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Borrowing Constraints and Protracted Recessions

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JEL Classification: E32, E44, E51, G12.

Key words: Borrowing constraint, labor wedge, nonperforming debts, monetary policy, deflation.

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(Former title: Endogenous collateral constraint and asset utilization)

Keiichiro Kobayashi*and Masaru Inaba†

November 11, 2005 (First draft: April 30, 2005)

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"I recognized this kind of paralysis from my Goldman Sachs days. The attitude of much of Japan's political establishment seemed to be that of a trader praying over his weakening positions, when what he needed to do was to reevaluate them unsentimentally and make whatever changes made sense."

Robert E. Rubin, *In an Uncertain World* (New York: Random House, 2003), chap. 8

1 Introduction

The Great Depression in the United States and the 1990s in Japan are both characterized as persistent recessions of economies suffering from serious nonperforming debt problems subsequent to asset-price collapses. This paper shows that a simple variant of a neoclassical growth model with borrowing constraints can account for some puzzling observations of the US Great Depression and the 1990s in Japan that ordinary real business cycle models have not been able to explain.

We address three puzzles in this paper. A puzzle for the Great Depression, which was recently pointed out by Mulligan (2002) and Chari, Kehoe, and McGrattan (2002, 2004), is the emergence of a large "labor wedge," which is a wedge between the marginal rate of substitution between consumption and leisure (MRS) and the marginal product of labor (MPL). Assuming that the aggregate behavior of the US economy is described by the neoclassical growth model, they show that the labor wedge emerged and widened during 1929–33. In a neoclassical model, this wedge is modeled as a labor tax. Mulligan argues that the actual tax policies of the federal and state governments during that time period cannot fully account for this wide wedge. Mulligan and Chari et al. conclude that any theories attempting to account for the Great Depression must explain the large labor wedge. We also calculated the labor wedge for the 1990s in Japan. Following Chari et al. (2002), we defined the labor wedge $(1 - \tau_{lt})$ as

$$1 - \tau_{lt} = \frac{-\frac{U_n(t)}{U_c(t)}}{(1-\alpha)A_t\left(\frac{k_t}{n_t}\right)^{\alpha}}, \tag{1}$$

where $U(c_t, n_t)$ is the flow utility for the consumer, c_t is consumption in year t, n_t is labor supply, $U_c(t)$ ($U_n(t)$) denotes the derivative of the utility function at t with respect to c_t (n_t), and A_t is the productivity of the Cobb-Douglas production function $A_t k_t^{\alpha} n_t^{1-\alpha}$. Figure 1 shows the labor wedge measured from the Japanese data. See Kobayashi and Inaba (2005) for the details of the calculation. We assumed that the flow utility for the representative consumer is $U(c_t, n_t) = \ln c_t + \gamma \ln(1 - n_t)$, where $\gamma = 2$.

Figure 1. Labor wedge in the 1990s in Japan

This figure shows that the labor wedge continued to deteriorate throughout the 1990s and the early 2000s. We think that this wedge might have been the primal contributor to the protracted recession. Thus it seems that the recession in Japan also shows the same puzzle for neoclassical models: Why did the labor wedge widen in the recession?[1]

Another finding by Chari et al. (2002, 2004) is the second puzzle for the Great Depression: The existence of investment frictions is not empirically established. Assuming that investment frictions must manifest themselves as an (imaginary) investment tax, Chari et al. estimated the Euler equation for capital stocks in a one-sector growth model:

$$(1 + \tau_{xt}) U_c(t) = \beta E_t U_c(t+1) \left\{ \alpha A_{t+1} \left(\frac{n_{t+1}}{k_{t+1}} \right)^{1-\alpha} + (1 + \tau_{xt+1})(1 - \delta) \right\}, \qquad (2)$$

where δ is the depreciation rate of capital and τ_{xt} is the imaginary investment tax that represents investment frictions. See Chari et al. (2002, 2004) for details. They found that τ_{xt} did not increase and even decreased after the onset of the Great Depression. We conducted the same estimation and got the same result in Kobayashi and Inaba (2005): τ_{xt} decreased during the 1930s, implying that investment frictions seem to have improved. In the same paper, we also conducted an estimation for the Japanese economy and found that τ_{xt} did not increase in the 1990s, implying no deterioration of investment

[1] One standard explanation suggested by Chari et al. (2004) is nominal wage rigidity. As we argue in Kobayashi and Inaba (2005), however, this explanation is not consistent with the facts in the late 1990s in Japan, when wages became more and more flexible. If nominal rigidity were the main cause of the deterioration of the labor wedge, it would have improved in the late 1990s, while the data show that it continued to worsen in that period.

frictions. These results for the Great Depression and the 1990s in Japan seem puzzling, because investment expenditure decreased drastically during both depression episodes.

The third puzzle concerns deflation and monetary policy. A big topic in macroeconomic policy debate in Japan since the late 1990s is persistent deflation and the seeming liquidity trap. The deposit rate has been virtually zero since the mid-1990s, and the call rate has been kept at zero since 1999. Although the Bank of Japan conducted unprecedented monetary easing, the consumer price index continued to decline for about eight years starting in 1998, and it is said that a wide output gap continued to exist. It seems to us a puzzling challenge to understand coherently the prolonged coexistence in the late 1990s and the early 2000s of the output gap, deflation, and unprecedented monetary easing (the zero-interest-rate policy and the quantitative easing policy).[2] The conventional view in academia is that the output gap and deflation were caused by an exogenous and somewhat exotic shock to productivity (Krugman [1998]) or preference (Auerbach and Obstfeld [2005]), and that the current monetary policy of the BoJ is not sufficiently expansionary to eradicate the perverse effects of the shocks (Eggertsson and Woodford [2003], Bernanke [2003], Svensson [2003]). The view that we pursue in this paper is quite different from the conventional view but simple and self-consistent: Extraordinary monetary easing that fixes the nominal interest rate at zero generates deflation as an equilibrium outcome in an economy where the real rate of interest is determined in the market equilibrium; and in the meantime, persistent real distortions, which are represented by the large labor wedge, are caused by a nonmonetary factor, i.e., tightened borrowing constraints.

One contribution of this paper is to show that a simple variant of the neoclassical growth model with borrowing constraints can account for the above puzzles. It is shown that persistent tightening of the constraints can be a major source of the puzzling features in depression episodes. Another contribution is to specify the most plausible cause of the tightening of the borrowing constraints. It is shown that productivity declines may

[2] There exist several studies that imply Japan's monetary policy in the *early* 1990s was too tight. See, for example, Bernanke and Gertler (1999) and Ahearne et al. (2002). But these studies may not explain the deflation since the late 1990s, when monetary policy has been sufficiently loosened.

not be the primal cause of the tightening; instead, the emergence and persistence of nonperforming debts may be the most promising factor that tightens the constraints. We also clarify the nature of financial arrangements and political distortions concerning debt restructuring that may lengthen the recession.

In this paper, we show that persistent tightening of borrowing constraints may be a useful building block for literature in which researchers try to account for historic business cycle episodes using quantitative dynamic general equilibrium models. For example, Christiano, Motto, and Rostagno (2004) try to account for the US Great Depression, and Christiano and Fujiwara (2005) for the 1990s in Japan. They incorporate many twists into a standard neoclassical growth model based on Christiano, Eichenbaum, and Evans (2005), the key features of which are habit persistence, variable capital utilization, adjustment costs for capital formation, and nominal rigidities.[3] The tightened borrowing constraints may be useful to improve the models if they are combined with habit persistence, adjustment costs in investment, and the like. The constraints may also be regarded as an alternative to a hypothesis that Christiano and Fujiwara adopt to explain the decline in labor input during the 1990s in Japan, i.e., tightened working-hour regulation.[4] The regulatory change may be a useful hypothesis but is unique to Japan, while declines in labor input and deterioration of labor wedges have been commonly observed in both the US Great Depression and Japan's recession. (There is also another episode: Ahearne, Kydland, and Wynne [2005] report the deterioration of a labor wedge in Ireland.) Our hypothesis of the borrowing constraints can be used to account for not only Japan but also the US Great Depression and others.[5]

The organization of the paper is as follows: In the next section, we present the basic model with an exogenous borrowing constraint, and show that a tightening of the

[3]Bernanke, Gertler, and Gilchrist (1999) put financial frictions in a similar setting.

[4]The change in labor policy is modeled as a sudden decline in the total endowment of time for the representative consumer.

[5]Borrowing constraints also seem to be a useful ingredient in the model of a small open economy for explaining the "Sudden Stops" observed in emerging economies. See, for example, Mendoza and Smith (2004).

constraint can consistently account for the above puzzling observations. In Section 3, we endogenize the borrowing constraint so that borrowing is constrained by the corporate value of the borrower. In this generalized model, we show that a sudden emergence of nonperforming debts and the existence of political or institutional distortions that delay debt repayment are both necessary to produce a persistent tightening of the borrowing constraint. We also show that the emergence of persistent nonperforming debts and an exogenous decline of productivity are both necessary for the endogenous model to account for the three puzzles consistently. In Section 4, we propose a modified model, in which firms own the shares of other firms and the shares work as collateral for the shareholders' debts. In this case, the emergence of persistent nonperforming debts alone can account for the above puzzles without resorting to an exogenous decline of productivity. Section 5 provides some concluding remarks.

2 The basic model - Exogenous borrowing constraints

The basic model is a dynamic general equilibrium model, which can be regarded as a simplified version of Einarsson and Marquis (2001). A borrowing constraint of a type proposed by Kiyotaki and Moore (1997) and Kocherlakota (2000) is incorporated in it.

The banking sector, nominal currency, and the monetary authority are explicitly introduced in this model, as in Einarsson and Marquis. All these features are relevant only to monetary policy issues. They could be abstracted away if we did not analyze monetary policy, and the model would become simpler. We decided, however, to pay the cost of complication of the model, since the implications for monetary policy seem quite important.

The economy is a variant of the discrete time neoclassical growth model, which is composed of consumers, firms, banks, and one government. Throughout this paper, we assume for simplicity of the analysis that there is no aggregate nor idiosyncratic risk. Later we analyze the dynamics in the case where the economy is hit by an unexpected macroeconomic shock, which tightens borrowing constraints for firms. We simply assume that the initial shock is unexpected in the sense that it is a measure zero event, and that it never occurs again.

2.1 Structure

The economy is populated with a continuum of consumers with identical preferences, whose measure is normalized to one. There are also continua of firms and banks with measure one, respectively.

Consumer

A representative consumer maximizes the following utility:

$$\sum_{t=0}^{\infty} \beta^t U(c_t, n_t), \tag{3}$$

where β is the discount factor ($0 < \beta < 1$), c_t is the consumption in year t, and n_t is the labor input sold to firms for production. In each year t, the consumer is endowed with 1 unit of time, which can be divided into labor and leisure. Thus, $1 - n_t$ is the amount of leisure that the consumer can enjoy in year t. The flow utility $U(c_t, n_t)$ is concave, twice-differentiable, and increasing in both consumption (c_t) and leisure ($1 - n_t$). In order to simplify the analysis, the functional form for $U(c, n)$ is specified as

$$U(c, n) = \ln c + \gamma \ln(1 - n),$$

where γ (> 0) is a positive parameter. The consumer's income consists of wage $w_t n_t$ and the returns from financial assets: Cash M_t, bank deposits D_t, and corporate shares s_t. Thus, the consumer's problem is written as follows:

$$\max_{c_t, M_{t+1}, D_{t+1}, s_{t+1}} \sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$$

subject to

$$c_t + p_t M_{t+1} + p_t D_{t+1} + q_t s_{t+1} \leq w_t n_t + p_t M_t + (1 + r_{dt}) p_t D_t + (\pi_t + q_t) s_t, \tag{4}$$

where p_t is the inverse of the nominal price of consumer goods, q_t is the real price of corporate shares, w_t is the real wage rate, r_{dt} is the nominal deposit rate, and π_t is the dividend from one unit of corporate shares. The consumer takes w_t, p_t, q_t, r_{dt}, and π_t as given. Note that the representative consumer does not maximize the *expected value* of the discounted sum of future utilities, since we assumed that there is no aggregate risk in this model. The first-order conditions (FOCs) for the consumer's problem imply that

$$\lambda_t = \frac{\beta^t}{c_t}, \tag{5}$$

$$w_t = \frac{\gamma c_t}{1 - n_t}, \tag{6}$$

$$q_t = \frac{1}{\lambda_t} \sum_{i=1}^{\infty} \lambda_{t+i} \pi_{t+i}, \tag{7}$$

where λ_t is the Lagrange multiplier for (4). Comparing the FOCs for M_{t+1} and D_{t+1}, it is easily shown that $M_{t+1} = 0$ if $r_{dt+1} > 0$, and

$$p_t = \frac{\beta c_t}{c_{t+1}} (1 + r_{dt+1}) p_{t+1}. \tag{8}$$

Firm

There exist identical firms that compete in a perfectly competitive market. The ownership of the firms is traded as corporate shares, the measure of which is normalized to one. We assume for simplicity that the consumers own all corporate shares. (An assumption that firms can invest in the corporate shares of other firms does not change the basic results in this section. See Section 4 for a modification of the model in which firms own other firms' shares.) A representative firm generates the following real profits in each year t:

$$\pi_t = A k_t^{\alpha} n_t^{1-\alpha} - [k_{t+1} - (1 - \delta) k_t] - (1 + r_{bt}) p_t L_t, \tag{9}$$

where the firm produces $A k_t^{\alpha} n_t^{1-\alpha}$ units of consumer goods from capital input k_t and labor input n_t, δ is the depreciation of capital, r_{bt} is the loan rate, and L_t is the nominal amount of bank loans that the firm borrows in year $t - 1$. As in Einarsson and Marquis (2001), we assume that loan L_t is used to finance the portion of the firm's working capital expenses consisting of its wage bill in year t, $w_t n_t$. Different from Einarsson and Marquis, we assume that loan L_t is provided in the form of a bank deposit, which earns interest $r_{dt}L_t$ before the firm pays the wage bill in year t. Thus, the wage bill and the bank loan satisfy

$$w_t n_t = (1 + r_{dt})p_t L_t. \tag{10}$$

As a basic model, we introduce an exogenous borrowing constraint for the firm like that in Kocherlakota (2000):

$$(1 + r_{bt})p_t L_t \leq b_t, \tag{11}$$

where b_t is an exogenous real limit of borrowing. The firm can borrow from banks in such a way that the repayment in year t does not exceed b_t. The parameter b_t represents the firm's limited ability of commitment. In Sections 3 and 4, we generalize this model so that b_t is endogenously determined. The firm acts in the interest of shareholders and maximizes the present value of the dividend stream. Therefore, the firm's problem is written as follows:

$$\max_{k_{t+1}, n_t} \sum_{t=0}^{\infty} \lambda_t \pi_t$$

subject to (10) and (11), where the firm takes p_t, w_t, r_{dt}, r_{bt}, and $\lambda_t (= \frac{\beta^t}{c_t})$ as given parameters. If the borrowing constraint is not binding, the FOC for n_t implies that

$$(1 - \alpha) A \left(\frac{k_t}{n_t} \right)^{\alpha} = \frac{1 + r_{bt}}{1 + r_{dt}} w_t. \tag{12}$$

If the borrowing constraint is binding, equations (10) and (11) imply that

$$n_t = \frac{b_t}{\frac{1+r_{bt}}{1+r_{dt}} w_t}. \tag{13}$$

In both cases, the FOC for k_{t+1} implies that

$$\lambda_t = \lambda_{t+1} \left[\alpha A \left(\frac{n_{t+1}}{k_{t+1}} \right)^{1-\alpha} + 1 - \delta \right]. \tag{14}$$

Bank

There are identical banks in a perfectly competitive market. A representative bank's liabilities consist of interest-bearing deposit accounts X_t, and its asset consist of reserves

Z_t and loans L_t^s. All these variables are nominal. The nominal profit of the bank in year t is

$$\Pi_t^b = (1 + r_{bt})L_t^s + Z_t - (1 + r_{dt})X_t. \tag{15}$$

As in Einarsson and Marquis (2000), we assume that the consumers own all banks. Although we omitted bank shares in the consumer's problem, this omission is justified, since competition among banks always makes banks' profit zero in the equilibrium. A bank, which acts in the interest of shareholders, solves the following problem:

$$\max_{Z_t, L_t^s, X_t} \sum_{t=0}^{\infty} \lambda_t p_t \Pi_t^b,$$

subject to a balance sheet constraint

$$L_t^s + Z_t = X_t, \tag{16}$$

its reserve requirements

$$Z_t \geq \zeta X_t, \quad 0 < \zeta < 1, \tag{17}$$

where ζ is the reserve requirement ratio, and the nonnegativity constraints (Z_t, L_t^s, X_t $\geq 0, \forall t$). Assuming that $r_{dt} > 0$, it is easily shown that in the equilibrium where $\Pi_t^B = 0$ for all t, the reserve requirements bind and that

$$r_{bt} = \frac{r_{dt}}{1 - \zeta}. \tag{18}$$

Government

The government determines the nominal deposit rate r_{dt} and the nominal bank reserves Z_t. It is shown in the next subsection that r_{dt} and Z_t are not independent in the equilibrium as long as $r_{dt} > 0$. The government supplies cash $M_t + Z_t$ passively to consumers on demand.

2.2 Equilibrium dynamics

The equilibrium condition for consumer goods is

$$c_t + k_{t+1} - (1 - \delta)k_t = Ak_t^{\alpha} n_t^{1-\alpha}. \tag{19}$$

Given k_0, the equilibrium path of $\{c_t, n_t, k_{t+1}\}_{t=0}^{\infty}$ is determined by (5), (6), (12) (or [13]), (14), and (19). In the case where the borrowing constraint is not binding or b_t is constant, the initial consumption c_0 is chosen so that the equilibrium path converges to the steady state.

Given the initial price p_0 and the sequence $\{c_t\}_{t=0}^{\infty}$, the inflation rate is determined by (8).

The equilibrium condition for bank loans is $L_t = L_t^s$, and that for bank deposits is $X_t = D_t + L_t$, since bank loans are provided to firms in the form of deposits. The balance sheet identity of the bank and the reserve requirements imply that $Z_t = D_t$, and $Z_t \geq \frac{\zeta}{1-\zeta} L_t$. The firm's problem implies that $L_t = \frac{w_t n_t}{(1+r_{dt})p_t}$. Therefore, Z_t is determined by

$$Z_t \geq \left(\frac{\zeta}{1-\zeta}\right) \frac{w_t n_t}{(1+r_{dt})p_t}. \tag{20}$$

Note that this relationship between Z_t and r_{dt} holds with equality if $r_{dt} > 0$. Thus, (20) uniquely determines the value of Z_t in the equilibrium if the government sets r_{dt} at a positive value. If, on the other hand, the government sets $r_{dt} = 0$, the bank reserve Z_t (and the consumers' deposits D_t) may be arbitrarily larger than the value on the right-hand side of (20).

2.3 Simulation

We set $\alpha = 0.3$, $\beta = 0.98$, $\gamma = 2$, $\delta = 0.06$, $\zeta = 0.1$, and $A = 1$. We assume that the economy was initially in the steady state where the nominal deposit rate was $r_{dt} = \frac{1}{\beta} - 1$, so that inflation is zero from equation (8), and the borrowing constraint was slightly binding. The initial value of b_t was 0.37 for $t < 0$. Thus the initial capital stock was $k^* = 2.0094$, the steady state value. In year 0, an unexpected macroeconomic shock hits the economy and the value of b_t becomes small, so that the borrowing constraint is tightened from year 0 onward.

We conduct two simulations: In one case, $b_t = b$ for all $t \geq 0$, where b $(= 0.3)$ is small; and in the other case, b_t becomes smaller gradually. Initially, $b_0 = 0.335$, and thereafter the borrowing constraint is tightened, so that $b_t = 0.335 - 0.0025 \times t$ for $1 \leq t \leq 14$, and $b_t = 0.3$ for all $t \geq 15$. In both cases, the equilibrium path is calculated on the premise that the government chooses one of the following two monetary policies: either unchanged at $r_{dt} = \frac{1}{\beta} - 1$ for all t, or monetary easing that sets $r_{dt} = 0$ for $t \geq 0$.

To compute the equilibrium path, we use a variant of the shooting method in which we solve the system of the difference equations backward from a point in the neighborhood of the new steady state and find the path that satisfies the initial condition: $k_0 = k^*$. We use this computation method for all simulations in this paper.

Figure 2 shows the simulation results for the case where $b_t = 0.3$ for all $t \geq 0$ and $r_{dt} = \frac{1}{\beta} - 1$ for all t. Since the difference in monetary policy does not change the simulation results essentially except for the inflation rate, we show only the inflation rate for the case of $r_{dt} = 0$ in the last panel of Figure 2. Figure 3 shows the simulation results for the case where b_t decreases gradually and remains at a low level from date 15 onward. In Figure 3 as well, all the panels except for the last one show the results for the case where $r_{dt} = \frac{1}{\beta} - 1$; the last panel shows the inflation rate for the case of $r_{dt} = 0$.

Figure 2. Dynamics with exogenous borrowing constraints (b_t constant)

Figure 3. Dynamics with exogenous borrowing constraints (b_t declines gradually)

These simulation results show that labor input, investment, and the labor wedge jump down in year 0 and stagnate afterwards; consumption and capital stock decrease gradually and converge to the new steady state where $b_t = 0.3$. These features seem consistent with the (detrended) performance of the economy during the US Great Depression and the 1990s in Japan.

Labor wedge

As for the first puzzle for the depression episodes, the simulation results for the labor wedge are consistent with recent empirical findings. Since wage bills are financed by bank loans, the tightening of the borrowing constraint makes labor more expensive for firms, which therefore reduce their demand for labor. Thus, we can interpret the persistent tightening of the borrowing constraint as a persistent demand shock that is observed as a deterioration of the labor wedge.[6]

Investment wedge

The decreases in investment and steady-state capital stock are a natural consequence of the decrease in labor input. Let us focus on a steady state. Equation (14) implies that $\frac{n}{k} = \left[\frac{\beta^{-1}-1+\delta}{\alpha A}\right]^{\frac{1}{1-\alpha}}$. Therefore, $\frac{n}{k}$ does not change even if b changes, and the decrease in the equilibrium value of n leads to the decrease in k. In other words, since labor input decreases, capital stock must also decrease to restore the marginal product of capital. The following can be said about the second puzzle concerning the investment wedge: Since we assumed that the expenditure for investment is not subject to the borrowing constraint in this basic model, it is easily shown that the investment wedge will be zero for all t in the simulation. This is a straightforward result from comparing (2) and (14). The consistency between the performance of this model and the empirical findings concerning the investment wedge implies that most of investment expenditures may not be subject to borrowing constraints in reality, while working capital expenses, mainly wage bills, may be subject to constraints. In other words, this result implies that in reality any distortions (or information asymmetry) that generate borrowing constraints may be severe for wage bills and the like but not for investment expenditures.

Deflation and monetary policy

The third puzzle concerns deflation and monetary policy. First of all, note that since in this model monetary distortion is the only reserve requirement for banks, it is virtually obvious that the optimal monetary policy is to set the nominal deposit rate at zero for all t. We do not argue the optimality of monetary policy but just compare price paths in the cases of a constant-interest-rate policy in which $r_{dt} = \frac{1}{\beta} - 1$ and the zero-interest-rate policy in which $r_{dt} = 0$.

The simulation results show that if the government does not lower the nominal deposit

[6] Christiano and Fujiwara (2005) argue that labor input decreased in the 1990s in Japan because of tightened working-hour regulation; they interpret this regulatory change as a supply shock.

rate from $\frac{1}{\beta} - 1$, inflation occurs. This result seems counterfactual for a model of the depression episodes of the 1930s in the United States or the 1990s in Japan. But we are quite confident that if Calvo-type staggered wage contracts, which are modeled by Erceg, Henderson, and Levin (2000), were incorporated with our model, the initial response of prices would be deflation rather than inflation. This is because the tightened borrowing constraint reduces firms' demand for labor input, and this shrinkage of demand together with sticky wages may generate deflation through the mechanism described in the new Keynesian Phillips curve (see Woodford [2003] and references therein). We are planning to modify our model in this direction in future research.

The simulation also shows that a zero-interest-rate policy that sets $r_{dt} = 0$ brings about deflation as an equilibrium outcome. The mechanism by which deflation occurs is exactly the same as that by which the Friedman rule brings about deflation. Although the Friedman rule is usually described as a reduction of money supply at a constant speed (see, for example, Ljungqvist and Sargent [2000]), the zero-interest-rate policy in our model is compatible with (extraordinary) expansion of money supply. See (20) and the discussion that follows. The government can set r_{dt} at zero and Z_t at an arbitrarily large value simultaneously. In the equilibrium, $D_t(= Z_t)$ becomes large, but the inflation rate that is determined by (8) is still negative. This result may not be relevant to the US Great Depression, but it may be relevant to the quantitative easing policy in Japan. In this policy regime, the Bank of Japan set the nominal short-term rate at zero and also set a large target value of excess bank reserves. This policy is properly translated in our model into a policy to set r_{dt} at 0 and Z_t at a unnecessarily large value. Therefore, the simulation results shown in the last panels of Figures 2 and 3 imply that to set the nominal rate at zero in a quantitative easing policy may be to cause persistent deflation, while real distortions, represented by a large labor wedge, may be caused by a nonmonetary factor, i.e., the sudden and persistent tightening of borrowing constraints.

Monetary policy may be or may not be effective to mitigate real distortions caused by a tightening of borrowing constraints. If, as we argue in the next section, the sudden emergence of large nonperforming debts, which may be caused by an unexpected asset-price collapse, brings about a severe tightening of borrowing constraints, monetary easing may have a quite limited ability to mitigate the recession. If, on the other hand, the tightening of borrowing constraints is caused by, say, pessimistic expectations over monetary policy through unknown transmission mechanisms, monetary easing may be effective in loosening borrowing constraints. The welfare implication of our simulations is as follows: Since we assume that the borrowing constraint is exogenous for monetary policy, the effect of monetary easing (the zero-interest-rate policy) is negligibly small. The distortion caused by the reserve requirements for banks is mitigated, but it has a very small impact on the welfare of the representative consumer. On one hand, social welfare ($\sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$) in the case where the economy stays in the steady state with the borrowing constraint not tightened and $r_{dt} = \frac{1}{\beta} - 1$ is calculated to be -80.1873. On the other hand, social welfare in the case where $b_t = 0.3$ for all $t \geq 0$ is -80.3875 if $r_{dt} = \frac{1}{\beta} - 1$, and is -80.3669 if $r_{dt} = 0$. Therefore, the improvement of welfare due to monetary easing in our simulations is negligible compared with the impact of the tightening of the borrowing constraint.

If we introduce price or wage staggeredness as in Erceg et al. (2000), it may be shown that monetary easing can improve welfare a little more, but we are confident that the effectiveness of monetary policy due to nominal rigidities would be considerably smaller than the welfare loss due to an exogenous tightening of borrowing constraints. To confirm this conjecture is another topic for future research.

3 The general model - Endogenous borrowing constraints

In this section, we elaborate our idea about the causes of a sudden tightening of borrowing constraints. There are two problems that we need to address: The first problem is why the constraints should exist at all, and the second problem is what *tightened* the constraints at the onset of the depressions. The first problem concerns the nature of the distortions or information asymmetry that generate borrowing constraints. The second problem concerns the nature of the events that tighten the constraints.

3.1 Endogenous borrowing constraints and productivity declines

Kiyotaki and Moore (1997) propose a plausible theory that borrowing is constrained by the (fixed) assets that the borrower owns: If a borrower does not have an ability to precommit to the repayment, the amount he can borrow is limited by the value of the collateral that he can put up ex ante. In the Kiyotaki-Moore model, the borrower can abscond freely holding borrowed money, but at that time he cannot take the fixed assets (i.e., land) with him; therefore, the creditor can seize the assets and recapture the loss by selling them when the borrower absconds; anticipating this course of action, the creditor and the borrower agree ex ante that the borrowing is to be limited by the value of the fixed assets that the borrower owns.

We can easily incorporate the Kiyotaki-Moore theory with our model by replacing b_t in equation (11) with θk_t, where θ $(0 < \theta < 1)$ is an exogenous collateral ratio.[7] This specification of the borrowing constraint is theoretically simple and tractable. But since our strategy is to analyze the model's performance by numerical simulations, we need not constrain ourselves to the simplest form. Since in reality the borrowing limit seems to be related to the going-concern value of firms, we use the following constraint instead of (11) in the modified model in this section:

$$(1 + r_{bt})p_t L_t \leq \theta V_t, \tag{21}$$

where V_t is the going-concern value of the borrower, which is defined by

$$V_t = \frac{1}{\lambda_t} \sum_{i=1}^{\infty} \lambda_{t+i} \pi_{t+i}. \tag{22}$$

The modified borrowing constraint (21) can be regarded as a generalized form of the Kiyotaki-Moore type constraint, and can be justified by a similar argument as that in Kiyotaki and Moore (1997): The manager of the borrowing firm can freely abscond holding the borrowed money, while he has to leave the firm behind; therefore, if the manager absconds, the creditor can seize (a part of) the ownership of the borrower-firm;

[7] We assume that the borrower can take $1 - \theta$ of her assets with her when she abscond, while Kiyotaki and Moore (1997) assumed that all assets must be left behind.

anticipating the seizure, the creditor and the manager agree ex ante that the borrowing is to be limited by the corporate value of the firm.[8]

The equilibrium dynamics are determined by (5), (6), (8), (19), and

$$n_t = \frac{1}{w_t}\left\{\frac{\theta V_t}{\frac{1+r_{bt}}{1+r_{dt}}}\right\}, \tag{23}$$

$$(1-\alpha)A\left(\frac{k_t}{n_t}\right)^{\alpha} = \left(1+\frac{\mu_t}{\lambda_t}\right)\frac{1+r_{bt}}{1+r_{dt}}w_t, \tag{24}$$

$$\lambda_t = \left(1+\theta\frac{\mu_t}{\lambda_t}\right)\lambda_{t+1}\left[\alpha A\left(\frac{n_{t+1}}{k_{t+1}}\right)^{1-\alpha} + 1 - \delta\right], \tag{25}$$

where μ_t is the Lagrange multiplier for (21).

We set θ at a small value, 0.18, so that there does not exist a steady state equilibrium in which (21) is nonbinding. The economic variables in the steady state are obtained by numerically solving the following equations:

$$c + \delta k = A k^{\alpha} n^{1-\alpha}, \tag{26}$$

$$n = \frac{1-n}{\gamma c}\left(\frac{\theta V}{\frac{1+r_b}{1+r_d}}\right), \tag{27}$$

$$1 = \beta\left\{1-\theta+\frac{(1-\alpha)A\theta\left(\frac{k}{n}\right)^{\alpha}}{\frac{1+r_b}{1+r_d}\frac{\gamma c}{1-n}}\right\}\left[\alpha A\left(\frac{n}{k}\right)^{1-\alpha}+1-\delta\right], \tag{28}$$

$$V = \frac{\beta}{1-\beta}\left(Ak^{\alpha}n^{1-\alpha} - \delta k - \frac{1+r_b}{1+r_d}\frac{\gamma c}{1-n}n\right). \tag{29}$$

Our numerical calculations show that there are two solutions to the system of equations (26)–(29): one with a large k and the other with a small k. These two solutions satisfy the FOCs and the second-order conditions for the firm's problem, so that both of them are local optima. But we find that only the solution with a smaller k survives as the steady

[8]This argument crucially depends on our assumption that there is no uncertainty in this model. Equation (21) implies that the corporate value (or the asset price) V_t is realized at the time of repayment. If V_t is a random variable at the time of loan contracting, the borrowing constraint must be much more complicated in form, since it must be derived as the solution of the optimal contracting problem between agents who have rational expectations toward V_t. For simplicity, it is assumed as in Kiyotaki and Moore (1997) that the future path of the corporate value $\{V_t\}_{t=0}^{\infty}$ is perfectly foreseen by the agents.

state equilibrium.[9] See footnote 10 for details.[10] So in what follows in this subsection, we pick a solution to (26)–(29) with a smaller k as the (possibly) unique steady state.

We calculate the steady state equilibrium where $A = 1$ as a benchmark: The allocations become $k = 2.1207$, $n = 0.3094$, and $c = 0.4240$; the labor wedge, $1 - \tau_l$, defined by (1) is 0.9847; and the investment wedge, $1 + \tau_x$, defined by (2) is 0.9698.

Did productivity declines tighten borrowing constraints? The most straightforward candidate for the cause of the sudden tightening of the borrowing constraint in this model is an exogenous decline of productivity, A. We confirm by numerical calculation, however, that a decline of A cannot account for the observations in the depression episodes. We numerically calculate the variables in the steady states where $A = 0.9$ or less and compare the results with the benchmark where $A = 1$. It is shown that capital stock k, consumption c, and corporate value V become smaller in a steady state corresponding to a smaller A. But the labor wedge is invariant for different values of A. The invariance of the labor wedge is analytically proven not only for the logarismic utility function but also for any type of utility function. See Appendix A for the proof. We also calculate the transitional dynamics of the economy, which is initially in the steady state where $A = 1$ and is hit by a shock in year 0 that lowers A permanently. The economy gradually converges to the new steady state where A is small. In this transition, the labor wedge is *improved* slightly and returns gradually to the original value.[11]

[9]Note that this argument is not a rigorous proof for the uniqueness of the steady state equilibrium, but a description of our numerical findings.

[10] Denote the variables in the solution with a smaller k by subscript 1 and those in the solution with a large k by subscript 2. Call the two solutions "State 1" and "State 2," respectively. Suppose that the economy is in State 2. Given that the initial capital stock is k_2, a firm obtains the discounted present value of V_{12} by choosing k_1 and n_1, where $V_{12} = k_2 - k_1 + \frac{\beta}{1-\beta}\left[Ak_1^{\alpha}n_1^{1-\alpha} - \delta k_1 - \frac{1+r_b}{1+r_d}w_2 n_1\right]$. If $V_{12} > V_2$, all firms are better off by choosing k_1 and n_1 in State 2, implying that State 2 cannot be sustainable. We numerically showed that this is exactly the case, i.e., $V_{12} > V_2$. We also confirmed that $V_{21} < V_1$, implying that no firms deviate from State 1 if all the other firms choose k_1 and n_1. This argument shows that State 1 is the (possibly) unique steady state equilibrium.

[11]We also compute the transitional dynamics of the model in the case where productivity A does not change but the future expectations for A decline. The economy is initially in the steady state where

Since the deterioration of the labor wedge is the central puzzle that a theory must explain, the above results imply that a productivity decline is not a plausible cause of the tightening of borrowing constraints.[12]

We also analyzed a different model in which land is used as collateral and examined the performance of the model in the case where an unexpected shock decreases the productivity of land. The result, which is briefly described in Appendix B, is counterfactual: Capital stock k increases in response to the decline of land productivity. Thus, a decline of land productivity cannot account for the depressions on its own either.

There is a caveat for our conclusion that productivity declines are not a plausible factor that accounts for the puzzling features in depression episodes. The above results crucially depend on the simplicity of our model (e.g., nonexistence of adjustment costs for investment). If we introduce a different set of assumptions, such as those in Christiano, Eichenbaum, and Evans (2005), productivity declines may generate plausible outcomes. But we do not explore in this direction, since in this paper we would like to maintain a simple neoclassical growth model with as few nonstandard assumptions as possible. To specify the setup of a model in which productivity declines solely generate plausible outcomes is a topic for future work.

3.2 Emergence of large debts and obstacles to debt repayments

Assuming that a sudden tightening of borrowing constraints is the correct explanation for the US Great Depression and the 1990s in Japan, we need to clarify the driving force that brought about the sudden tightening. As we discussed in the previous subsection, a decline of productivity A can explain the decline of θV_t, the right-hand side of (21), but

$A = 1$ and is hit by a shock in year 0 that makes all agents believe that A will become 0.95 in year 10. Parameter θ is set at 0.05 for convenience in numerical calculation. In the transition period between years 0 and 9, the labor wedge declines, while labor input remains at the same value as that in the initial steady state, and investment increases. These features are inconsistent with the actual depression episodes, in which both labor input and investment decreased.

[12]This conclusion also holds for the Kiyotaki-Moore type model in which the borrowing constraint is $(1 + r_{bt})p_t L_t \leq \theta k_t$ instead of (21).

it cannot explain the deterioration of the labor wedge.

Our conjecture is that what is necessary is the emergence of large nonperforming debts subsequent to an unexpected collapse of asset prices.

During several years until the asset-price collapses in 1929 in the United States and in 1990 in Japan, firms and households accumulated debts and assets in accordance with the rise of asset prices. When the asset prices collapsed, people suddenly noticed that their debts were backed by nothing. We do not attempt to explain why asset-price "bubbles" are generated and why they collapsed; we simply assume that an unspecified exogenous shock generated a large asset-price fluctuation that left large debts in the corporate sector.

These events can be described in our model as a sudden and unexpected emergence of large debts, N_0, in year 0 in firms' balance sheets. If a firm has inherited a debt, N_t, from year $t-1$, the borrowing constraint (21) becomes

$$(1 + r_{bt})p_t(L_t + N_t) \leq \theta V_t, \tag{30}$$

showing that the borrowing constraint is tightened by the debt.[13] Although it is obvious that the constraint is tightened by the emergence of the debt, it may not last for a long time. In what follows, we show that in order for the tightening of the borrowing constraint to remain for years, there must be some political or institutional distortion that prevents firms from repaying their debts as completely as they want to.

To show this result, we now examine the case where firms are subject to no restrictions in repaying debts. We maintain the assumption that firms act in the interest of their shareholders. Therefore, the firm's problem becomes

$$\max_{n_t, k_{t+1}, N_{t+1}} \lambda_t \pi_t^n,$$

where $\pi_t^n = Ak_t^\alpha n_t^{1-\alpha} - [k_{t+1} - (1-\delta)k_t] + p_t[N_{t+1} - (1 + r_{bt})N_t] - (1 + r_{bt})p_t L_t$, subject to (10) and (30). In this problem, we assume that the firm can freely choose the amount

[13] Lamont (1995) also analyzes the adverse effect of corporate-debt overhang. In the Lamont model, the existing debts constrain the amount of new borrowing and thus reduce aggregate investment. He focuses on the adverse effect of debt overhang on investment expenditure, while we address the relationship between the debt problem and labor input.

of repayment, $p_t[(1 + r_{bt})N_t - N_{t+1}]$, where N_{t+1} is the debt that is carried over to the next year.[14] The first-order condition for N_{t+1} implies that

$$\lambda_t p_t = (1 + r_{bt+1})(\lambda_{t+1} + \mu_{t+1})p_{t+1}, \tag{31}$$

if $N_{t+1} > 0$, where μ_t is the Lagrange multiplier for (30) and thus $\mu_t \geq 0$. Equations (8) and (31) imply that if $N_{t+1} > 0$, it must be the case that $(r_{bt+1} - r_{dt+1})p_{t+1}\lambda_{t+1} + (1 + r_{bt+1})\mu_{t+1}p_{t+1} = 0$. This equation does not hold as long as $r_{dt+1} > 0$. Therefore, if the government sets the nominal deposit rate at a positive value in year 1, firms optimally choose $N_1 = 0$, i.e., they repay all the debts in year 0, and the tightening of the borrowing constraint does not continue.[15]

The above argument implies that once-for-all emergence of large debts is not sufficient to explain a persistent tightening of borrowing constraints. The persistent tightening may be explained by successive reemergence of debts during the first several years of a depression and/or by institutional or political obstacles in repaying debts (e.g., collusive forbearance policy by firms, banks, and the government). Since the asset-price deflation continued for several years in both depression episodes in the US and Japan, it seems plausible to assume in our model that there are multiple shocks that generate large debts for the first several years. The multiple-shock story may not be sufficient, however, since

[14]The corporate value, V_t, in (30) is still defined by (22) using π_t, not π_t^n. This is because the value that the creditor of N_t can recapture by seizing the firm in the event of default is the discounted present value of the flow of π_ts, not π_t^ns.

[15]In this argument, we ignored the restriction that $\pi_t^n \geq 0$. If the debt repayment becomes large, the nonnegativity of dividends may be violated. But it is easily shown as follows that for realistic parameter values, this restriction does not bind. Since $(1 + r_{bt})p_t L_t$ is the labor share of the output, which is approximately 0.7 of the total output in reality, and $k_{t+1} - (1 - \delta)k_t$ is investment, which is approximately 0.1 of the total output in reality, the remaining amount that can be used for repayment of debts is approximately 0.2 ($= 1 - 0.7 - 0.1$) of the total output. Therefore, if the debt, N_0, is less than 0.2 of the total output, firms can repay all debts at date 0 without violating the constraint $\pi_0^n > 0$. The total amount of nonperforming loans during the entire period of the 1990s in Japan is said to have been about 100 trillion yen (0.9 trillion US dollars), which is about 0.2 of the annual gross domestic product of Japan. Therefore, the assumption that the initial amount of debts, N_0, is less than 0.2 of the total output is quite realistic.

the above argument implies that all debts are repaid immediately after the shocks are gone. This feature is not consistent with empirical findings. Chari et al. (2002, 2004) show that the labor wedge deterioration continued throughout the 1930s, and Mulligan (2002) shows that it continued at least until 1950.

A more realistic hypothesis is the existence of institutional obstacles or political distortions that prevent firms from repaying their debts optimally. Anari, Kolari, and Mason (2002) report that asset liquidations of nationally chartered banks lasted on the average for over six years during the US Great Depression and argue that their data series suggests that perverse effects of the banking crises did not end with the bank holiday of March 1933 but persisted well into the late 1930s. This research implies that bankruptcy practices of firms and banks might have been inefficient compared with today's standard and that this inefficiency in the corporate restructuring process might have delayed the reduction of large nonperforming debts in the 1930s in the United States.

The type of political distortion that seems typical for the 1990s in Japan is a collusive forbearance policy (see, for example, Peek and Rosengren [2003] and Caballero, Hoshi, and Kashyap [2004]). It is a widely accepted view that throughout the 1990s firms, banks, and the government decided to roll over huge bad loans in the hope of an asset-price recovery, which would turn nonperforming loans into performing ones. A symbolic episode is the bankruptcy of Sogo, a major department store chain. The Sogo group filed under the Civil Rehabilitation Law on July 12, 2000, with its total debt mounting up to nearly 2 trillion yen (16 billion dollars). Just as astonishing as the amount of Sogo's debt was the testimony before the National Diet by Masao Nishimura, head of the Industrial Bank of Japan, Sogo's largest creditor. On July 17, 2000, he confessed in the Diet that his bank had known six years before Sogo's bankruptcy that the department store group was insolvent. During the six years, Sogo doubled the amount of its debt. The Sogo case is only one example of the prevalent forbearance and procrastination in the 1990s. Journalists reported successively throughout the 1990s that many *de facto* insolvent companies were being kept alive by the rolling over of bad loans.

3.3 Dynamics with debts and a productivity shock

In order to formalize the arguments in the previous subsection, we assume that the rate of debt repayment $\{v_t\}_{t=0}^{\infty}$ is given exogenously, where $v_t(1+r_{bt})p_t N_t$ is the real amount of debt repayment by a firm. Therefore, the amount of debts evolves by $N_{t+1} = (1-v_t)(1+r_{bt})N_t$. We also assume that banks are the creditors of the nonperforming debts N_t. There is a caveat for the interpretation of N_t: Although we interpret in this paper that N_t represents a "nonperforming debt" or "bad debt," no distinction is drawn between nonperforming (or bad) debts and good debts in the formal model below; as long as firms have a large debt N_t from banks subject to the above exogenous rates of repayment, the model has the same outcomes; therefore, we can interpret alternatively that N_t is just a long-term debt.

The basic model is changed as follows: The consumer's problem is unchanged; the firm's problem is to maximize $\sum_{t=0}^{\infty} \lambda_t \pi_t^v$, subject to (10) and (30), where $\pi_t^v = Ak_t^{\alpha} n_t^{1-\alpha} - [k_{t+1} - (1-\delta)k_t] - v_t(1+r_{bt})p_t N_t - (1+r_{bt})p_t L_t$; and the bank's problem is

$$\max_{Z_t, L_t^s, N_t^s, X_t} \sum_{t=0}^{\infty} \lambda_t p_t \Pi_t^{nb},$$

where $\Pi_t^{nb} = (1+r_{bt})(L_t^s + N_t^s) + Z_t - (1+r_{dt})X_t$, subject to (17), the nonnegativity constraints, and

$$L_t^s + N_t^s + Z_t = X_t, \tag{32}$$

instead of (16), where N_t^s is the amount of bad loans.[16] In the equilibrium, equation (18) holds, $\Pi^{nb} = 0$, $L_t^s = L_t$, $N_t^s = N_t$, and $D_t = Z_t + N_t$.

The equilibrium dynamics of the economy are described by (5), (6), (8), (19), (24), (25), and

$$n_t = \frac{1}{w_t} \left\{ \frac{\theta V_t - (1+r_{bt})p_t N_t}{\frac{1+r_{bt}}{1+r_{dt}}} \right\} \tag{33}$$

instead of (23).

[16] Note as we mentioned in the above caveat that there is no distinction in this formal model between bad and good loans. We can interpret N_t^s as just a long-term loan, the law of evolution of which is given exogenously.

Before we analyze the dynamics, we compute the steady state where the real value of the nonperforming debt $p_t N_t$ is constant at N to see the basic features of the model. In order to keep the real value of the debt constant, we need to assume that $v_t = 1 - \frac{p_t}{(1+r_{bt})p_{t+1}}$, i.e., firms are allowed to repay only the (real) interest on the debt. The steady state in which the real value of the debt is N is the solution to the system of equations (26), (28), (29), and

$$n = \frac{1-n}{\gamma c} \left(\frac{\theta V - (1+r_b)N}{\frac{1+r_b}{1+r_d}} \right) \tag{34}$$

instead of (27). We numerically solve the above system of equations and find that there are two solutions, only one of which survives as a steady state equilibrium by the same reasoning as in footnote 10. We calculate the steady states corresponding to various values of N, while keeping A at 1. In this case, the labor wedge is worsened and the investment wedge is improved as N increases. This result is consistent with the actual depression episodes. But steady-state capital stock k and corporate value V also increase as N increases. This result is counterfactual, since in actual depression episodes the deterioration of the labor wedge coexists with declines in (detrended) capital stocks. The economic intuition behind this result is rather simple: An increase in N tightens the borrowing constraint and therefore makes k more valuable as collateral, since the borrowing is limited by V, which is an increasing function of k; since k becomes more valuable, investments become more profitable for firms, or, in other words, the investment wedge is improved; and therefore the investments are enhanced and the steady state values of k and V increase. A simple but theoretically problematic modification of the model in this section may enable the tightened borrowing constraint alone to account for the decrease in k. We explore this possibility in Appendix C.

Numerous trials and errors in calculations by computer showed us that both the productivity declines and the emergence of debts are necessary under the endogenous borrowing constraint to account for the depression episodes.[17] It seems plausible to assume that the emergence of bad debts is associated with a negative productivity shock.

[17] This conclusion also holds for the Kiyotaki-Moore type model in which the borrowing constraint is $(1 + r_b)p_t(L_t + N_t) \leq \theta k_t$.

In the steady state where $A = 0.9$ and $N = 0.02$, the allocations are $k = 2.0149$, $n = 0.3081$, and $c = 0.3662$. The labor wedge is 0.9564 and the investment wedge is 0.9019. Comparison with the steady state where $A = 1$ and $N = 0$ (see Section 3.1) implies that in the steady state with lower productivity and a positive amount of debts, the capital stock and labor input both decrease, while the labor wedge is worsened and the investment wedge is improved. These features are consistent with the observations in actual depression episodes. A noticeable point is that the improvement of the investment wedge seems too large, since it improved only slightly in the actual depression episodes (see Kobayashi and Inaba [2005]). We can easily make the improvement of the investment wedge smaller by a plausible modification of the model by assuming $w_t n_t + k_{t+1} - (1 - \delta)k_t = (1 + r_{dt})p_t L_t$ instead of (10). That is, if investment expenditure is also subject to the borrowing constraint, the investment wedge does not improve very much. (In the modified model, $1 - \tau_l = 0.9270$ and $1 + \tau_x = 0.9052$ if $A = 1$ and $N = 0$, and $1 - \tau_l = 0.9130$ and $1 + \tau_x = 0.8847$ if $A = 0.9$ and $N = 0.02$. This result implies that the improvement of the investment wedge becomes moderate under this modification. To save space, we do not report the detailed results of this modification here.)

We show the transitional dynamics of the economy from the steady state where $A = 1$ and $N = 0$ to that where $A = 0.9$ and $N = 0.02$ in Figure 4. It is assumed that the economy was in the former steady state until year 0; and that in year 0 an unexpected shock hits the economy and A becomes 0.9 and N becomes 0.02 permanently. We conduct the simulation for both $r_{dt} = \frac{1}{\beta} - 1$ for all t and $r_{dt} = 0$ for $t \geq 0$. Since the movements of real variables are qualitatively the same for both cases, we show in all panels except the last one the results for the cases where the government sets $r_{dt} = \frac{1}{\beta} - 1$ for all t; the last panel shows the inflation rate in the case where $r_{dt} = 0$ for $t \geq 0$.

Figure 4. Transitional dynamics with debts and a productivity decline

The results are qualitatively the same as Figures 2 and 3. There are slight improvements: Labor input falls slowly, while investment jumps down on impact. The movements of these variables seem more close to actual data than those in Figures 2 and 3. On the other hand, the labor wedge jumps up on impact and then falls gradually to the lower steady state value. Compared with the other figures, the rise on impact of the labor wedge is unique to Figure 4 and is caused by the decline of productivity A. One may consider this jump as counterfactual and regard it as a ground to judge that the model in this section is inferior to that in the next section. The implication of this simulation for the inflation rate is the same as that in Section 2: The zero-interest-rate policy that sets $r_{dt} = 0$ brings about persistent and moderate deflation, while the real distortion, represented by the labor wedge, also persists because of the tightening of the borrowing constraint. Social welfare ($\sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$) is -86.7831 in the case where $r_{dt} = \frac{1}{\beta} - 1$ and is -86.7762 in the case where $r_{dt} = 0$. It would be -79.9255 if the economy stayed in the original steady state where $A = 1$ and $N = 0$. The welfare effect of monetary policy is negligibly small.

Implications for asset prices Corporate value V is 2.116 in the steady state where $A = 1$ and $N = 0$, while it is 1.924 in the steady state where $A = 0.9$ and $N = 0.02$. It is shown in our numerical calculation that a decrease in A *per se* decreases steady-state corporate value V, and an increase in N increases V. The result implies that the effect of a productivity decline on corporate value is dominant. Since corporate value represents asset prices in this model, it can be said as follows: If the productivity decline and the nonperforming debts in combination are the causes of persistent recession, the resolution of the debt problem that makes $N = 0$ may bring about economic recovery by eradicating real distortions caused by the labor wedge, but it may not bring about the recovery of asset prices.

4 The model with collateralizable corporate shares

In this section, we introduce a twist in the portfolio structure of firms so that the borrowing is not directly limited by a borrower's own value. With this (realistic) complication of corporate balance sheets, the emergence of large debts can account for the puzzling observations in depression episodes without resorting to a decline of productivity.

Although the structure of the model is slightly more complicated than the model in

Section 3, only one exogenous factor can account for the observations, while two factors are necessary in the model of Section 3.3. From the principle of parsimony, one may judge the model in this section to be superior as a hypothesis for the puzzling observations in the depressions.

The twist we introduce is mutual shareholdings among firms (see the following subsection for formal arguments). We assume that firms issue bonds to finance buying shares and that, in the end, the firms mutually hold corporate shares and the consumers hold corporate bonds. Financial assets, i.e., corporate shares, work as collateral for loans to the holder-firms. Mutual shareholding among firms might seem to be an unnecessary twist theoretically. But it seems quite realistic as a description of corporate balance sheets just after the collapse of a speculative bubble. This is because in the periods of a speculative boom, when share prices skyrocket, firms buy shares of other firms, by issuing debts. This is what happened during the booms in the late 1920s in the United States and in the late 1980s in Japan.[18] Although it seems realistic, whether mutual shareholding is optimal in whatever sense is a theoretically important question. Since we do not introduce aggregate or idiosyncratic risk in the model of this paper, we cannot judge whether the financial arrangements in Sections 2 and 3 or this section can provide the optimal form of risk-sharing among firms and consumers. We must say, as Christiano et al. (2004), that we have not explored whether the distribution of risk associated with our market arrangements is optimal or even close to optimal. We leave this for future research.

4.1 Structure

The key assumptions are as follows: Consumers cannot hold corporate shares directly; they hold corporate bonds, which are nominal bonds with the gross rate of return $1+r_{dt}$;[19] firms buy and hold other firms' shares using money they get by issuing bonds; and a firm's borrowing from a bank for wage bills is limited by the corporate shares that it owns

[18] There is also the well-known fact that Japanese firms developed cross-shareholding as a long-lasting structure of the postwar Japanese economy. See, for example, Miyajima (2004).

[19] We assume just for simplicity that corporate bond B_t has the same rate of returns as bank deposits.

as financial assets. Therefore, in the model of this section, a firm is a shareholder for other firms, and the shares work as collateral for working capital loans to the holder-firm.

According to the above assumption, the model in Section 3.3 is modified as follows. The consumer's problem is

$$\max_{c_t, M_{t+1}, D_{t+1}, B_{t+1}} \sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$$

subject to

$$c_t + p_t M_{t+1} + p_t\{D_{t+1} + B_{t+1}\} \leq w_t n_t + p_t M_t + (1 + r_{dt}) p_t \{D_t + B_t\}, \tag{35}$$

where B_t is the nominal amount of the corporate bonds. The real profits of a firm in each year t are

$$\pi_t^s = A k_t^{\alpha} n_t^{1-\alpha} - [k_{t+1} - (1-\delta)k_t] - (1+r_{bt}) p_t L_t - (1+r_{dt}) p_t B_t + \{\overline{\pi}_t + q_t\} s_t - v_t (1+r_{bt}) p_t N_t, \tag{36}$$

where $\overline{\pi}_t$ is the dividend from one unit of corporate shares and is exogenously given for the holder-firm, q_t is the share price, s_t is the amount of shares, and v_t is the exogenously determined rate of repayment. Note that we maintain the assumption in Section 3 that some political or institutional distortion prevents firms from repaying debts optimally. In the equilibrium, $\overline{\pi}_t = \pi_t^s$, $s_t = 1$, and $N_{t+1} = (1 - v_t)(1 + r_{bt})N_t$. The firm chooses k_{t+1}, n_t, and s_{t+1} in year t, to maximize the present value of the dividend stream subject to the constraints:

$$q_t s_{t+1} = p_t B_{t+1}, \tag{37}$$

$$w_t n_t = (1 + r_{dt}) p_t L_t, \tag{38}$$

$$(1 + r_{bt}) p_t \{L_t + N_t\} \leq \theta q_t s_t. \tag{39}$$

The reduced form of the firm's problem is

$$\max_{k_{t+1}, n_t, s_{t+1}} \sum_{t=0}^{\infty} \lambda_t \left\{ A k_t^{\alpha} n_t^{1-\alpha} - [k_{t+1} - (1-\delta)k_t] - \frac{1 + r_{bt}}{1 + r_{dt}} w_t n_t \right.$$
$$\left. + \left[\overline{\pi}_t + q_t - (1 + r_{dt}) \frac{p_t}{p_{t-1}} q_{t-1} \right] s_t - v_t (1 + r_{bt}) p_t N_t \right\}$$

subject to

$$\frac{1+r_{bt}}{1+r_{dt}}w_t n_t + (1+r_{bt})p_t N_t \leq \theta q_t s_t. \tag{40}$$

The bank's problem is identical to that in Section 3.3.

4.2 Dynamics

The FOCs for the consumer's problem imply that equations (5), (6), and (8) hold in the equilibrium. The FOCs for the firm's problem imply that

$$\lambda_t = \lambda_{t+1}\left[\alpha A\left(\frac{n_{t+1}}{k_{t+1}}\right)^{1-\alpha} + 1 - \delta\right], \tag{41}$$

$$(1-\alpha)A\left(\frac{k_t}{n_t}\right)^{\alpha}\lambda_t = \frac{1+r_{bt}}{1+r_{dt}}w_t\{\lambda_t + \mu_t\}, \tag{42}$$

$$\lambda_t q_t = \lambda_{t+1}[\overline{\pi}_{t+1} + q_{t+1}] + \theta q_{t+1}\mu_{t+1}, \tag{43}$$

where we used (8) to derive (43). From the binding borrowing constraint, n_t is determined as follows:

$$n_t = \frac{\theta q_t s_t - (1+r_{bt})p_t N_t}{\frac{1+r_{bt}}{1+r_{dt}}w_t}. \tag{44}$$

The equilibrium dynamics are determined by (5), (6), (8), (19), (41), (42), (43), (44), and the equilibrium conditions: $s_t = 1$, $\overline{\pi}_t = \pi_t$, and $N_{t+1} = (1-v_t)(1+r_{bt})N_t$. For simplicity, we assume that some political or institutional distortion makes

$$v_t = 1 - \frac{p_t}{(1+r_{bt})p_{t+1}},$$

so that the real value of the remaining debt, $p_t N_t$, is constant at N for all t.

We set all parameters at the same values as those in Sections 2 and 3. The productivity parameter A is assumed to be constant at 1 for all simulations in this section.[20]

Computing the steady states corresponding to various values of N, we find that capital stock k, consumption c, and labor input n decrease as N increases; and that the labor wedge is worsened (i.e, $1-\tau_l$ decreases) as N increases. The investment

[20]It is easily shown by virtually the same arguments as those in Appendix A that the labor wedge $1-\tau_l$ is the same for different values of A. This implies that in this model, a change in A on its own cannot explain the deterioration of the labor wedge.

wedge $1 + \tau_x$ is constant at 1 as N changes (this result is obvious from the comparison between equations [2] and [41]). These features are quite consistent with the puzzling observations in the depression episodes. What seems odd is share price q, which rises as N increases. This is because an increase in N tightens the borrowing constraint and makes corporate shares more valuable as collateral. Thus the model in this section has the same implication for share prices as the last paragraph of Section 3.3: Share prices may not recover even if debt N is removed.[21]

In Figure 5, we report the transition of the economy. Initially in the steady state where there are no bad debts, it is hit by an unexpected shock in year 0 that generates a nonperforming debt $p_0 N_0 = N$ in year 0. The economy converges to the new steady state where there is a positive amount of bad debt N. We set $N = 0.02$. We conduct two simulations, with $r_{dt} = \frac{1}{\beta} - 1$ in one case and $r_{dt} = 0$ in the other. Since the results are qualitatively the same in both cases, we report the results for the case of $r_{dt} = \frac{1}{\beta} - 1$ in all panels of Figure 5, except for the last panel, in which we report the inflation rate for the case of $r_{dt} = 0$. The results are plausible: Consumption and labor jump down on impact and then gradually fall to the new steady state values; investment jumps down on impact and then rises slightly; capital stock gradually falls to the new steady state value; the labor wedge jumps down on impact and then gradually falls; and the investment wedge is constant at 1. As anticipated from the comparison of steady states, the share price rises on impact. The inflation rate is positive in the case of $r_{dt} = \frac{1}{\beta} - 1$ and negative in the case of $r_{dt} = 0$. Social welfare ($\sum_{t=0}^{\infty} \beta^t U(c_t, n_t)$) is -80.1336 in the case where $r_{dt} = \frac{1}{\beta} - 1$ and is -80.1327 in the case where $r_{dt} = 0$. It would be -80.1316 if the economy stayed in the original steady state where $A = 1$ and $N = 0$. Therefore, the welfare effect of monetary policy is only about one-third of the adverse effect of nonperforming debts.

Figure 5. Transitional dynamics of the model with collateralizable corporate shares

[21] Since we informally argued that the emergence of bad debt N may be caused by an asset-price collapse, this implication seems problematic. But we do not need to judge the model counterfactual. Maybe the high asset price before the depression is a nonfundamental bubble, while the low price, i.e., the value of q corresponding to $N = 0$, is the fundamental price of the asset.

5 Concluding remarks

In this paper we explored a theory that explain three puzzling observations of the Great Depression in the United States and the 1990s in Japan: Persistent deterioration of the labor wedge; no deterioration or even improvement of the investment wedge; and protracted deflation under extraordinary monetary easing in Japan.

In Section 2, we showed that if firms need to finance wage bills using bank loans subject to a borrowing constraint, a persistent tightening of the constraint can coherently account for the puzzles. The tighter borrowing constraint implies a larger labor wedge; the investment wedge does not worsen if investment expenditure is not subject to the borrowing constraint; and deflation is a natural result of a monetary policy that fixes the nominal interest rate at zero, while the real distortion caused by the tightened borrowing constraint is not mitigated by the monetary policy.

It was shown that persistent tightening of borrowing constraints is best explained by an unexpected emergence of large debts and the existence of institutional or political obstacles that prevent firms from repaying their debts optimally. In the endogenous constraint model in Section 3.3, the emergence and persistence of large debts in combination with an exogenous decline of productivity can account for the puzzles. The endogeneity of the borrowing constraint leads to improvement of the investment wedge in response to the productivity decline and the debt emergence. In the collateral constraint model in Section 4, the problem of persistent bad debts solely accounts for the three puzzles, just like the basic model in Section 2.

In sum, the emergence and persistence of large bad debts in the corporate sector may be a major contributor to a protracted recession.

If debt repayment was delayed by collusive forbearance by firms, banks, and the government, which hoped for an economic recovery that would turn bad debts into good ones, it can be said that the models in Sections 3 and 4 deliver an ironic lesson for economic policy: Economic activities may have been forced into stagnation for a long time by the forbearance policy, even though the government, banks, and firms pursued this policy simply to endure the recession until the economy recovered spontaneously. If instead the forbearance policy had been terminated and bad debts disposed of quickly, borrowing constraints might have been loosened, and the economy might have escaped from the recession more quickly. In other words, a forbearance policy that causes large debts to remain may be a major cause of the lengthening of a recession brought on by an asset-price collapse. This lesson is precisely a theoretical translation of what Robert E. Rubin, the seventieth US Secretary of the Treasury, said about the Japanese in the 1990s (see the epigraph).

To incorporate the borrowing constraint in this paper into the quantitative business cycle models developed in recent literature (e.g., Christiano, Eichenbaum, and Evans [2005] and Bernanke, Gertler, and Gilchrist [1999]) will be a topic of our future work. If borrowing constraints can be incorporated with realistic twists, such as stochastic shocks, nominal rigidities, habit persistence, and adjustment costs for capital formation, they may be useful in accounting for, say, the observed productivity declines in depression episodes[22] and asset price dynamics. They may also be useful for assessing monetary policy in a more realistic environment.

6 Appendix

6.1 Appendix A: The invariance of the labor wedge under productivity changes

In this appendix, we show that in the model of Section 3.1 the steady-state labor wedge is invariant for different values of productivity A. We show that this invariance holds for any type of utility function. The system of equations that characterizes the steady state, i.e., (26)–(29), can be rewritten under the general utility function as follows:

$$c + \delta k = Ak^{\alpha}n^{1-\alpha}, \tag{45}$$

[22] Many researchers point to a decline in total factor productivity as a primal cause of great depressions: See Cole and Ohanian (1999), Ohanian (2001), and Chari et al. (2002, 2004) for the Great Depression in the United States; Hayashi and Prescott (2002) for Japan; Ahearne et al. (2005) for Ireland; and Kehoe and Prescott (2002) and references therein for other episodes and great depressions in general.

$$n = \frac{U_c}{-U_n}\left(\frac{\theta V}{\frac{1+r_b}{1+r_d}}\right), \tag{46}$$

$$1 = \beta\left\{1-\theta+\frac{(1-\alpha)A\theta\left(\frac{k}{n}\right)^{\alpha}}{-\left(\frac{1+r_b}{1+r_d}\right)\frac{U_n}{U_c}}\right\}\left[\alpha A\left(\frac{n}{k}\right)^{1-\alpha}+1-\delta\right], \tag{47}$$

$$V = \frac{\beta}{1-\beta}\left(Ak^{\alpha}n^{1-\alpha}-\delta k+\frac{1+r_b}{1+r_d}\frac{U_n}{U_c}n\right), \tag{48}$$

where U_c and U_n are the derivatives of the utility function with respect to consumption and the labor supply, respectively. The steady-state labor wedge is defined by

$$1-\tau_l = \frac{-\frac{U_n}{U_c}}{(1-\alpha)A\left(\frac{k}{n}\right)^{\alpha}}. \tag{49}$$

We define three variables x, y, and z by

$$x = \frac{c}{k}, \tag{50}$$

$$y = A\left(\frac{n}{k}\right)^{1-\alpha}, \tag{51}$$

$$z = \frac{-\frac{U_n}{U_c}}{(1-\alpha)A\left(\frac{k}{n}\right)^{\alpha}}\ (=1-\tau_l). \tag{52}$$

The system of the four equations (45)–(48) is converted by some algebra to the system of the following three equations for x, y, and z:

$$x+\delta = y, \tag{53}$$

$$y = \frac{1}{1+\frac{\beta\theta}{1-\beta}\left(\frac{1+r_b}{1+r_d}\right)}\frac{x}{z}, \tag{54}$$

$$1 = \beta\left\{1-\theta+\frac{z\theta}{\frac{1+r_b}{1+r_d}}\right\}\left[\alpha y+1-\delta\right]. \tag{55}$$

The economic variables in a steady state (i.e., c, n, and k) are calculated from equations (50)–(52), using the solution to the system of equations (53)–(55). It is obvious that the system of equations (53)–(55) is invariant to a change in A, implying that the steady-state labor wedge $1-\tau_l = z$ is invariant to a change in A. (End of proof)

6.2 Appendix B: A model with collateralizable land

One conjecture that can explain a sudden and persistent tightening of borrowing constraints is prevalent pessimism over (future) productivity of collateralizable assets, e.g., land. In this appendix, we formally posit this hypothesis and show that it cannot consistently explain a tightening of borrowing constraints and decline in capital stocks.

We assume that the firms' borrowing is constrained by the value of a collateralizable asset that the borrower owns. For simplicity, we assume that land is the only collateralizable asset and that the total supply of land is fixed at one. The firm can produce consumer goods from capital and labor by the production function, $Ak_t^{\alpha}n_{1t}^{1-\alpha}$, and also from land and labor by $Ba_t^{\eta}n_{2t}^{1-\eta}$, where a_t is the amount of land and n_{1t} and n_{2t} are labor inputs to capital and land, respectively.

The consumer's problem and the bank's problem are identical to those in Section 2.1. The firm's problem is

$$\max_{k_{t+1},a_{t+1},n_{1t},n_{2t}} \sum_{t=1}^{\infty} \lambda_t \pi_t$$

where

$$\pi_t = Ak_t^{\alpha}n_{1t}^{1-\alpha} + Ba_t^{\eta}n_{2t}^{1-\eta} - [k_{t+1} - (1-\delta)k_t] - [a_{t+1} - a_t]q_t^a - (1+r_{bt})p_t L_t,$$

and q_t^a is the market price of land, subject to

$$\begin{cases} w_t n_t = (1+r_{dt})p_t L_t, \\ (1+r_{bt})p_t L_t \leq q_t^a \theta a_t. \end{cases} \tag{56}$$

This problem is rewritten as

$$\max_{k_{t+1},a_{t+1},n_{1t},n_{2t}} \sum_{t=1}^{\infty} \lambda_t \left[Ak_t^{\alpha}n_{1t}^{1-\alpha} + Ba_t^{\eta}n_{2t}^{1-\eta} - [k_{t+1} - (1-\delta)k_t] - [a_{t+1} - a_t]q_t^a - \frac{1+r_{bt}}{1+r_{dt}} w_t n_t \right],$$

subject to

$$\frac{1+r_{bt}}{1+r_{dt}} w_t n_t \leq q_t^a \theta a_t. \tag{57}$$

Denoting the Lagrange multiplier for (57) by μ_t, the FOCs are

$$\lambda_t = \lambda_{t+1}[\alpha A x_{1t+1}^{1-\alpha} + 1 - \delta], \tag{58}$$

$$\lambda_t(1-\alpha)Ax_{1t}^{-\alpha} = \frac{1+r_{bt}}{1+r_{dt}} w_t n_t (\lambda_t + \mu_t), \tag{59}$$

$$\lambda_t(1-\eta)Bx_{2t}^{-\eta} = \frac{1+r_{bt}}{1+r_{dt}} w_t n_t (\lambda_t + \mu_t), \tag{60}$$

$$\lambda_t q_t^a = \lambda_{t+1}[\eta B x_{2t+1}^{1-\eta} + q_{t+1}^a] + \mu_{t+1}\theta q_{t+1}^a, \tag{61}$$

where $x_{1t} = \frac{n_{1t}}{k_t}$ and $x_{2t} = \frac{n_{2t}}{a_t}$. The equilibrium path is determined by (57) with equality, the above four FOCs, the resource constraint,

$$k_{t+1} = Ak_t x_{1t}^{1-\alpha} + Ba_t x_{2t}^{1-\eta} + (1-\delta)k_t - c_t, \tag{62}$$

and the equilibrium condition, $a_t = 1$. We numerically compute two steady states, in one of which B is large and in the other B is small. A noticeable feature of the simulation outcome is that the capital stock is larger in the steady state where B is smaller. The economic intuition behind this result is as follows: Since (58) holds in both steady states, x_1 is the same in both. This fact and equations (59) and (60) imply that x_2 (and n_2) is smaller in the steady state with a smaller B. Since we may assume that the amount of total labor supply $(n_1 + n_2)$ by the consumers does not change much between the two steady states, a smaller n_2 implies that n_1 is larger in the steady state with a smaller B. Since $x_1 = \frac{n_1}{k}$ is identical for the two steady states, a larger n_1 implies that capital stock k is larger in the steady state with a smaller B than in the steady state with a larger B. In summary, if the productivity of land B decreases, capital stocks become relatively more productive than land (and labor), and therefore firms will invest more in k.

This result implies a counterfactual prediction in the case where B decreases suddenly due to an exogenous shock: In this case, capital stocks would *increase*, while the borrowing constraint is tightened. This prediction is not consistent with the drastic shrinkages of investment and (detrended) capital stocks that were observed in the US Great Depression and the 1990s in Japan.[23]

6.3 Appendix C: A model with heavy information asymmetry

In this appendix, we explore a modification of the model of Section 3.3 that enables the tightening of the borrowing constraint to account for a depression, without resorting to

[23] We checked the model in the case where investment expenditure is also subject to the borrowing constraint: We replaced equation (57) by $\frac{1+r_{bt}}{1+r_{dt}}\{w_t n_t + k_{t+1} - (1-\delta)k_t\} \leq q_t^a \theta a_t$, and we compared the steady states for various values of B to find the same result that k increases as B decreases. We also found that k becomes smaller in a steady state where A is smaller; but in this case, the labor wedge $1 - \tau_l$ becomes larger. This is again inconsistent with the actual depression episodes.

an exogenous decline of productivity.

The modification is to change the firm's problem to maximize $\sum_{t=0}^{\infty} \lambda_t \pi_t^v$ subject to (10) and

$$(1 + r_{bt})p_t(L_t + N_t) \leq b_t \tag{63}$$

instead of (30), and to impose the equilibrium condition that the following equation must hold in the equilibrium:

$$b_t = \theta V_t. \tag{64}$$

The key difference from Section 3.3 is that the firm takes the borrowing limit b_t as an exogenous parameter, which equals θV_t in the equilibrium. In Figure 6, we report the transitional dynamics when an economy, which was initially in the steady state where $N = 0$, is hit by a macroshock that makes $N = 0.02$. We assume that productivity A is constant at 1 for all t. The economic variables and wedges exhibit plausible features. In particular, it is noticeable that capital stock k decreases without productivity change. Another noticeable point is that asset price $V_t - N$ rises, a movement we do not consider to be inconsistent. See footnote 21.

Figure 6. Transitional dynamics of the information asymmetry model

Therefore, if we adopt the above modification, the model implies that the emergence of persistent debts may be the sole cause of the puzzling features in depression episodes.[24]

There is, however, a theoretical difficulty in justifying this modification. This is because the model requires that corporate value be in some sense exogenous to the firm itself. One possible way to justify this is to assume serious information asymmetry between firms and banks (or investors in the stock market, i.e., consumers in the model). If banks cannot observe the firm's choice of variables $\{k_{t+1}, n_t\}_{t=0}^{\infty}$, they cannot know the exact value that they can recover when they seize the borrower-firm in the event of default; therefore, banks may set the limit of lending b_t at $\theta \overline{V}_t$, where $\overline{V}_t$ is the market average of corporate value. In this case, the firm's problem becomes what we described above. Even in the case where banks can observe $\{k_{t+1}, n_t\}$ of the borrower, they may

[24]Similar results are obtained even if we change the equilibrium condition (64) to $b_t = \theta k_t$.

set $b_t = \theta\overline{V}_t$, if we assume that a bank cannot operate the seized firm but needs to sell it in the market and that investors in the market cannot observe $\{k_{t+1}, n_t\}$ of the firm before they buy it.

The existence of serious information asymmetry between firms and banks may be regarded as a plausible assumption if we consider the working capital loan in the model to represent not only bank loans but also trade credits in reality. A supplier who provides trade credit to its customers may not have monitoring technology like banks and may be subject to serious information asymmetry, so that it cannot know the borrowers' choice of $\{k_{t+1}, n_t\}$.

Although these assumptions concerning information asymmetry may be questionable, the modified model delivers an interesting implication for economic policy: The emergence of persistent nonperforming debts may be the sole cause of real distortions, represented by decreases in both labor and capital; therefore, the resolution of the bad debt problem may bring about economic recovery, but it may not induce a rise in asset prices.

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Figure 1. Labor wedge in the 1990s in Japan

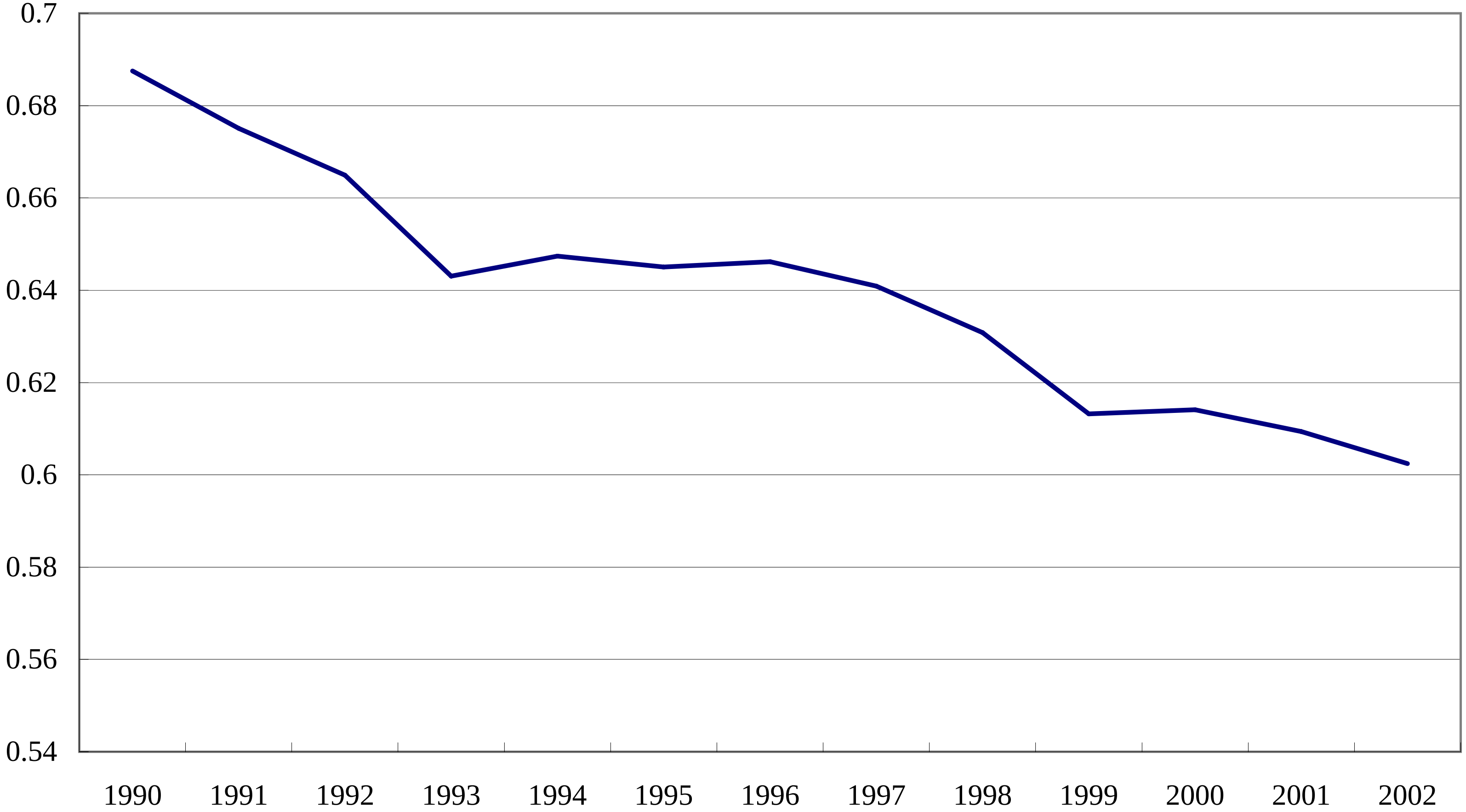

Figure 2. Dynamics with exogenous borrowing constraints (b_t constant)

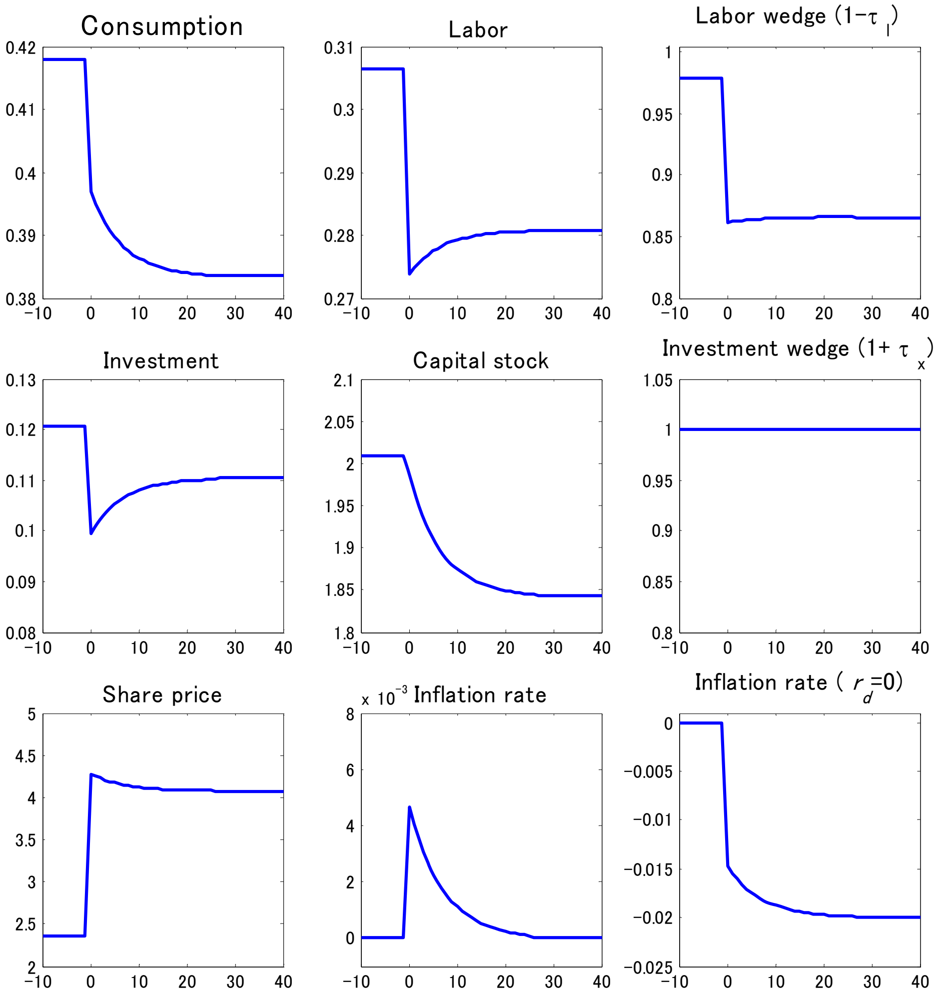

Figure 3. Dynamics with exogenous borrowing constraints (b_t declines gradually)

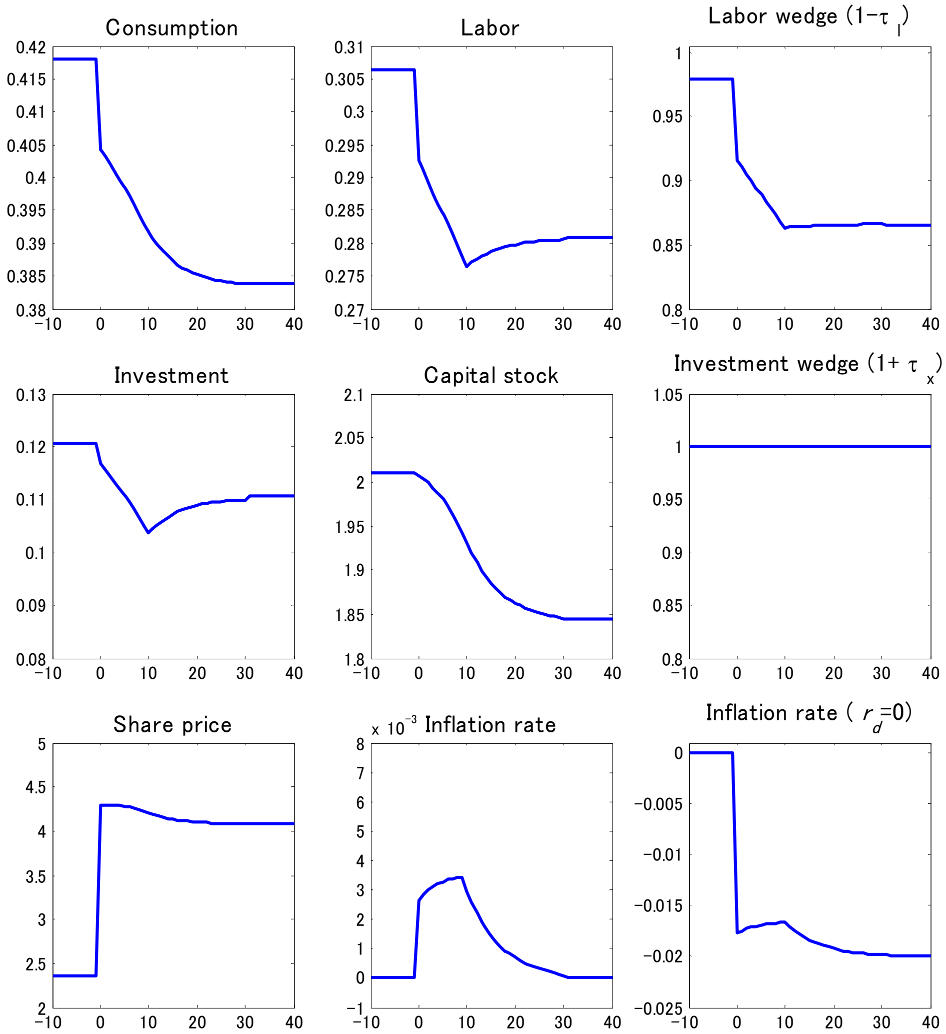

Figure 4. Transitional dynamics with debts and a productivity decline

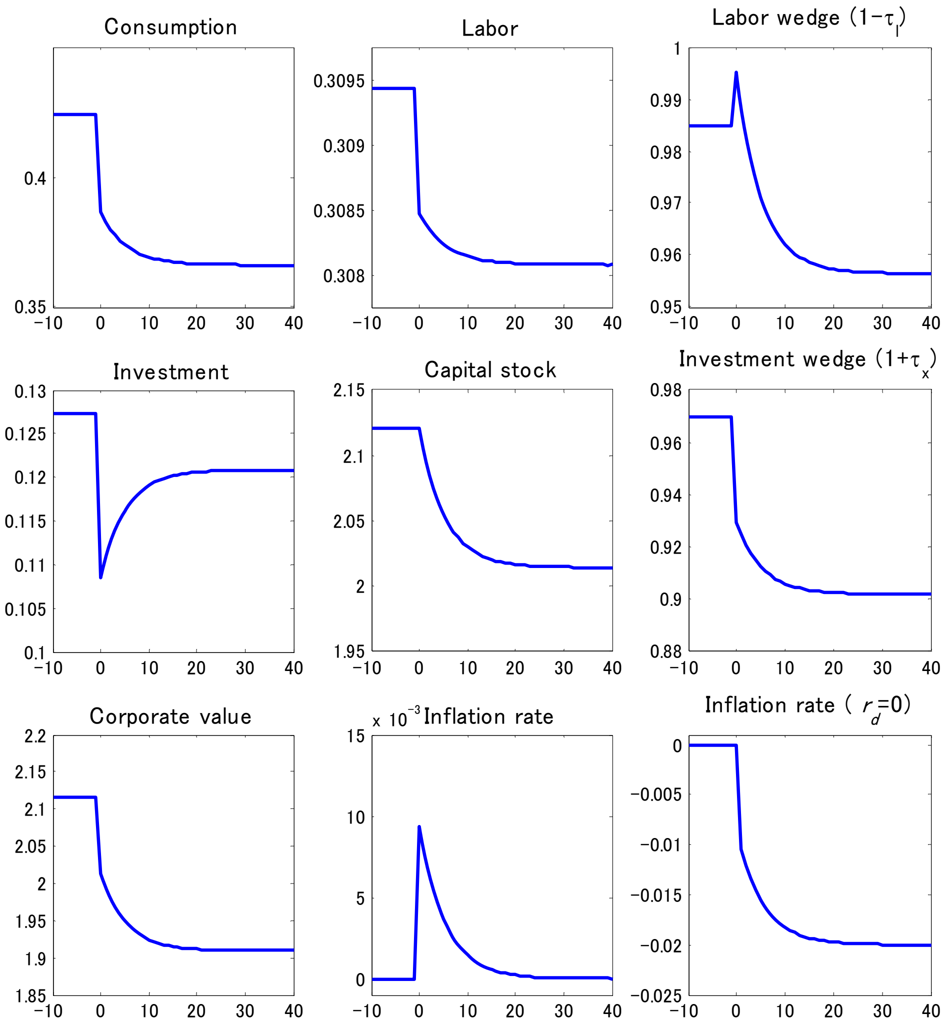

Figure 5. Transitional dynamics of the model with collateralizable corporate shares

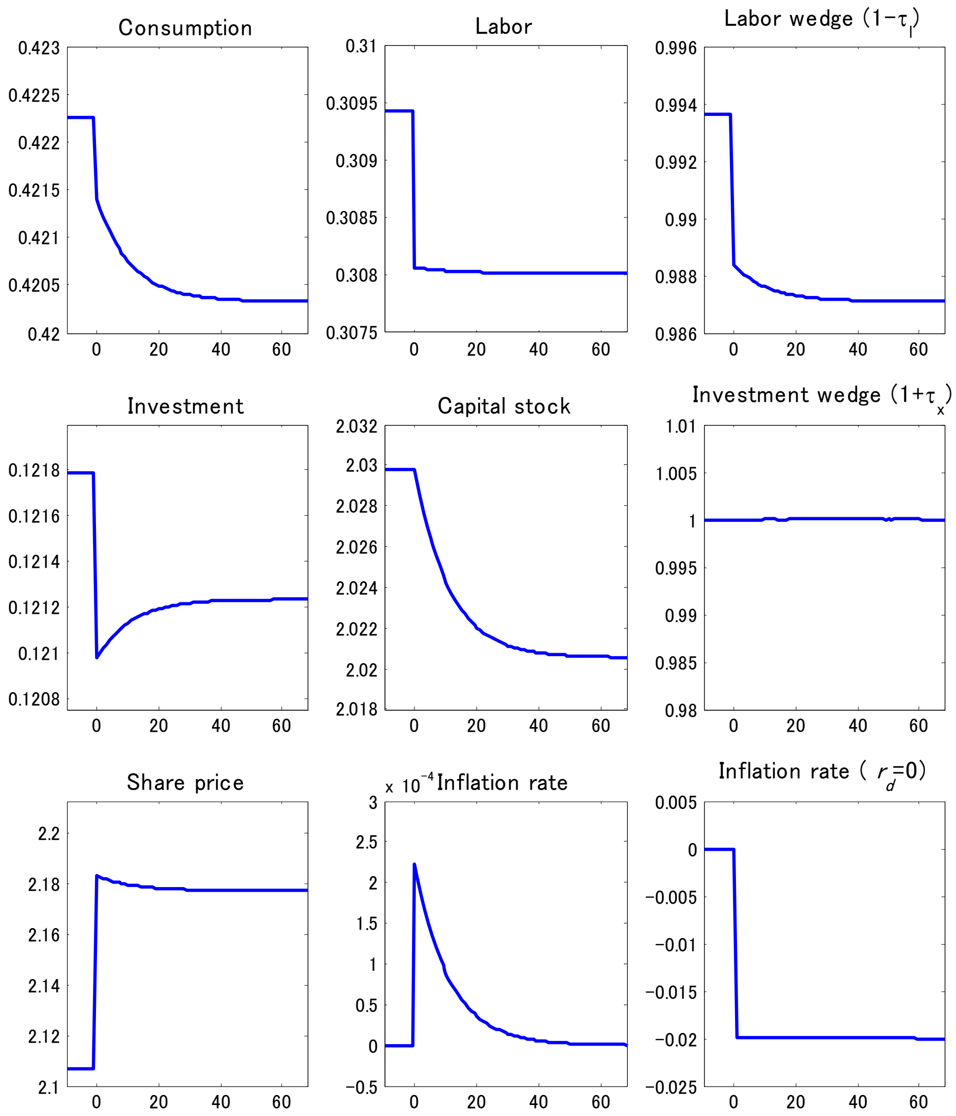

Figure 6. Transitional dynamics of the information asymmetry model