Business cycle accounting for the Japanese economy*

(Incomplete and preliminary)

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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 three-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. 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. Finally, we show that a simple model of bank distress can reproduce qualitatively the same movements of wedges as those in the BCA results for the 1990s in Japan and the Great Depression.

Keywords: Business cycle accounting; 1990s in Japan; 1920s in Japan; 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 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.

Finally, we explored whether there exists a theoretical model of depression, which is consistent with the results of both the original BCA with the investment wedge and the new BCA with the capital wedge. We found, through a heuristic try-and-error approach, that a simple model with bank distress is a good candidate for such a model. The structure of the model is as follows: We assume that firms need to borrow from banks for their working capital expenses. We also assume that there emerges a risk of bank failures due to an exogenous shock (e.g., asset-price collapse), and that the firms will incur additional refinancing cost if the banks collapse. The risk of bank failure makes the working capital expenses (i.e., wage payment and rent for capital) costly for the firms, worsening the labor and capital wedges, while the response of the monetary authority, which lowers nominal interest rates, improves the investment wedge.

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. A simple theoretical model of depression that is consistent with both the original and the new BCA is described in Section 5. Section 6 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 law of mothon 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 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]

[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}.

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 continued, and it lead to nationwide bank panics in 1997–99 and subsequent deflation. 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 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 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 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 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 concerned had a depressing (expanding) effect on output. 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 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]).

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 3, 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 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 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. Decomposition of output with just one wedge

Figure 3. 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 4. 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 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 4. Output and the four measured wedges in the 1920s

The decomposition result for output is shown in Figure 5. We set the benchmark wedges at their initial values as of 1920.

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

[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.

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 investment wedge implies that financial frictions (e.g., bank distress) might have played a major role in the recession. 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 5. Decomposition of output with just one wedge

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 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." 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 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

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

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]

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:

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

[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^*.

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 6 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 6. 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 7 and 8 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 7, and those with the capital wedge are shown in Figure 8.

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.

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 7 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 8 show the corresponding results for BCA with the capital wedge. Figure 7 indicates that almost throughout the period, the investment wedge had a considerable expansionary effect on the economy, while Figure 8 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. 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 of the Great Depression. Our result for BCA with the capital wedge is opposed to their conclusion. The lower panel of Figure 8 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 7. Decomposition with the investment wedge: Output in the Great Depression

Figure 8. Decomposition with the capital wedge: Output in the Great Depression

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

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 shown in Figure 9, and are qualitatively similar to those in Figure 8.

Figure 9. Decomposition with the capital wedge and larger depreciation: Output

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 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 A simple explanation – Depression due to bank distress

The accounting results for the 1990s in Japan and the 1930s in the United States show that the labor and capital wedges deteriorated and the investment wedge improved, following the onset of the depressions. In particular, Mulligan (2002) emphasizes that the deterioration of the labor wedge during the Great Depression is a puzzle that cannot be accounted for by standard neoclassical growth models.

In this section we propose a simple theoretical explanation for these movements of wedges. It is shown that a simple model with bank distress can replicate the wedges in the actual depression episodes.[6]

[6] Our theoretical model in this section is not an explanation for the 1920s in Japan. Since the development stage of the economy and the structures of labor and capital markets seem quite different from the other depression episodes, we may need a different model to account for the 1920s in Japan.

5.1 Structure of the model

The model is a simplified variant of the business cycle model with bank intermediation formulated by Einarsson and Marquis (2001, 2003). The model consists of four sectors: consumers, firms, banks, and the government. The measures of consumers, firms, and banks are normalized to one.

Firms produce output from capital and labor, while there is no distinction between consumer goods and capital goods. We assume that firms need to borrow money from the banks to finance their working capital expenses, i.e., wage payments and rents for capital.

We assume that in the initial period, an unexpected exogenous shock (e.g., asset-price collapse) makes all banks insolvent. Therefore, in each period t the government can choose whether to close the banks. If it chooses not to close the banks, it (implicitly) guarantees the nonperforming assets of the banks and they continue operation to maximize their profits (see subsection "Bank" below). If the government chooses to close the banks, it guarantees all deposits, disposes of the nonperforming assets of banks by a lump-sum transfer from the consumers, and the bank loans to firms are terminated in the middle of the period. Thus if the insolvent banks are closed in period t, the firms need to refinance their working capital in the middle of period t by borrowing from new financiers (i.e., restructured banks). This refinancing is costly for the firms, since the firms need to search for new financiers and verify the viability of their projects with the financiers.

We assume that for each period t, the productivity θ_t, the monetary policy variable (i.e., the deposit rate r_{dt}), and the probability of bank failure q_t are revealed at the beginning of the period, and that s_t, the measure of banks that are closed during period t, is revealed in the middle of the period after the agents make some of their decisions for the period. For simplicity, we assume that all banks either fail or continue: $s_t = 1$ with probability q_t and $s_t = 0$ with probability $1 - q_t$. We denote the conditioning information including s_t by Ω_t, and that excluding s_t by Ω_t^s

Consumer The representative consumer makes decisions that maximize expected utility:

$$\max_{n_t^s, M_t^d, D_t^d} E\left[\max_{c_t, k_{t+1}, N_{t+1}^d, A_{t+1}} E\left(\sum_{t=0}^{\infty} \beta^t U(c_t, 1-n_t^s, \frac{M_t^d}{P_t}) \middle| \Omega\right) \middle| \Omega^s\right], \quad (8)$$

where $U(c, l, m) = \ln c + \gamma_l \ln l + \gamma_m \ln m$, c_t is consumption, n_t^s is labor supply, M_t^d cash holding, P_t the goods price, and β $(0 < \beta < 1)$ the discount factor. The consumer chooses n_t^s, M_t^d, and bank deposits D_t^d before bank failure s_t is revealed. After s_t is revealed, she chooses c_t, capital holdings for the next period k_{t+1}, the government bonds N_{t+1}^d, and the nominal asset A_{t+1}. The consumer's budget constraint conditioning on s_t is

$$P_t\{c_t + k_{t+1}\} + A_{t+1} + N_{t+1}^d + \tau_t \leq M_t^d + (1+r_{dt})D_t^d + P_t k_t + \Pi_t^f(s_t) + \Pi_t^b(s_t) + \Delta_t(s_t), \quad (9)$$

where $\Pi_t^f(s_t)$ and $\Pi_t^b(s_t)$ are the per-capita profits from firms and banks, respectively, and τ_t is a lump-sum tax. As we see in subsection "Bank," if the government does not close the banks in period t, it guarantees the nonperforming loans of banks, which are bequeathed to banks of period $t+1$ in the form of government bonds N_{t+1}^d, while if the government closes the banks in period t, it disposes of the nonperforming loans by a lump-sum transfer τ_t from the consumers to the banks. Therefore, denoting the amount of the NPLs at the end of period t by N_{t+1}, we have in the equilibrium that $N_{t+1}^d = N_{t+1}(1-s_t)$ and $\tau_t = N_{t+1}s_t$. Therefore, $N_{t+1}^d + \tau_t = N_{t+1}$ is independent of s_t. As we describe below, we assume that the firm incurs additional cost when the bank fails. We assume that the cost of bank failure for the firm is transferred to the consumer. This transfer is denoted by $\Delta_t(s_t)$. Therefore, the firm's problem below implies that $\Pi_t^f(s_t) + \Delta_t(s_t)$ is independend of s_t. Since it is shown that $\Pi_t^b(s_t) = 0$ in the equilibrium, the right-hand side of (9) does not depend on s_t, implying that we can posit that the Lagrange multiplier for (9) is independent of s_t. The consumer divides her nominal assets into M_t^d and D_t^d before s_t is revealed:

$$M_t^d + D_t^d \leq W_t n_t^s + R_t k_t + A_t + N_t^d + T_t, \quad (10)$$

where W_t is the nominal wage rate, R_t the nominal rental rate for capital, and T_t is exogenous cash transfer from the monetary authority. The consumer solves (8) subject to (9) and (10).

Firm The firms exist for only one period. At the beginning of each period, new firms are born, borrow from banks, and pay wages and rents. Using labor and capital, the firms produce goods during the period, and at the end of the period they sell output, repay bank loans, pay dividends to the consumers, and die. The period profit for a firm is $\Pi_t(s_t) = P_t\theta_t F(k_t, n_t) - (1 + r_{bt} + \Delta_t^k \cdot s_t)B_t^k - (1 + r_{bt} + \Delta_t^n \cdot s_t)B_t^n$, where $F(k, n) = k^\alpha n^{1-\alpha}$, n_t is the labor demand, r_{bt} is the loan rate, B_t^k the bank loan to finance the rent for capital, B_t^n that to finance the wage payment, Δ_t^k (Δ_t^n) is the rate of additional cost to refinance B_t^k (B_t^n) when the bank fails in the middle of the period. The costs of bank failure (Δ_t^k and Δ_t^n) are interpreted as the information cost to find a new financier and to verify the viability of the firm's project to the new financier. Since the information costs for capital may be different from that of labor, we assume that $\Delta_t^k \neq \Delta_t^n$ in general. Although Δ_t^k and Δ_t^n are perceived as exogenous parameters for firms, we assume that the refinance costs satisfy the following conditions in the equilibrium:

$$\Delta_t^k \cdot B_t^k = \delta_k P_t \theta_t F_k(t) k_t, \tag{11}$$

$$\Delta_t^n \cdot B_t^n = \delta_n P_t \theta_t F_n(t) n_t, \tag{12}$$

where δ_k and δ_n are technological parameters. We assume that the costs are simply transferred to the consumers. Thus $\Delta_t(s_t) = \Delta_t^k \cdot s_t B_t^k + \Delta_t^n \cdot s_t B_t^n$, implying that $\Pi_t^f(s_t) + \Delta_t(s_t)$ is independent of s_t. The representative firm makes its decision before bank failure s_t is revealed to solve the following:

$$\max_{k_t, n_t, B_t^k, B_t^n} E[\Pi_t(s_t)|\Omega_t^s], \tag{13}$$

subject to $R_t k_t + P_t \delta k_t \leq B_t^k$ and $W_t n_t \leq B_t^n$, where δ is the rate of depreciation for capital. Note that we assume for consistency with the BCA prototype models that the depreciation of capital is paid by the firm.

Bank The banks also continue for only one period. The banks in period t take the nominal amount of bank reserves Z_t and the nominal deposit rate r_{dt} as given by the government. We assume that the banks in period t inherit the nonperforming loans N_t from the banks in period $t-1$. We assume that the nonperforming loans (NPLs) are originally generated at period 0 by an exogenous shock, such as an asset-price collapse, and that the government allows banks of period t to bequearth at most $(1+r_{bt})N_t$ of the NPLs to the next generation as long as $s_t = 0$. In this case, at the end of period t the government guarantees the NPLs N_{t+1}, as long as $N_{t+1} \leq (1+r_{bt})N_t$, and the consumers are willing to hold them as assets, regarding them as government bonds. At the beginning of period $t+1$, the NPLs held by the consumers are sold to the (new) banks in exchange for bank deposits (see equation (10)). Therefore, the amount of government bonds issued at the end of period t is $(1-s_t)N_{t+1}$. If the government chooses $s_t = 1$, it disposes of the NPLs at the end of period t by a lump-sum transfer $\tau_t = s_t N_{t+1}$ from the consumer to the banks. The bank's profit is $\Pi_t^b(s_t) = (1-s_t)\{(1+r_{bt})B_t + N_{t+1} + Z_t - (1+r_{dt})D_t - \xi D_t\}$, where B_t is the loans to the firms, D_t the deposit liability, N_{t+1} the NPL to bequeath to the next generation, and ξ is the cost of deposit management (e.g., cost of providing transaction services to depositors). Given Z_t, N_t, and r_{dt}, the banks solve

$$\max_{B_t, D_t, N_{t+1}} E[\Pi_t^b(s_t)|\Omega_t^s] \tag{14}$$

subject to $D_t = B_t + N_t + Z_t$, $N_{t+1} \leq (1+r_{bt})N_t$, and $Z_t \geq \zeta D_t$, where ζ is the ratio of reserve requirement, which is an exogenous constant.

Government At the beginning of period t, the government determines the monetary policy (the deposit rate r_{dt}, bank reserve Z_t, and cash transfer to the consumers T_t) and announces the probability of bank closure q_t. In the middle of period t, the government chooses whether to close banks ($s_t = 1$) or not ($s_t = 0$). At the end of period t, it issues bonds $(1-s_t)N_{t+1}$ and raises tax $\tau_t = s_t N_{t+1}$. As easily shown, the three monetary policy variables (r_{dt}, Z_t, and T_t) are not independent: If the government picks one of the three, the other two are automatically determined in the equilibrium.[7] For simplicity, we assume that the government simply announces that it will set $s_t = 1$ with probability q_t and $s_t = 0$ with probability $1-q_t$. This is because it is difficult to formulate a rational

[7] We assume that the government acts as a price taker, i.e, the government policy is Ricardian.

expectations equilibrium in which q_t is justified as an equilibrium outcome, since q_t is the probability concerning an aggregate event. Therefore, we simply assume that q_t is a choice variable for the government.[8]

Market clearing conditions There are markets for labor, goods, deposits, bank loans, and the government bonds. Market clearing conditions are $n_t^s = n_t$, $c_t + k_{t+1} - (1-\delta)k_t = \theta_t F(k_t, n_t)$, $D_t^d = D_t$, $B_t^k + B_t^n = B_t$, and $N_{t+1}^d = N_{t+1}(1-s_t)$. Note also that $\tau_t = N_{t+1}s_t$ and $\Delta_t(s_t) = \Delta_t^k \cdot s_t B_t^k + \Delta_t^n \cdot s_t B_t^n$.

5.2 Equilibrium and simulation

Profit maximization for banks implies

$$r_{bt} = \frac{r_{dt} + \xi}{1-\zeta}, \tag{15}$$

and $\Pi_t^b(s_t) = 0$ for any s_t. The firm's problem implies

$$\frac{R_t}{P_t} = \frac{\theta_t F_k(t)}{1 + r_{bt} + \Delta_t^k q_t}, \text{ and } \frac{W_t}{P_t} = \frac{\theta_t F_n(t)}{1 + r_{bt} + \Delta_t^n q_t}. \tag{16}$$

Noting that the Lagrange multiplier and macroeconomic variables in (9) do not depend on s_t, these conditions and the first-order conditions (FOCs) for the consumer's problem imply

$$\frac{U_l(t)}{U_c(t)} = \left(\frac{1 + r_{dt}}{1 + r_{bt} + \Delta_t^n q_t}\right)\theta_t F_n(t), \tag{17}$$

and

$$U_c(t) = \beta E_t\left[\left\{\frac{(1 + r_{dt+1})\theta_{t+1}F_k(t+1)}{1 + r_{bt+1} + \Delta_{t+1}^k q_{t+1}} + 1 - (1 + r_{dt+1})\delta\right\} U_c(t+1)\right] \tag{18}$$

Equations (17) and (18), together with the resource constraint, determine the real variables $\{c_t, n_t, k_{y+1}\}$. The FOCs for A_{t+1} and D_t^d in the consumer's problem imply

$$E_t\left[(1 + r_{dt+1})\frac{\beta U_c(t+1)}{U_c(t)}\frac{P_t}{P_{t+1}}\right] = 1, \tag{19}$$

[8] This simplification may be problematic when we consider the case of the 1990s in Japan. The Japanese government repeatedly announced that the banks would not be closed, i.e., $q_t = 0$. In the meantime, the general public feared financial crisis during the 1990s, meaning that they felt $q_t > 0$. In the simulation below, we set q_t at a value which must be consistent with the expectations of the general public.

which determines the price level $\{P_t\}$. The FOC for M_t^d implies

$$U_m(t) = r_{dt} U_c(t), \tag{20}$$

which determines the amount of cash M_t held in the consumer sector.

Simulation To reproduce the movement of wedges in the BCA results, we simulated the model in which $q_t = 0.2$ for $1 \le t \le 10$ and $q_t = 0$ for $t \ge 11$. This is the case where bank distress continues for 10 years and all banks are restructured in period 10.

We simulated the model with various parameter values and monetary policy patterns, and found that if $\delta_k < \delta_n$ the movements of the labor, investment, and capital wedges are reproduced qualitatively, and that if the government reduces r_{dt} gradually the deterioration of the capital wedge is magnified.

Figure 10 shows the simulation results in the case where the parameters are $\delta_k = 0.1$ and $\delta_n = 0.4$, and the monetary policy moves as $r_{dt} = .03 - .006 \cdot (t-1)$ for $1 \le t \le 5$, $r_{dt} = .001$ for $6 \le t \le 10$, and $r_{dt} = .03$ for $t \ge 11$. In this example, the government gradually reduces the nominal deposit rate during the first five periods of bank distress, maintains a very low rate for the rest of the distress periods, and restores the steady-state value of r_{dt} when bank distress ends.[9]

The preference and technology parameters are set as follows: $\theta_t = 1$, $\alpha = .3$, $\beta = .98$, $\gamma_l = 2$, $\gamma_m = .5$, $\delta = .08$, $\xi = .0151$, and $\zeta = .1$. The values for ξ and ζ are taken from Einarsson and Marquis (2001). This figure shows that the labor wedge deteriorates and the investment wedge improves during the periods of bank distress, and the capital wedge deteriorates during the first five periods. These movements of the three wedges seem qualitatively consistent with the actual wedges in the BCA results for the 1990s in Japan and the 1930s in the United States. Output, consumption, investment, and labor decrease during the first ten periods; and deflation occurs in the latter half of the period of bank distress. The loan-to-output ratio and the deposit-to-output ratio

[9] We assume that the steady-state value of r_{dt} is .03. Note that in this model this value is not "optimal" in the sense that maximizes the consumer's utility. It is easily shown that the optimal monetary policy when $q_t = 0$ for all t is $r_{dt} = 0$.

increase during bank distress, since we assume that the NPL to output ratio is 0.1 for the initial period, $N_{t+1} = (1 + r_{bt})N_t$ for $1 \leq t < 10$, and $N_t = 0$ for $t \geq 11$.

The results are moderately robust against small perturbations of parameters, policy, and probability q_t, while they change qualitatively if δ_k, q_t, and/or the conduct of monetary policy changes considerably: If δ_k exceeds .15 or q_t exceeds 0.3, both the investment and capital wedges deteriorate; If r_{dt} remains at .03 for all periods, the investment wedge does not change from its steady-state value; If $r_{dt} = .001$ for $1 \leq t \leq 10$ and $r_{dt} = .03$ for $t \geq 11$, the result is qualitatively the same as that shown in Figure 10, but the deterioration of τ_k is weakened. The deterioration of the labor wedge is quite robust for these changes in parameters and policy.

Discussion The model in this section successfully replicates the deterioration of the labor wedge during the depressions using simple assumptions: (1) firms need to borrow from banks for wage payments (and rents for capital), (2) an exogenous shock, e.g., asset-price collapse, generates the risk of bank failure, and (3) the refinancing of working capital in the case of bank failure is costly for the firms. The model indicates that the improvement of the investment wedge may not imply the nonexistence of financial friction, but may rather imply an accommodative response of the monetary policy to the onset of recession. The capital wedge might have reflected both the emergence of financial friction and the accommodative response of monetary policy. In our simulation, deflation occurs as a result of monetary policy that keeps the nominal interest rate at nearly zero. This implication seems consistent with the episode of the 1990s in Japan, but may not be a good explanation for the severe deflation during the Great Depression.[10] In our model, we assumed that the government guarantees all deposits in the case of bank failure. This assumption enables the consumer's budget constraint to be immune to bank failure and simplifies the analysis greatly, but is counterfactual for the Great Depression. In order to explain the deflation during the Great Depression, we may need

[10] The model simulation generates similar results for wedges in the case where the deposit rate is high (at, e.g., .06) in the steady state and is lowered (to, e.g., .03) during bank distress. But the inflation rate is always positive in this case.

to assume that depositors incur large costs when banks fail.

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

In the last section, we show that the movements of the labor, investment, and capital wedges may be explained consistently in a simple model of bank distress: If firms need to borrow working capital from banks and the refinancing of bank loans in the case of bank failure is costly for the firms, the emergence of bank distress causes the labor wedge to deteriorate. The investment wedge then improves if the monetary authority lowers the nominal interest rate in response to the onset of recession. Since bank distress worsens the capital wedge and the accommodative monetary policy improves it, the capital wedge deteriorates if the bank distress is severe.

In this paper we provide a necessary condition for a theory of the long recession in Japan, i.e., the movements of the key wedges that must be consistently explained by such a theory. We also provide a candidate for such a theory in which bank distress generates these changes in the wedges.

7 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).

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

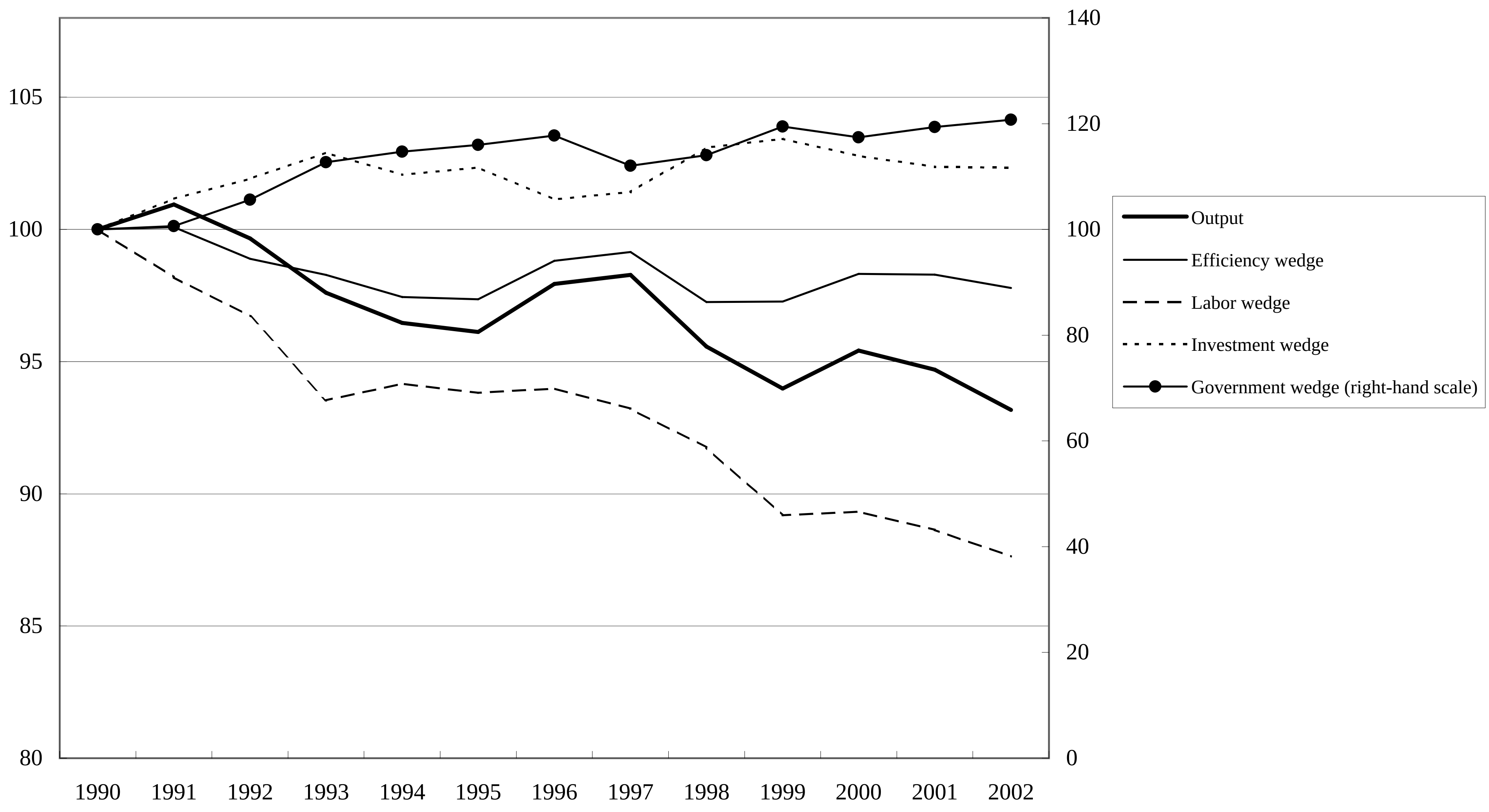


Figure 2. Decomposition of output with just one wedge

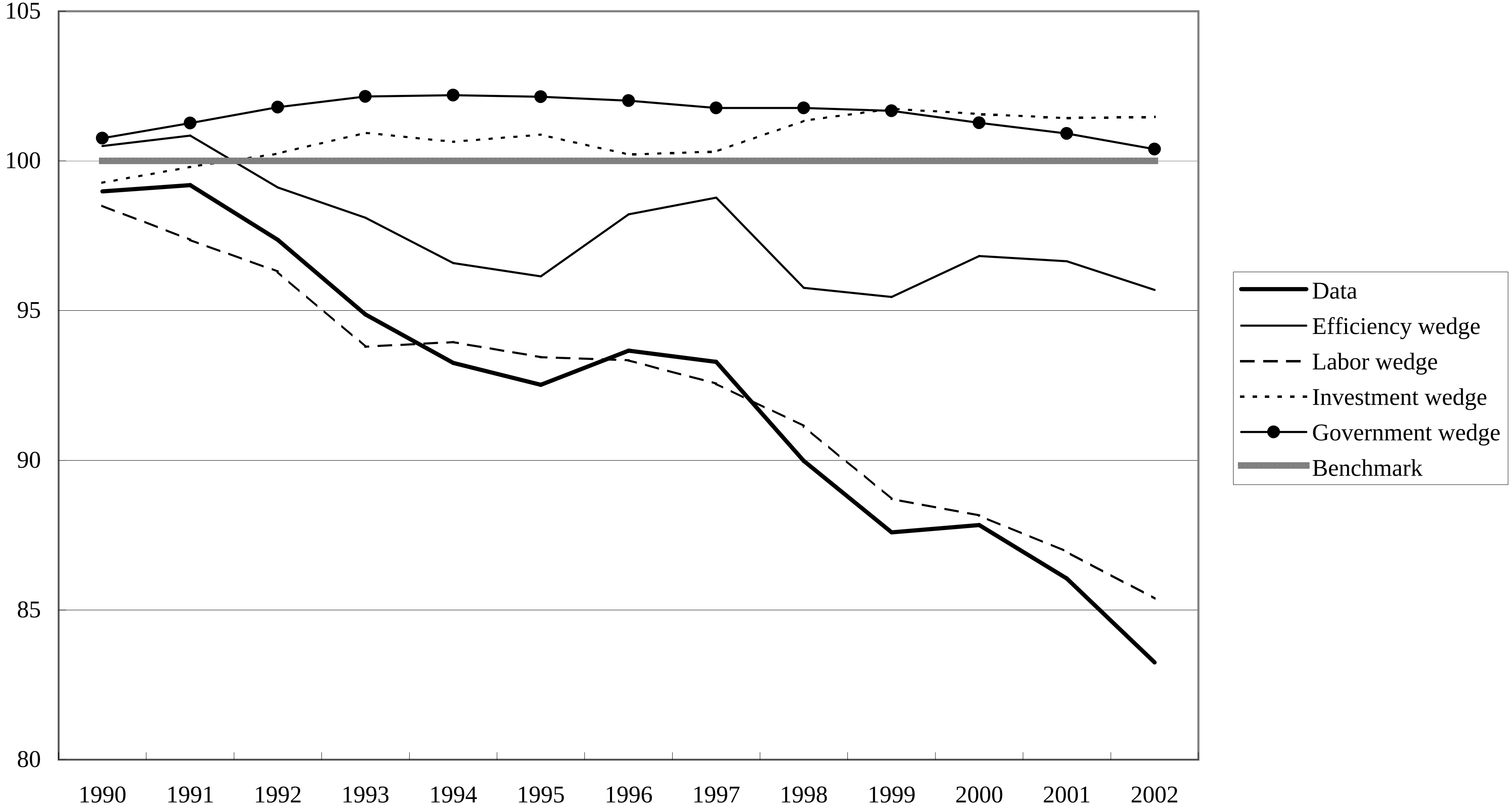


Figure 3. Combined effect of two and three wedges on output

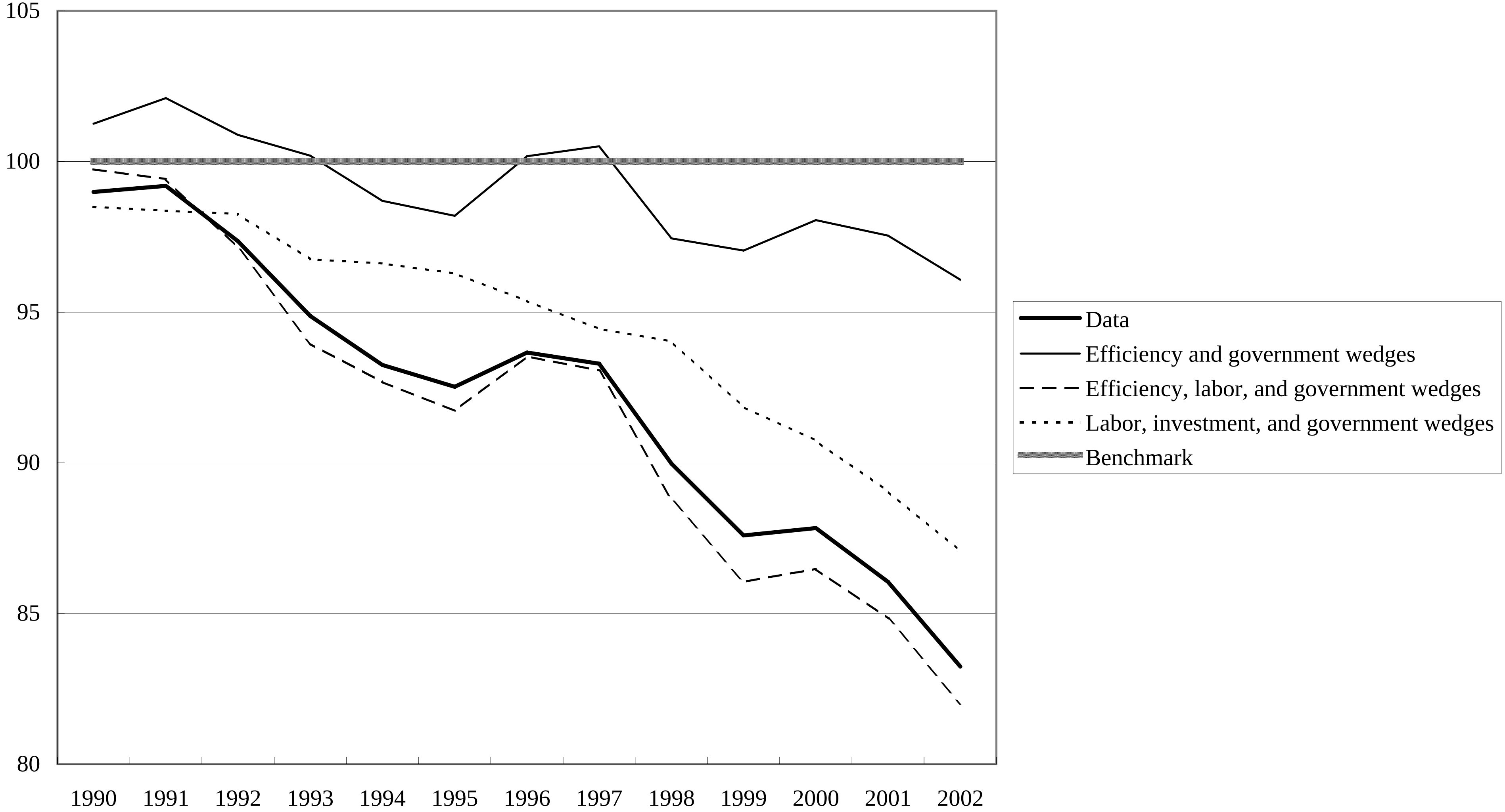


Figure 4. Output and the four measured wedges in the 1920s

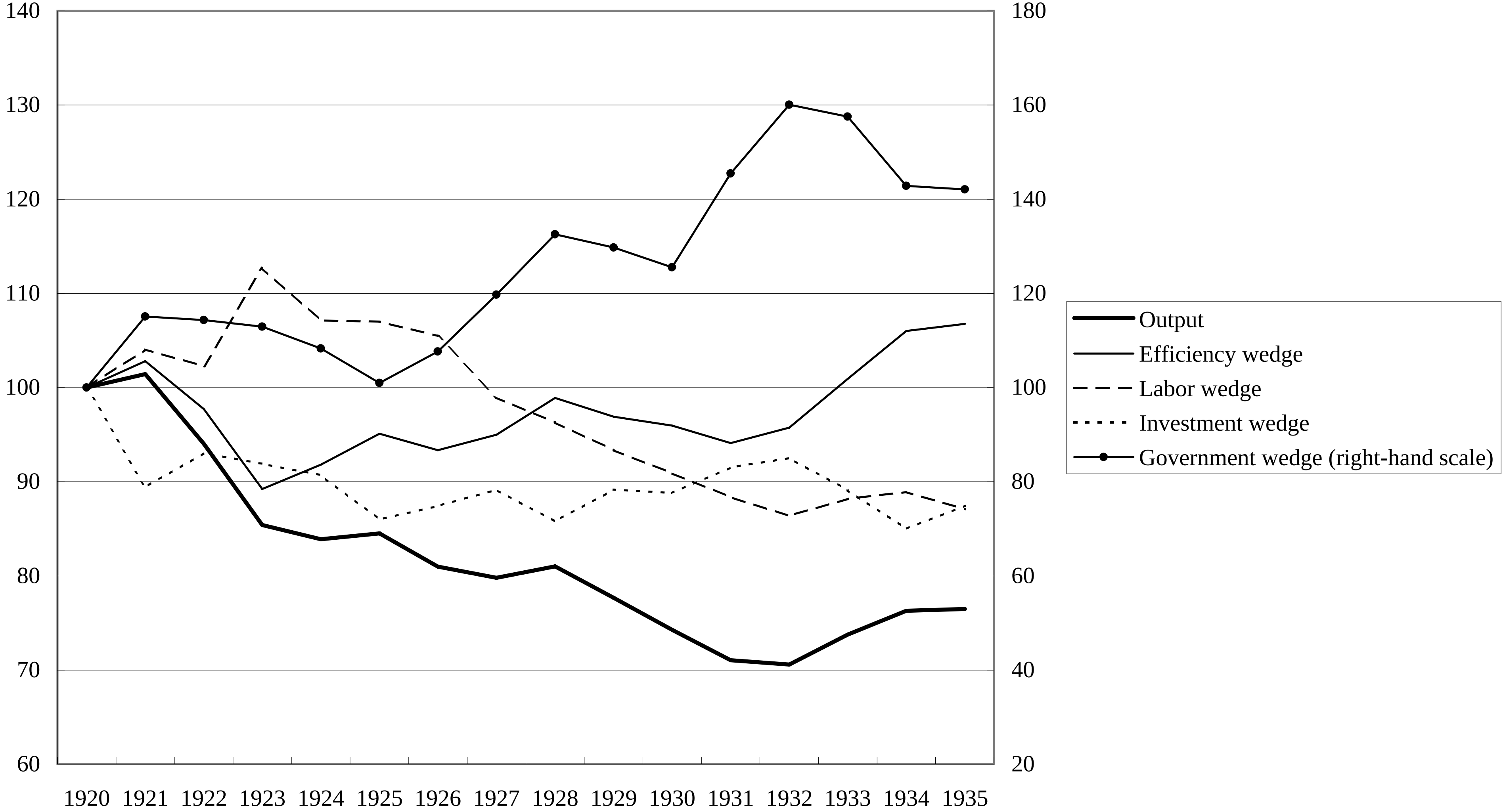


Figure 5. Decomposition of output with just one wedge

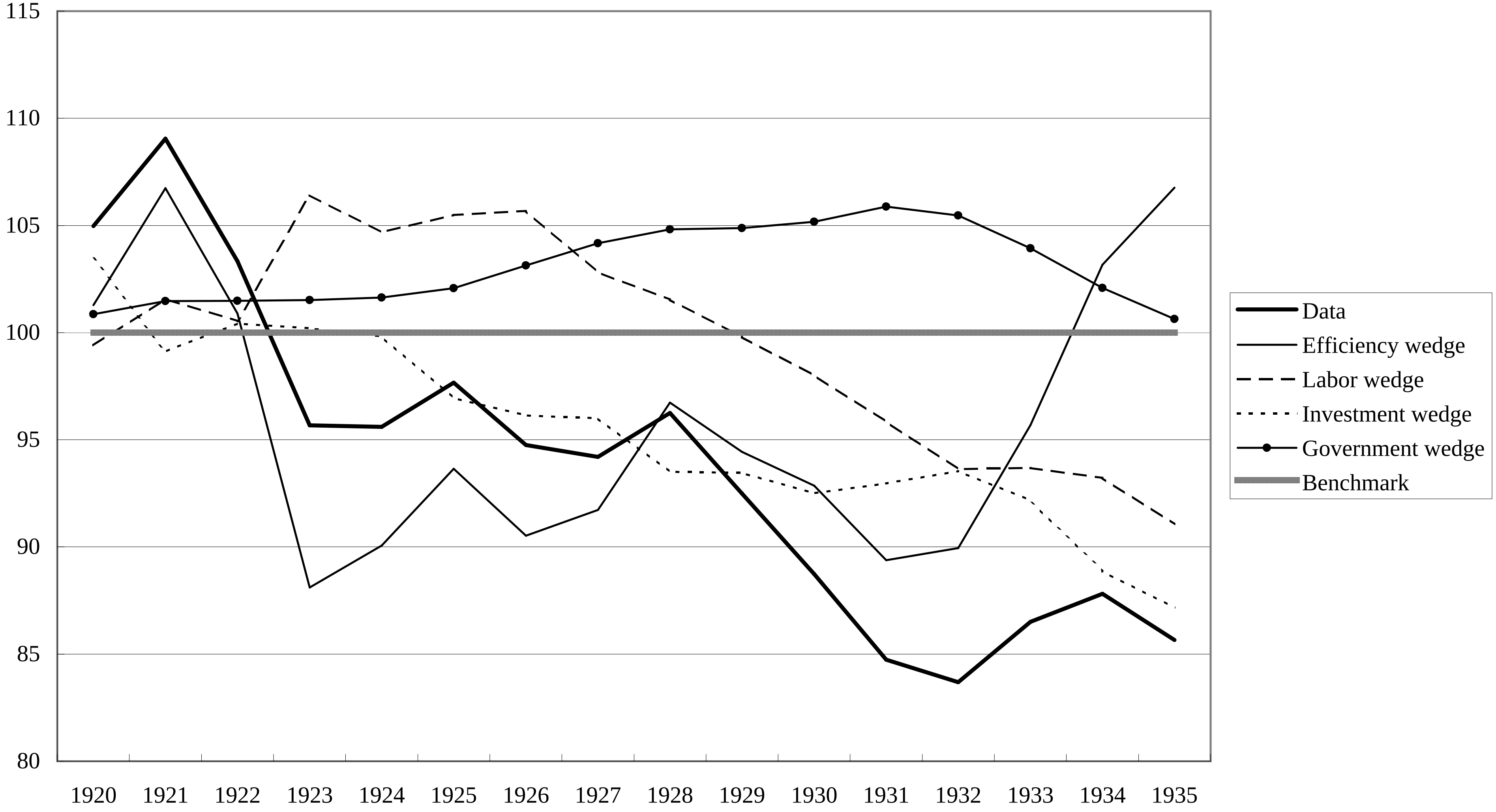
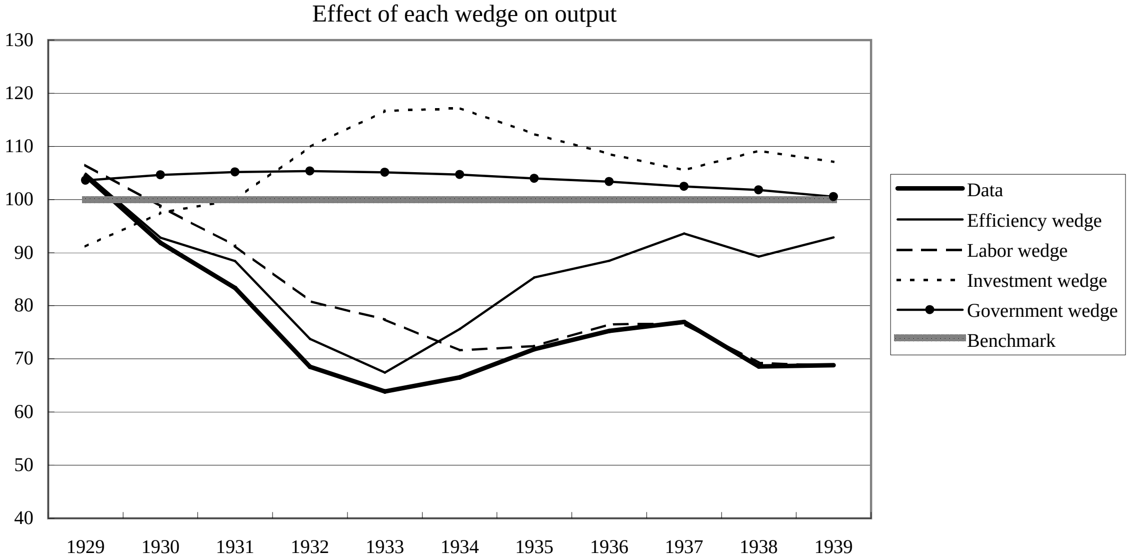


Figure 6. Decomposition with the capital wedge: Output in the 1990s in Japan

Figure 7. Decomposition with the investment wedge: Output in the Great Depression



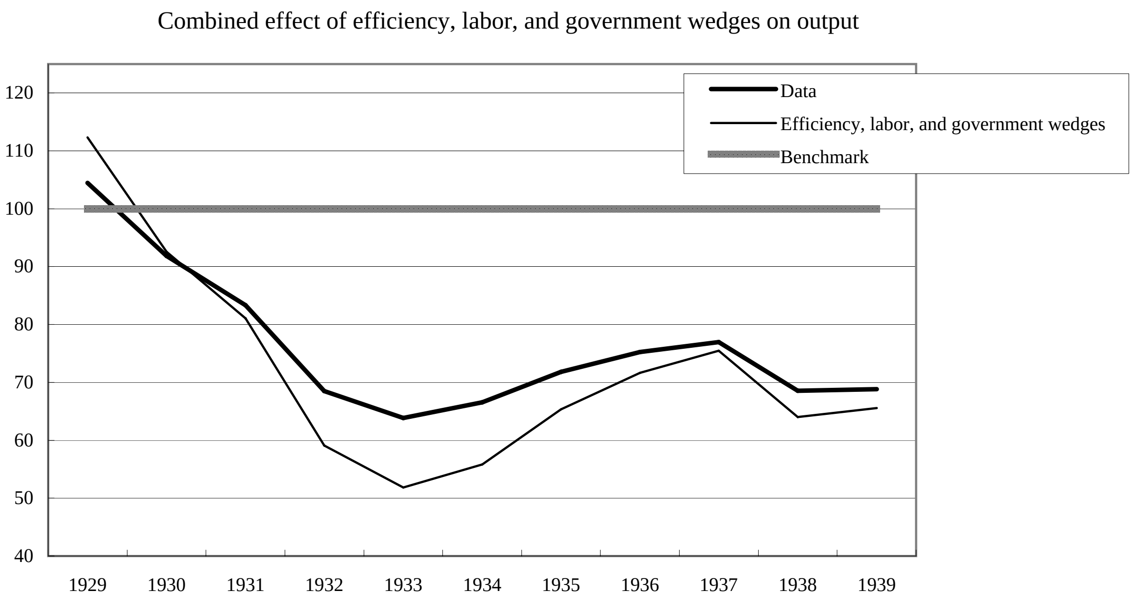
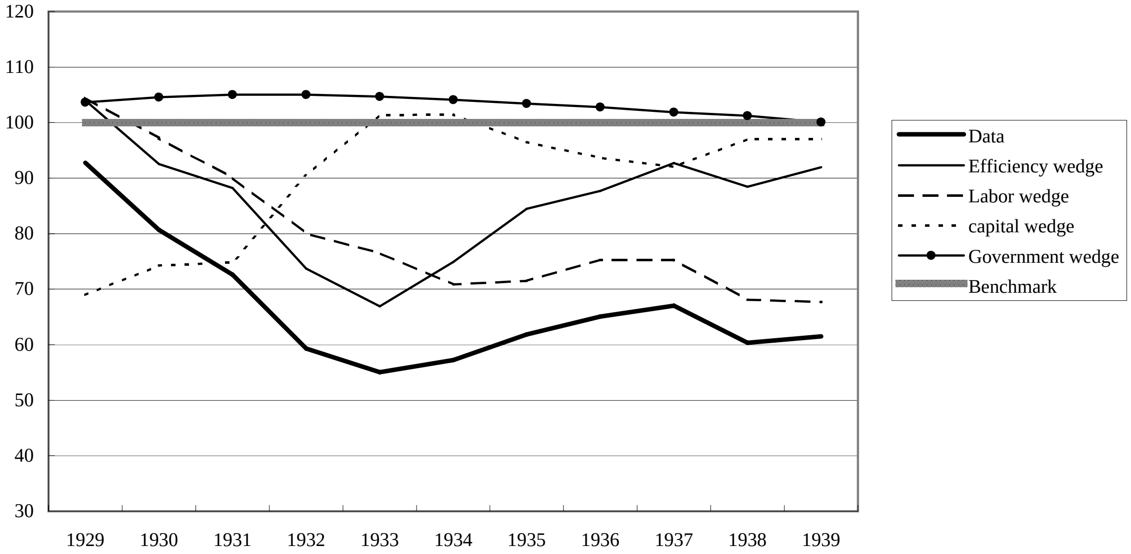


Figure 8. Decomposition with the capital wedge: Output in the Great Depression

Effect of each wedge on output



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

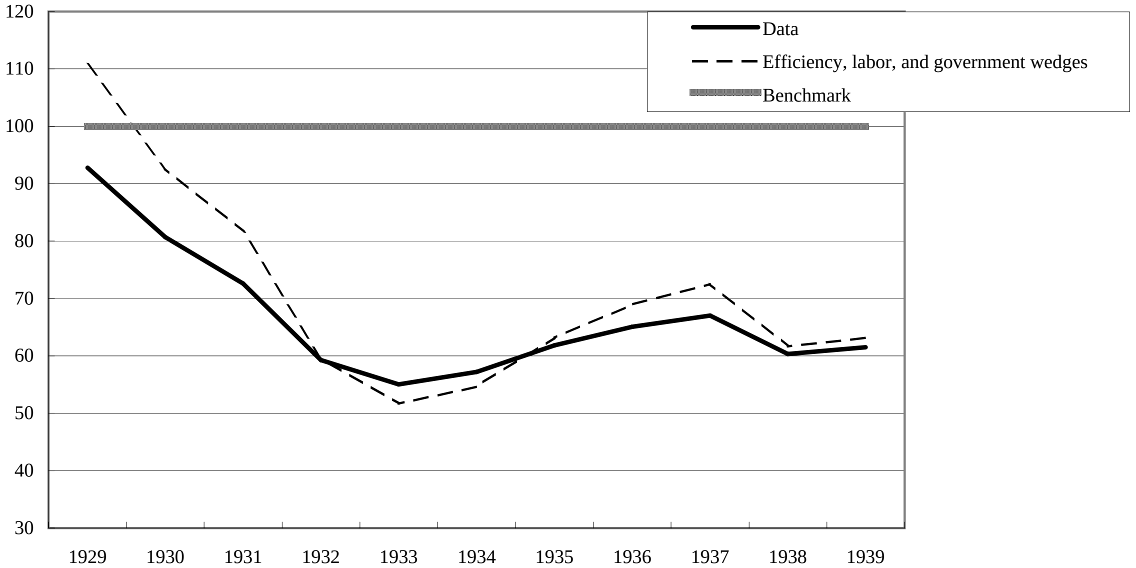


Figure 9. Decomposition with the capital wedge and large depreciation: Output

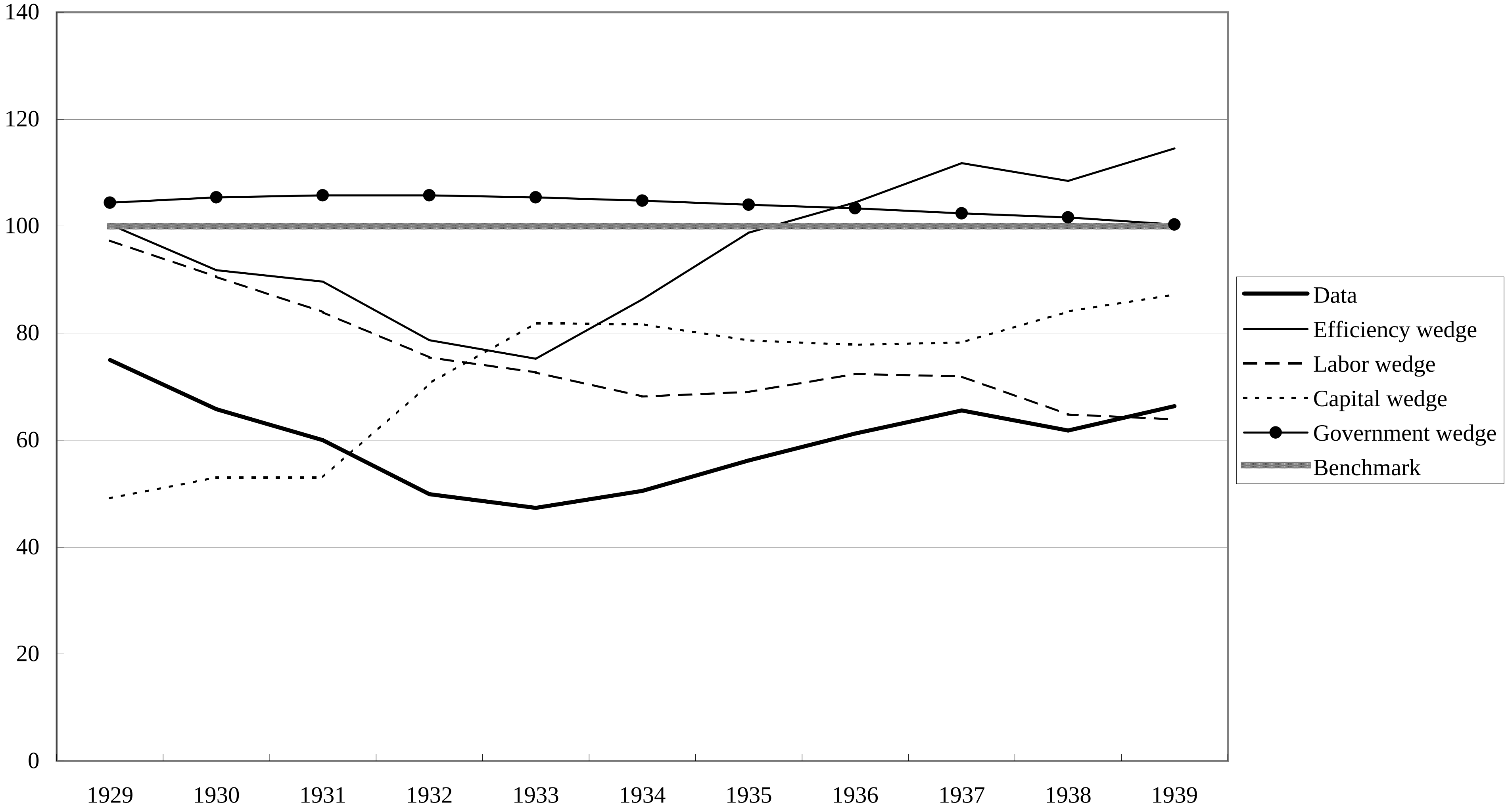


Figure10. Simulation results