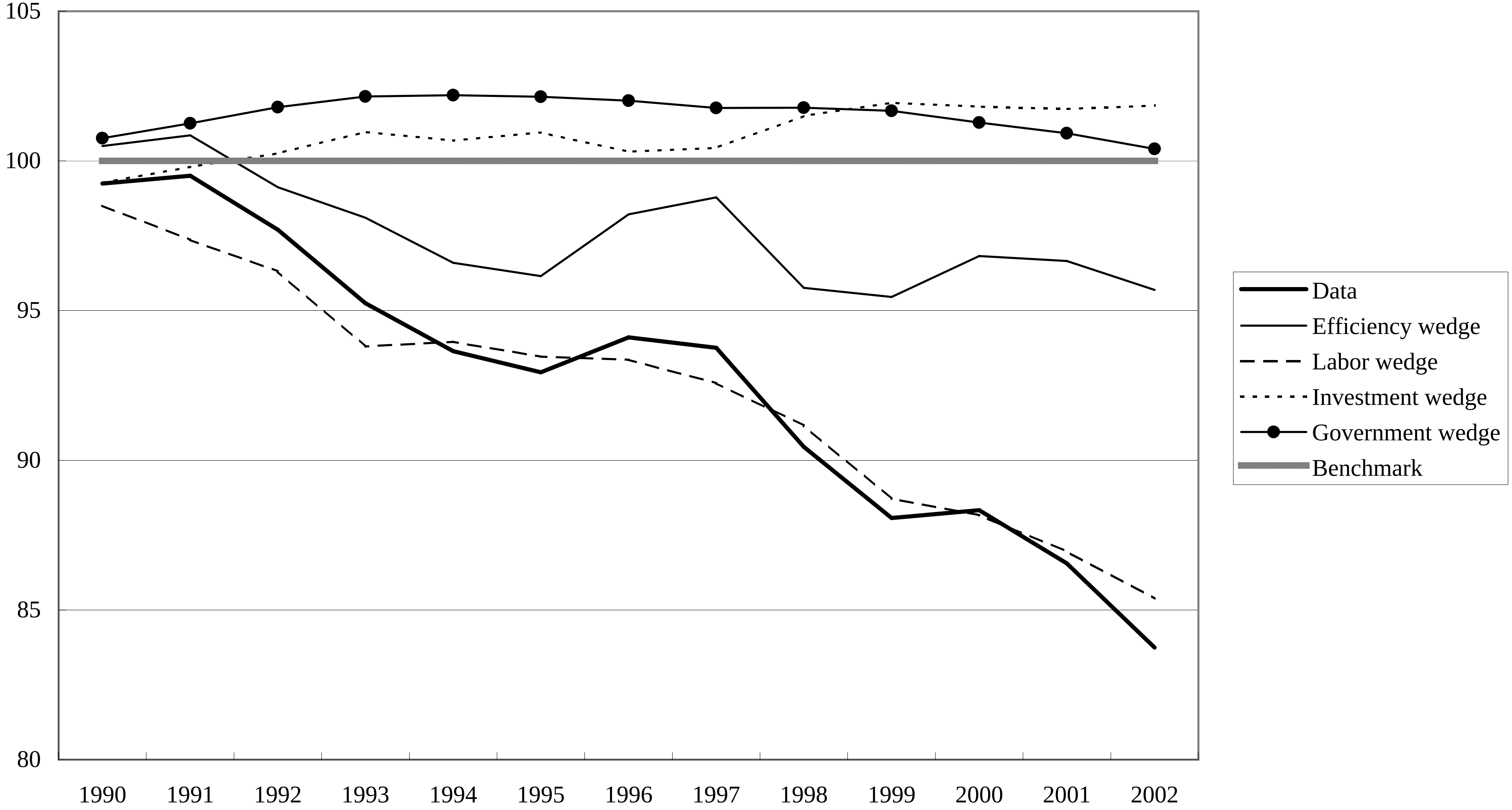


Figure 3. Decomposition result with just one wedge: Consumption

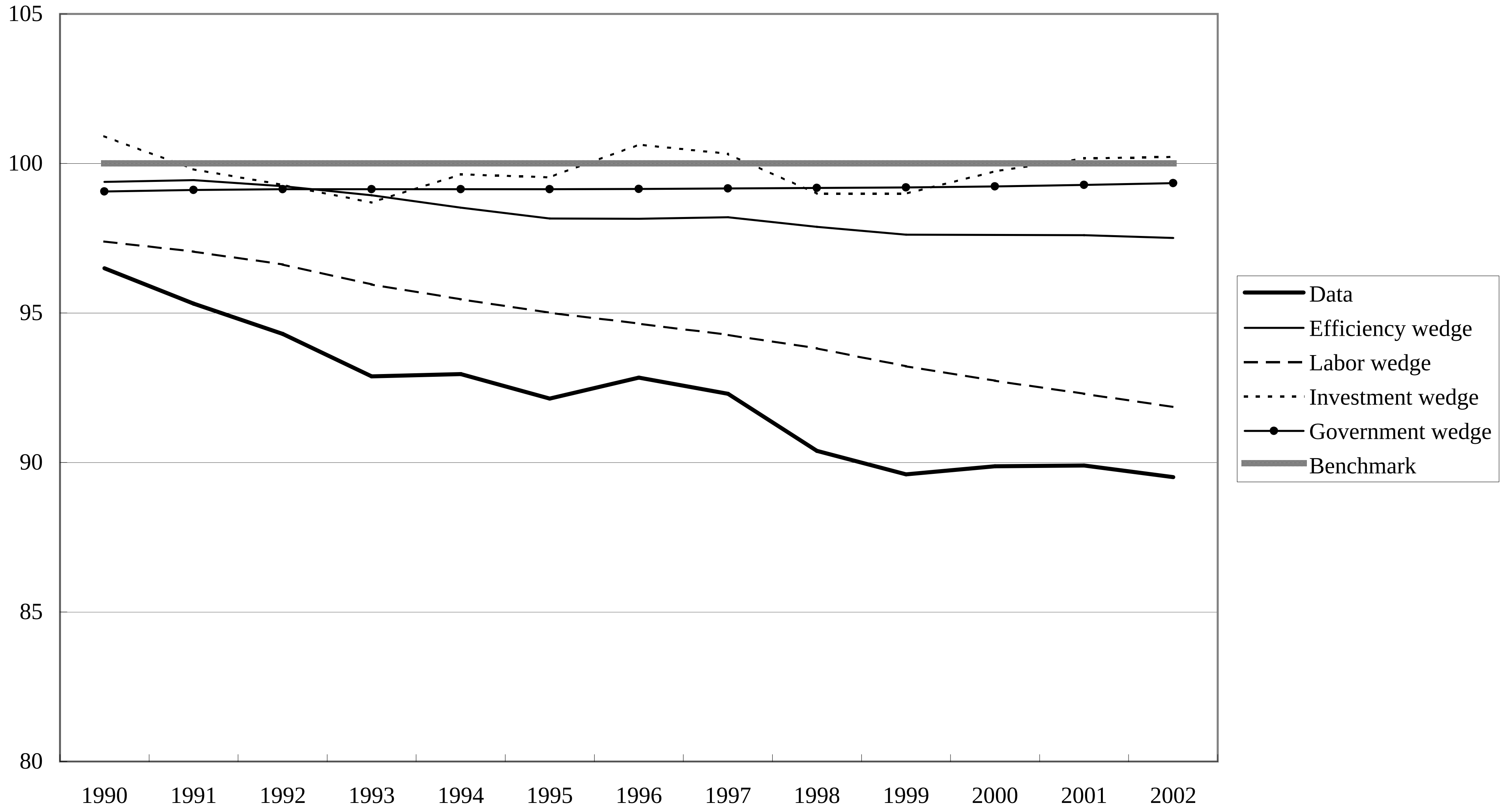


Figure 4. Decomposition result with just one wedge: Labor

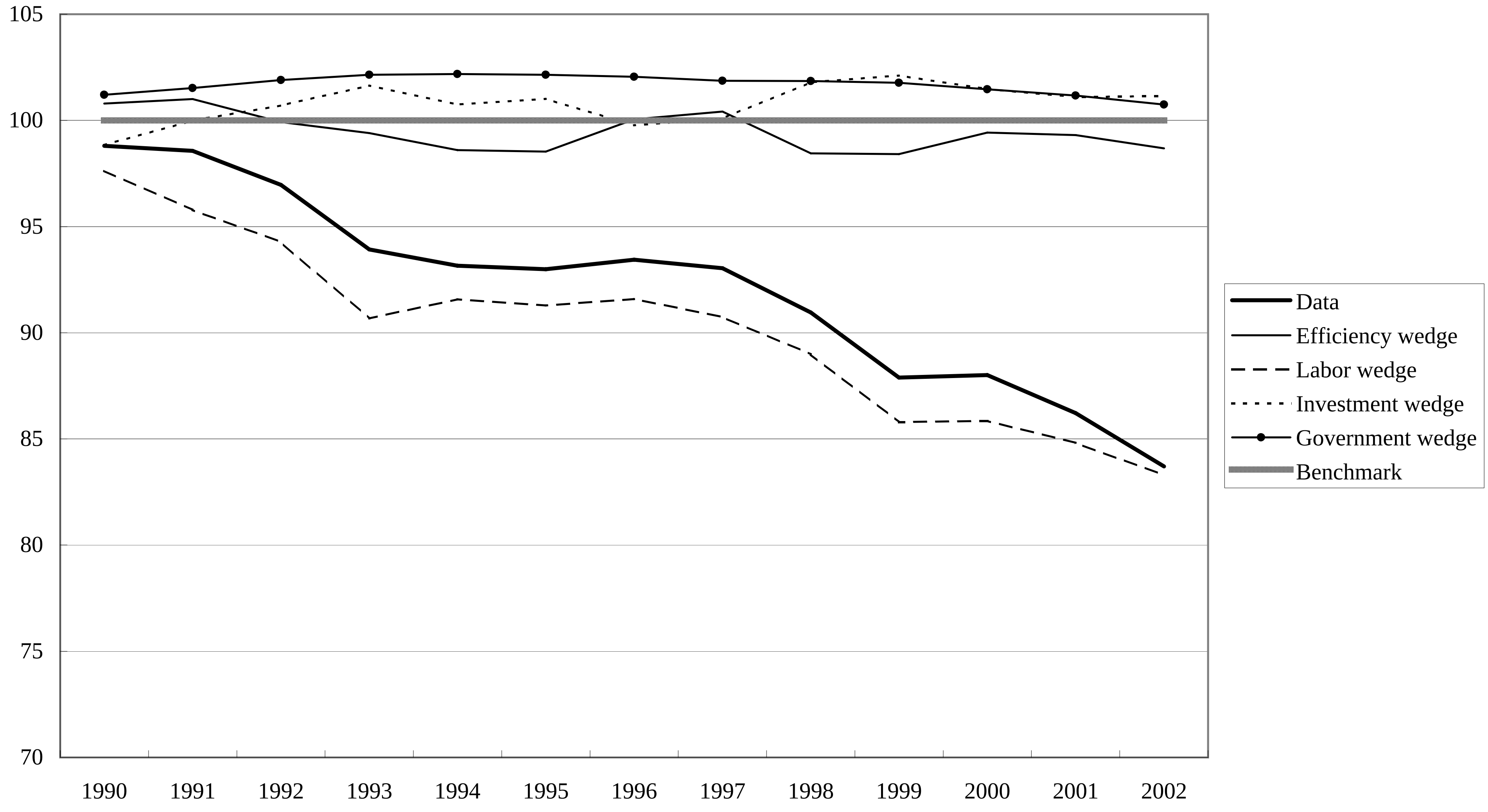


Figure 5. Decomposition result with just one wedge: Investment

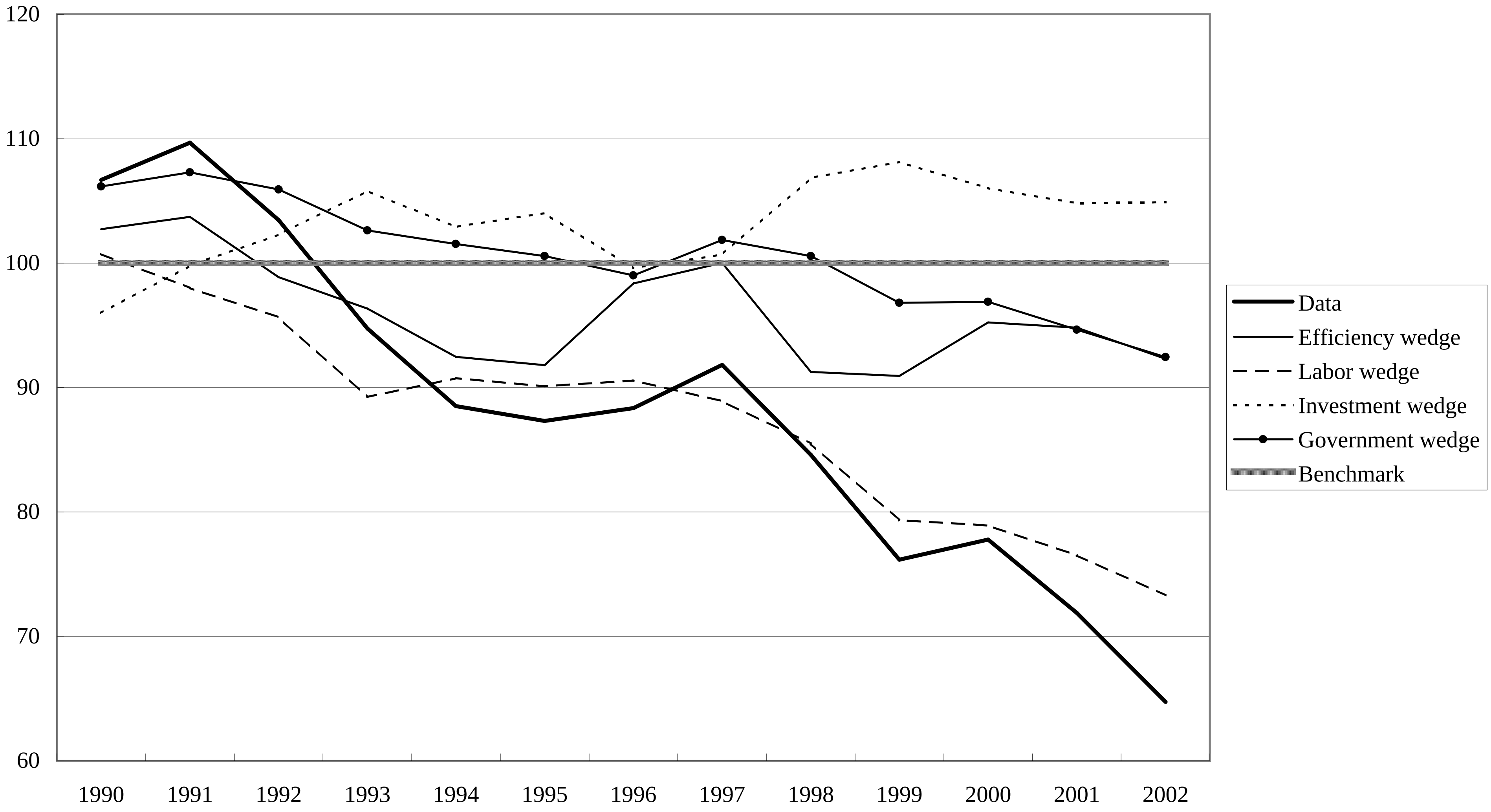


Figure 6. Combined effect of two and three wedges on output

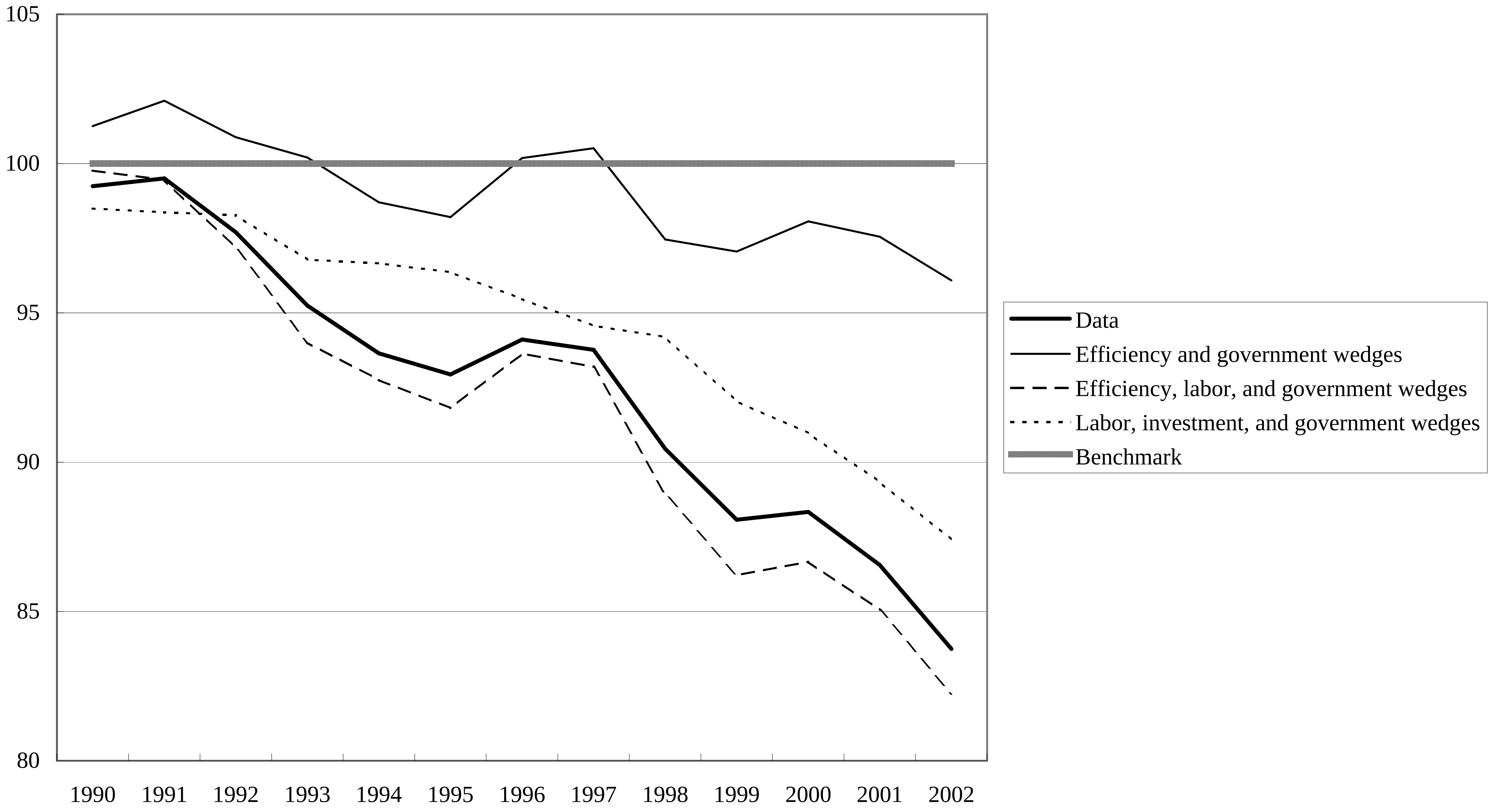


Figure 7. Output and the four measured wedges in the 1920s

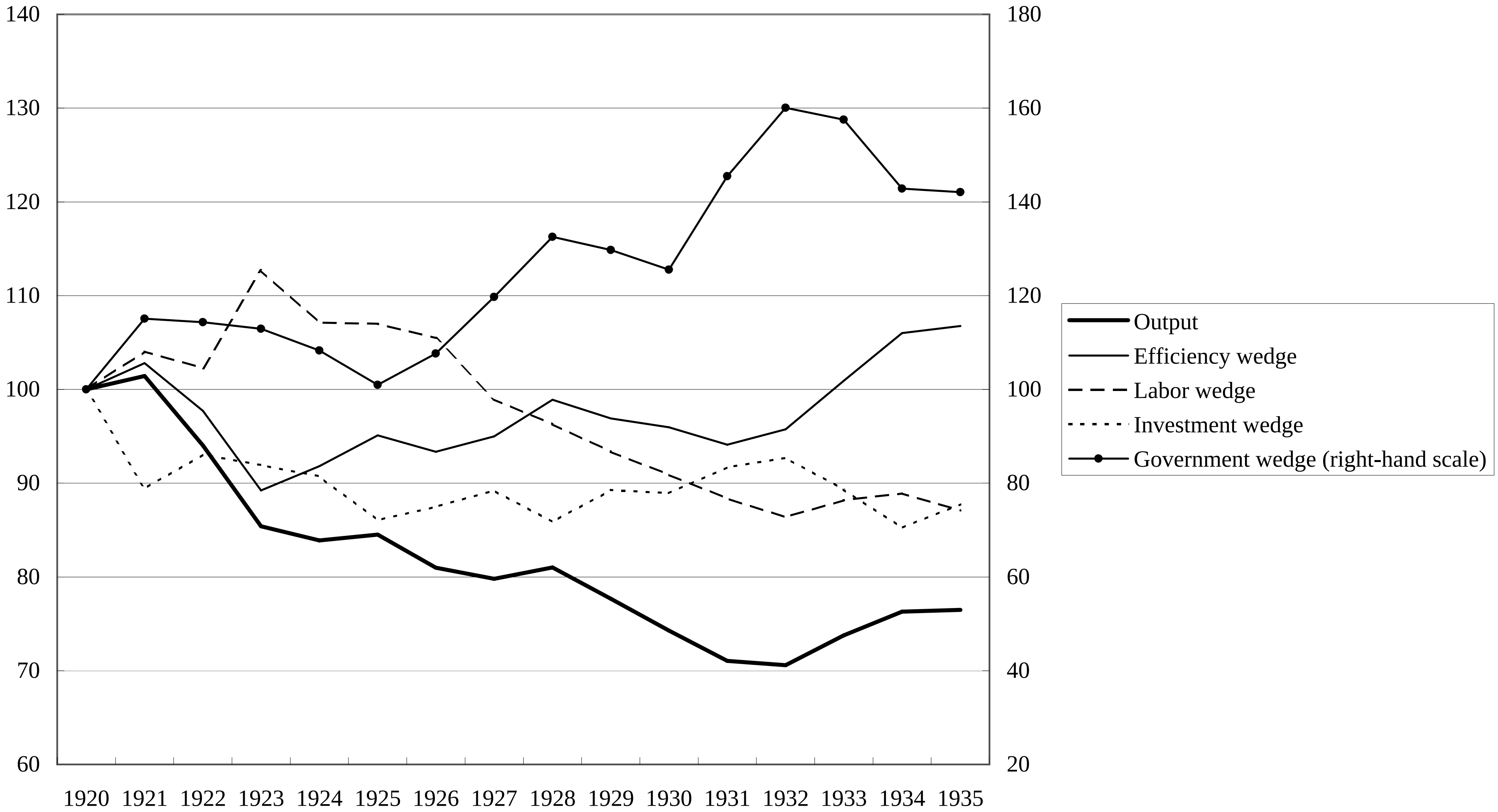


Figure 8. Decomposition of output with just one wedge

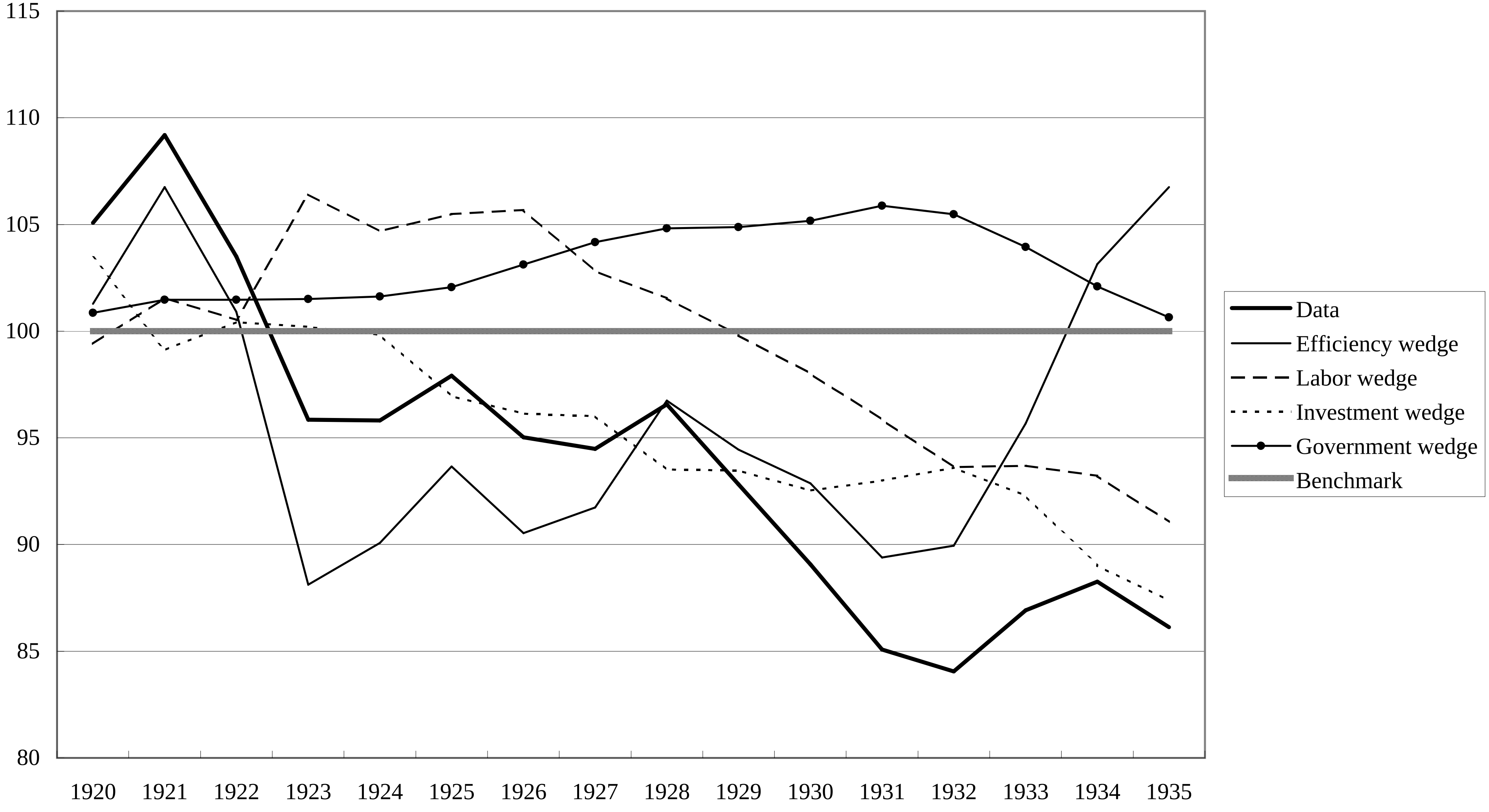


Figure 9. Decomposition with the capital wedge: Output in the 1990s in Japan

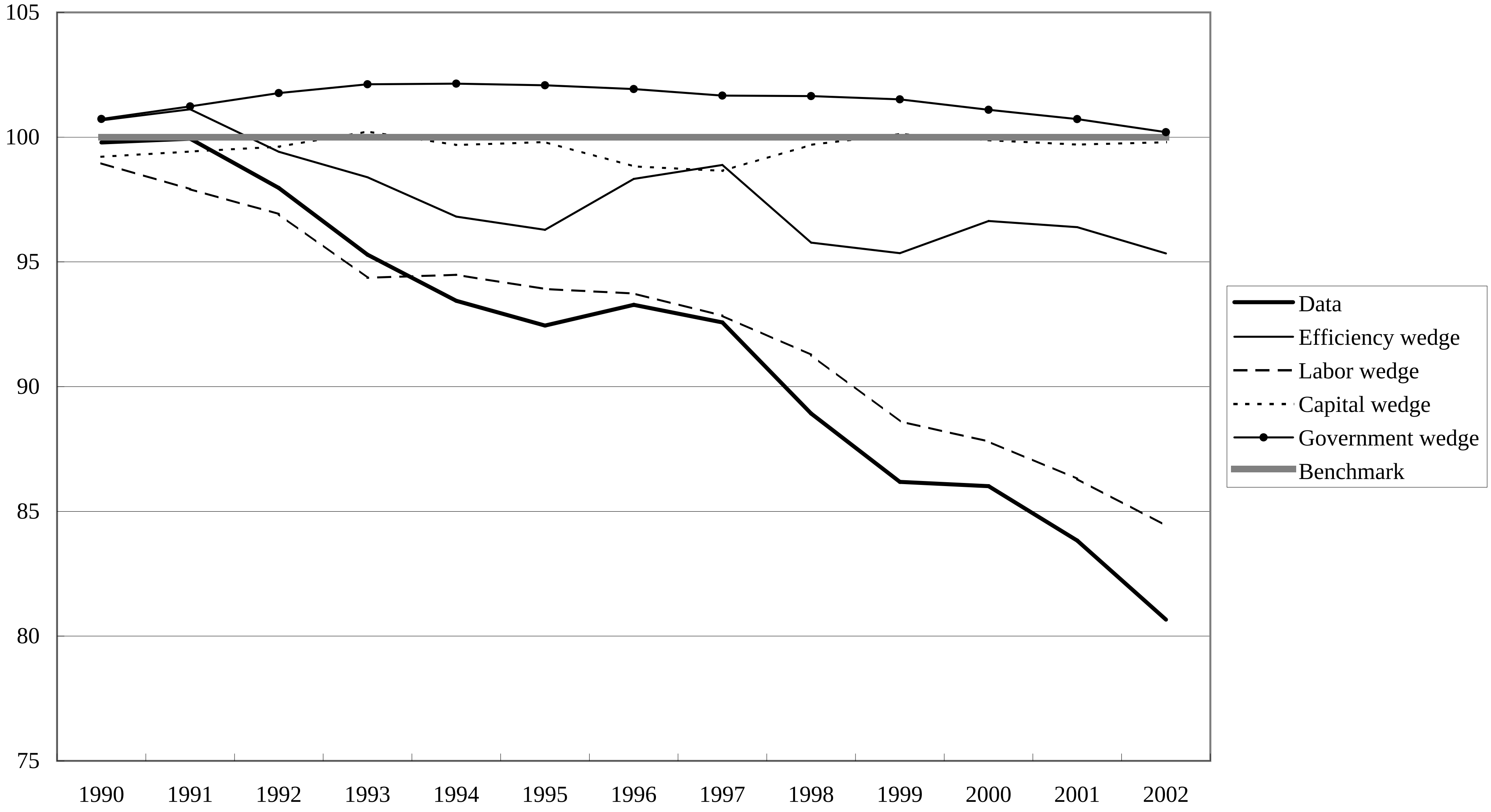
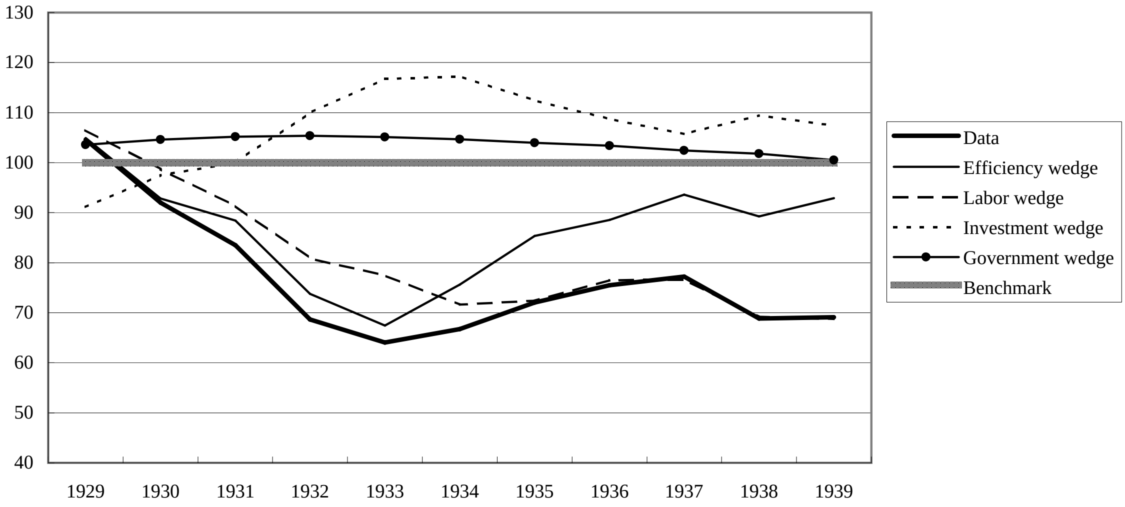


Figure 10. Decomposition with the investment wedge: Output in the Great Depression

Effect of each wedge on output



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

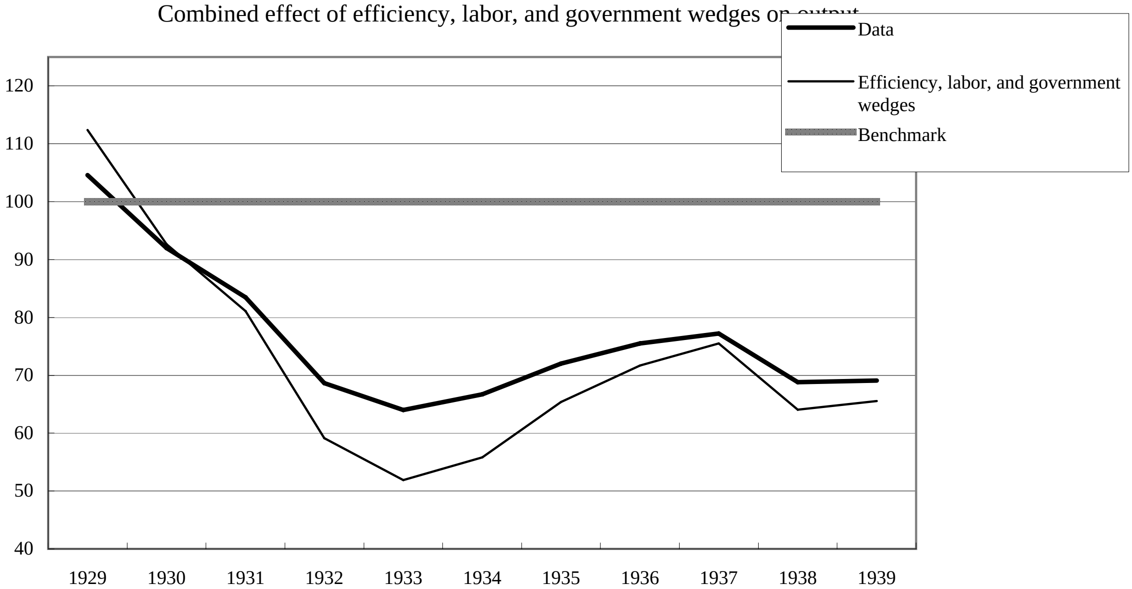
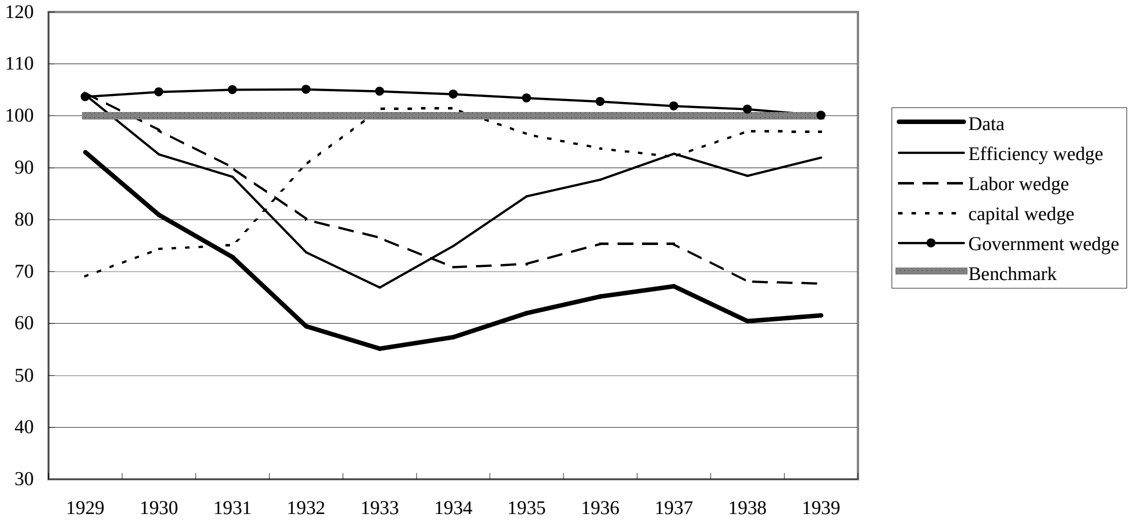


Figure 11. Decomposition with the capital wedge: Output in the Great Depression

Effect of each wedge on output



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