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Abstract

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JEL Classification: D21; G12; G20; G33.

Keywords: nonperforming loans; division of labor; relation-specificity; coordination failure; multiple equilibria.

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Abstract

The Japanese economy has suffered from three anomalies since the beginning of the 1990s: persistently low economic growth, continuously declining asset prices, and prevalence of procrastination over the serious problems of nonperforming loans (NPLs). We present the notion of a *complexity externality*: coordination failure by which inefficiency in one firm affects other firms' productivity through the network of the division of labor. A simple model illustrates that the spreading of the complexity externality, which was triggered by NPL problems, may lead the economy into a bad equilibrium where these anomalies become conspicuous. Our empirical results suggest that the Japanese economy shifted to a bad equilibrium at the beginning of the 1990s.

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1 INTRODUCTION

The last decade of the twentieth century for the Japanese economy is often described as "the lost decade." The performance of the economy was persistently poor over the decade, in which Japan suffered from three anomalies.

The first is the persistently low rate of economic growth starting from the beginning of the 1990s, when a significant kink in the growth rate occurred (See Figure 1). The average annual growth of real GDP was only 0.4% in the 1991–99 period except for 1995 and 1996, while it was 4.0% in the 1980s.

The second anomaly is the decade-long decline of asset prices. Figure 1 also shows the collapse of land and stock prices in Japan. Stock prices have stagnated at a very low level, and land prices have fallen steadily. Even in 2001, ten years after the asset-price bubble collapsed, land prices were still declining.

Figure 1. Growth Rate and Land and Stock Prices Indices

The initial decline of asset prices at the beginning of the 1990s generated a difficult problem for the Japanese economy. Since such corporate assets as land and buildings were traded on the premise that their prices would continue to rise, it turned out that many of those assets could not generate sufficient cash flow to cover their purchase prices once the asset-price bubble burst. Thus large amounts of the loans made in the late 1980s and early 1990s for the purchase of corporate assets became nonperforming or subperforming. Figure 2, showing the ratio of debt outstanding to operating surplus for nonfinancial businesses, indicates the serious indebtedness of the Japanese economy in comparison with other developed economies. Although differences in methods of data construction among countries rule out direct comparisons of indebtedness ratios, the growth rates of the ratios show significant contrasts. The indebtedness worsened only in Japan and was stable in the other countries, indicating slow adjustment to the problem of nonperforming loans (NPLs) in Japan and that recession pushed profits far down.

Figure 2: Ratio of Debt Outstanding to Operating Surplus for Nonfinancial Corporate and Quasi-corporate Enterprises

The third anomaly is in the response to this NPL problem by banks, corporations, and regulators. These three groups have a strong inclination for forbearance in calling loans in and for procrastination in restructuring debtors. General construction companies, realtors, and retailers were given successive concessions and opportunities to reschedule repayments throughout the 1990s. The bankruptcy of Sogo, a major department store chain, was symbolic. The Sogo group filed under the Civil Rehabilitation Law on July 12, 2000, with its total debt amounting 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, the head of the Industrial Bank of Japan (IBJ), 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 had been insolvent. 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 by banks. Figure 3

shows the amounts of NPLs that were disposed of by banks and that still remained on their balance sheets. Although banks wrote off NPLs at an accelerating speed in the 1990s, the remaining NPLs kept on growing, Not only were new NPLs created by the persistent recession, but loans that had been categorized as performing but actually were not were moved into the NPL category as banks gave up on badly battered companies.[1]

Figure 3. Nonperforming Loans Disposed of and Remaining

These three anomalies (slow economic growth, declining asset prices, and procrastination by economic agents) need to be coherently explained in a model of the Japanese economy. One possible explanation is that the economy experienced a big downturn because of a large but ordinary swing in the business cycle. But the slump of the economy seems too persistent to be a cyclical recession. In fact, policymakers in the 1990s initially regarded the slump as a cyclical downturn, and this made it embarrassing for them when business failed to pick up despite extraordinary monetary and fiscal stimulation throughout the 1990s. The short-term interest rate (the overnight rate of interbank loans) fell quickly in the first half of the 1990s, and it has been kept at zero for more than five years since 1995.[2] The government followed an expansionary fiscal course throughout the 1990s,[3] and this caused the public debt to snowball from 60% of GDP in 1990 to 120% at the end of 1999.

Despite this aggregate demand management, the situation in 2001 is even worse than it was in the 1990s. The ineffectiveness of the measures intended to prop up demand indicates that more than a cyclical swing is involved. There may also be underlying structural problems.

What has changed structurally? Japan did not experience a war or a natural disaster

[1]The official bank-inspection criteria used by the Financial Services Agency have ambiguous clauses that imply that a bank can, if it wishes, categorize a nonperforming loan as performing as long as the interest payments on it are kept up, even if there is little prospect of repayment of the principal.

[2]The Bank of Japan formally committed itself to keeping the short-term interest rate at zero only in April 1999, but the rate had been almost zero for four years before that.

[3]The government has adopted economic stimulus packages, which include supplementary budgets for additional public works and tax cuts, once or twice a year since 1992.

early in the 1990s, one that could have destroyed significant amounts of the economy's human or physical capital. The levels of knowledge and education, the demographic structure, and the allocation of physical resources did not change abruptly.

In our view, the key change was the emergence of a kind of externality at the beginning of the 1990s that moved the Japanese economy from one equilibrium where economic growth and asset prices were both high to another equilibrium where both are low. We regard the asset-price bubble of the late 1980s and its collapse at the beginning of the 1990s as exogenous shocks to the economy. In the following section we argue that the deterioration of balance sheets caused by the deflation of the bubble induced a *complexity externality*, which brought about inefficient economic performance. A complexity externality is, briefly stated, a coordination failure in the network of the division of labor, by which inefficiency of one agent is transmitted to many other agents in the same network. We argue that this inefficiency may not be removed by market competition since procrastination becomes the optimal behavior for economic agents in a case where the complexity externality has become extremely severe. The complexity externality and procrastination amplify each other, forming a vicious circle that can trap an economy in a stagnant equilibrium.

Our paper is organized as follows: In the next section we present a simple model of the complexity externality and explain how procrastination becomes optimal behavior. In Section 3 we review our model in the light of existing literature. In Section 4 we examine the empirical evidence. Section 5 provides concluding remarks.

2 MODEL

In this section we describe a simple and stylized model of the complexity externality (Subsection 2.1) and explain how debt contracts play the role of commitment devices that, in normal circumstances, minimize any complexity externality and lead to an optimal equilibrium (Subsections 2.2 and 2.4). Then we show that when an unexpected exogenous shock brings about too many defaults, rolling over bad loans becomes the optimal choice for banks (Subsection 2.5).

Essence of the Model We assume the division of labor enhances the productivity of firms. The activities of firms are complementary with one another in production technology, and thus there is a possibility of coordination failure among firms, since they are linked together by relation-specific technology and incomplete contracts. The debt contract serves as a device for firms to commit themselves to the division of labor. A macroeconomic shock can break apart the financial arrangements for these commitments by making many firms default. If the shock is large and asset prices plummet, the optimal choice for banks is to roll over bad loans. When banks behave in this way, the coordination failure among firms may become protracted.

Inefficiency in our model is not caused by shortages in capital supply (*credit crunch*) or by moral hazard of nonviable firms whose debts are rolled over (*soft budget*). The coordination failure triggered by the rollover of bad loans to some firms causes a *productivity decline* of all the other firms in the economy, working through the chains of production.

Economic Environment Time extends from 0 to infinity: $t = 0, 1, 2, \cdots, \infty$. Economic agents have unlimited access to investment opportunities in which investment at time t produces a return at time $t+1$ with the risk-free rate of interest r_t. The sequence $\{r_t\}_{t=0}^{\infty}$ is an exogenously given parameter. The economy consists of N entrepreneurs and M banks. We assume N and M are large integers: $N \gg 1$ and $M \gg 1$. There are also N firms, each of which is a nondepletable asset that produces output from input in every period.[4] For this model, we assume simply that the output and the input are the same good and that a firm only increases the amounts of the good. Firms are initially owned by unspecified owners and are sold in the market at the price V_t. The price V_t is fully specified in the equilibrium. Entrepreneurs and banks take the sequence $\{V_t\}_{t=0}^{\infty}$ as given. An entrepreneur buys a firm (at price V_t) in the market at time t, conducts production over period t, and sells the output and the firm (at price V_{t+1}) to unspecified

[4]In this paper we assume there is no entry (or exit) of firms. We can relax this assumption without qualitative change of our results, however, as long as the number of entry (or exit) is exogenous and sufficiently small compared with N and M.

owners in the market at time $t+1$.[5]

Time Table In every period between time t and time $t+1$, events take place in the following order. (The details of the events are described in the following subsections.)

Time t:

(1) An entrepreneur borrows from a bank;

(2) The entrepreneur buys a firm in the market;

(3) Firms form groups for a division of labor by random matching;

(4) Firms undertake production activity;

Time $t+1$:

(5) Firms obtain the output;

(6) Firms are hit by an idiosyncratic shock, with probability $(1-p)$, which destroys the output;

(7) In compliance with the debt contract, the entrepreneur sells the firm in the market and repays the bank, or the bank takes over the firm;

(8) If the bank takes over the firm, the bank chooses whether to sell it in the market or operate it in and after the next period.

Then, between times $t+1$ and $t+2$, the same eight events in the production process are repeated.

2.1 Production Technology and the Complexity Externality

The division of labor among specialized agents is one major source of the rise of productivity. Not only do the workers in a single workplace divide thier tasks among them

[5] We could construct a general equilibrium model in which all economic agents are specified and the market rate of interest is determined endogenously. In this paper, though, we describe a partial equilibrium model of entrepreneurs and banks, since our results do not change qualitatively in the general equilibrium setting, where several complications would have to be introduced.

(Smith [1776]), but also individual firms take part in production chains in which they form a division of labor and enhance their productivity.

The externality arises from the problem of coordinating among specialized firms in a chain of production. In this case, since firms' activities are interlinked with each other in the manner of the Leontief production function, a failure of one firm affects the productivity of many others in the same production chain. Our model of the division of labor among firms is a simplified version of the model developed by Becker and Murphy (1992).

Production Suppose that n firms need to form a network for a division of labor in order to conduct production in period t ($t = 0, 1, 2, \cdots$), where n is an exogenous parameter. Suppose that groups of n firms are formed by random matching at time t. Then, at time $t+1$, the network of n firms produces Y units of the final good in total by the following Leontief-type technology:

$$Y = A(n) \min\{y_1, y_2, \cdots, y_n\}. \tag{1}$$

Here,

$$y_i = \begin{cases} y_H & \text{or} \\ y_L & \end{cases} \tag{2}$$

is the production of intermediate goods (described below) by firm i ($i = 1, 2, \cdots, n$), and $A(n)$ is a productivity parameter. The parameters satisfy $y_H > y_L$. We assume that the n firms divide the final output equally so that each firm obtains $\frac{Y}{n}$ units of the final good. We also assume $A(n) = n$ for simplicity of exposition. Then each firm obtains

$$\min\{y_1, y_2, \cdots, y_n\} \tag{3}$$

units of the final good at time $t+1$.

We assume that firm i produces y_i units of intermediate goods from 1 unit of input. We also assume that, after the formation of the network of n firms, each firm chooses one of the following options for production of the intermediate goods: If the firm makes a relation-specific investment for the network at time t, it enhances the degree of its

specialization and can produce y_H units of intermediate goods at time $t+1$; if the firm does not make a relation-specific investment, it will produce y_L units of intermediate goods. We assume that part of the 1 unit of input is used for the relation-specific investment and that there is no need of additional input at the moment. But when the entrepreneur sells the firm (after the production) at time $t+1$, he or she must pay cost c for restoring the firm so that it can be used for general purposes. Thus, the entrepreneur will obtain $V_{t+1} - c$ by selling the firm at the market price V_{t+1}, if he or she makes the relation-specific investment at time t. We also assume an information asymmetry: A firm cannot observe whether the other firms in the same network invest or not.

Idiosyncratic Shocks If firms start production at time t, they obtain the output (3) at time $t+1$. We assume that after the firms in the network divide the final output among them, a firm is hit by an idiosyncratic shock with exogenous probability $(1-p)$, where $0 < 1-p \ll 1$. We assume that the shock destroys all the output of the firm before the firm pays back its financiers. (See Subsection 2.2 for a description of the debt contract.) The shock is i.i.d. across firms, and we can regard that approximately ratio $(1-p)$ of the total firms are hit by the shock.

Complexity Externality Assumption (20) in Subsection 2.4 for the parameter values implies that

$$p(y_H - y_L) > c. \tag{4}$$

In this case, there is the possibility of a coordination failure concerning a firm's choice of whether or not to make the relation-specific investment (c). If all the firms in the network choose to implement relation-specific specialization, then each firm obtains the net output $py_H - c$, and the economy attains the optimum. But if firm i anticipates that another firm in the same network (firm j) will not implement the investment, its best move is not to invest. Because firm j will produce only y_L, firm i would obtain only $py_L - c$ by investing.[6] Therefore, if the pessimistic view that at least one firm in

[6]This game between firm i and firm j is the hawk-and-dove game.

the network will not invest prevails, then all firms will choose rationally not to invest, and each firm obtains py_L. The pessimism thus traps the economy in a bad equilibrium where all firms choose inefficient production py_L.

This rough argument outlines the essential mechanism of the externality. We should emphasize that multiple equilibria can be reached in an economy because there is relation-specificity in production technology as well as incomplete information, or the incomplete contracting technology firms must employ. That is, if intermediate goods are not relation-specific to the network, a firm can gain an optimum return on its investment by selling intermediate goods y_H in the market. Similarly, if n firms can make use of contracts that are designed beforehand on the premise of relation-specific investments, or if they can penalize afterwards a firm that fails to make such an investment, then they will always attain the optimum. We have nonetheless assumed relation-specificity and incomplete contracts in our simple model of the Japanese economy because both are often observed in reality.

The extent of the external effect is shown in Subsection 2.5 to be correlated with the number of firms (n) in a chain of production. Since n represents the complexity of the network, we call the external effect that causes the bad equilibrium the *complexity externality*.

2.2 Debt as a Commitment Device

Our argument for a complexity externality assumes that a bad equilibrium can result from firms' expectation that other firms in their production network will not invest. Thus changeable macroeconomic expectations can move the economy from one equilibrium to another in this model. Though the model corresponds with some aspects of reality, it remains true that the business world has the capability to develop economic institutions avoiding multiple equilibria and attaining the optimum. In this subsection, we argue that debt contracts between banks and firms might have worked to steer the economy away from the bad equilibrium.

One of the main reasons that the mechanism of our model works in the fashion of

the hawk-and-dove game is that firms cannot mutually commit themselves to relation-specific investments because of the technological restriction of incomplete contracts. To solve this difficulty, firms can make use of financial contracts as a commitment device.

Debt Contract We make the following crucial assumption for our model:

Assumption 1 *The debt contract between the entrepreneur and the bank, and the ownership of the firm (see (D3) below), are observable for the other* $n-1$ *firms in the same network.*

The debt contract at time t between a bank and an entrepreneur is defined by the following set of (D1) to (D3):

(D1) The bank and the entrepreneur determine (D_t, R_{t+1}), where the bank lends D_t to the entrepreneur at time t, while the entrepreneur must repay R_{t+1} at time $t+1$ (after the production).

(D2) The entrepreneur buys a firm in the market and produces the final output from 1 unit of input.

(D3: Default) If the sum of the net output[7] and V_{t+1} is greater than or equal to R_{t+1}, then the entrepreneur repays R_{t+1} (by selling the firm in the market if necessary). Otherwise, the bank takes over the firm and the net output, and the entrepreneur is released (*limited liability*).

We assume that each entrepreneur has a certain amount of wealth. Thus the purchase of the firm and the input is financed partially by the entrepreneur (internal finance),[8] and the remaining sum is financed by a bank loan. We have assumed that a bank loan is the only available means of external finance for reasons that are not explicitly modeled in our paper, such as a principal-agent consideration based on information asymmetry between banks and firms (Gale and Hellwig [1985]). The limited liability in (D3) is a technological constraint for the debt contract. Thus the entrepreneur is released when

[7]The output is destroyed if an idiosyncratic shock hits the firm. The net output is the output minus cost of investment c if the firm implemented a relation-specific investment.

[8]Equity investment by shareholders is represented by internal finance in our model.

he or she defaults, even when his or her personal wealth is large enough to repay the debt.[9]

Choice for Banks If the firm defaults on the debt obligation, the bank takes over the firm. After taking over, the bank can choose one of the following two options:

(B1: Liquidation) The bank can sell off the remaining output and the firm in the market. The price of the firm is $V_{t+1} - c$ if the previous firm owner invested and V_{t+1} otherwise. The bank incurs the coordination cost z when selling off the firm.

(B2: Rollover of loans) The bank can continue to operate the firm by itself, without incurring coordination cost z. In this case, the bank must provide the firm with the cost of restoration c at time $t+1$, and it must undertake production employing the following inferior technology until it sells off the firm in the market.

If a bank determines not to liquidate the firm at time $t+k$ ($k = 1, 2, \cdots$.), it must operate the firm until time $t+k+1$, when it can choose either (B1) or (B2) again. In this case, the firm taken over by the bank must join a group of n firms, which is formed by random matching at time $t+k$; the bank must provide the 1 unit of input;[10] and the firm produces y_L units of intermediate goods. Accordingly, the bank (i.e., the owner of the defaulted firm) obtains y_L units of the final output. This production technology of the bank-owned firm is *inferior*, since the firm cannot make a relation-specific investment to produce y_H.[11]

We should explain why we assume that a bank incurs coordination cost z when it sells the defaulter. In reality, invoking bankruptcy of a debtor and/or disposing of NPLs are

[9] We assume that an entrepreneur's personal wealth is not observable by the creditor bank.

[10] We assume that if the bank (i.e., the firm owner) has another bank provide a part of the input, then the bank incurs the coordination cost z. This is because to accept another creditor is for the incumbent bank to become a junior claimant, which is equivalent to formally canceling (a part of) the past loan to the firm. The coordination cost z is a dead-weight loss associated with debt cancellation, as described in the text. Therefore, the bank must provide the defaulter with all of the necessary input if it is to avoid paying z at $t+k$.

[11] We can relax this assumption so that a bank-owned firm has the same production frontier as an entrepreneur-owned firm. Still, if we assume that bank-owned firms are so suspicious that they always choose not to invest when they face the hawk-and-dove game, we reach the same result.

costly for a bank. It is normal for a bank to incur a significant cost of coordination when one of its debtors fails. For example, the bank manager who is responsible for the bad loan usually opposes writing it off and insists on refinancing until the debtor recovers. By admitting the loss of the bad debt, the bank management may incur the risk of being sued by its shareholders for the loss.[12] For such reasons we consider it reasonable to posit that if a bank resorts to liquidation of a defaulter, it must pay the coordination cost z.

On the other hand, option (B2) of a loan rollover does not impose a coordination cost on the bank. In (B2), we implicitly model the situation where enforcement of corporate accounting rules is incomplete and bank managers can hide the true state of their bank. The bank can hide the insolvency of the debtor and postpone its bankruptcy only if it provides it with working capital (1 unit of input every period) and receives the inefficient outcome (y_L).

Optimal Capital Structure If the debt contract (D_t, R_{t+1}) between a bank and a firm is appropriately determined, the equilibrium where firms choose no investment can be effectively eliminated.

Given the market price of the firm $\{V_t\}_{t=0}^{\infty}$, the pair of (D_t, R_{t+1}) that satisfies the following condition guarantees that a firm will always invest:

$$y_L + V_{t+1} \leq R_{t+1} < y_H - c + V_{t+1}. \tag{5}$$

Suppose that all firms in a supply network are owned by entrepreneurs who have debt contracts with banks satisfying (5). In this case, the game of whether or not to implement the relation-specific investment does not have two equilibria. If a firm chooses not to invest, the firm owner (entrepreneur) obtains 0 no matter what the other firms' choices are, since the limited liability of the debt contract guarantees a nonnegative payoff for the firm. If and only if all firms in the network choose to invest, each firm owner

[12]The risk of a lawsuit gives an overwhelming disutility to bank managers in Japan, because they are not protected by limited liability against shareholders in the Commercial Code as of 2001.

obtains the positive expected surplus. Therefore, the dominant strategy for a firm owner (entrepreneur) is to make the investment.

If a firm owner (entrepreneur) does not have a debt contract satisfying (5), the payoff becomes positive by choosing not to invest. Thus the best strategy for the entrepreneur is no investment if another firm in the same network is expected to make the same choice. In what follows, we concentrate our attention on the case where the following pessimism prevails:

Assumption 2 *Entrepreneurs expect that an entrepreneur who does not have a debt contract with a bank satisfying (5) always chooses not to invest.*

Therefore, if an entrepreneur observes that there is a firm without a debt contract satisfying (5), he or she decides whether to invest on the premise that the other firm will choose not to invest.

2.3 Definition of Equilibrium

The equilibrium is the set of prices $\{r_t, V_t, (D_t, R_{t+1})\}_{t=0}^{\infty}$ and the net production $\{y_{it}\}_{t=1}^{\infty}$, where y_{it} is the net production of firm i $(i = 1, 2, \cdots, N)$ at time t, that satisfy the following conditions:

1. *Entrepreneur's Optimality*

Given $\{r_t, V_t, (D_t, R_{t+1})\}_{t=0}^{\infty}$, the entrepreneur i decides whether to implement the relation-specific investment to maximize the expected rate of return. Thus

$$y_{it} = \arg \max_{y \in \Lambda(y_{-i})} ROA(y), \tag{6}$$

where

$$\Lambda(y_{-i}) = \begin{cases} \{y_L, y_H - c\} & \text{if firm } i \text{ expects that all firms in the network invest,} \\ \{y_L, y_L - c\} & \text{otherwise,} \end{cases} \tag{7}$$

and

$$ROA(y) = \frac{p \max\{y + V_{t+1} - R_{t+1}, 0\} + (1-p) \max\{V_{t+1} - c(y_{it}) - R_{t+1}, 0\}}{V_t + 1 - D_t}, \tag{8}$$

where

$$c(y_{it}) = \begin{cases} c & \text{if } y_{it} = y_H - c \text{ or } y_L - c \\ 0 & \text{otherwise.} \end{cases} \tag{9}$$

The choice $y_{it} = y_H - c$ or $y_L - c$ means that entrepreneur i chooses to implement the relation-specific investment. There are two points to note on the entrepreneur's optimality. We can reasonably assume that

$$D_t < V_t + 1 \text{ for all } t, \tag{10}$$

because otherwise entrepreneurs can earn infinite profits by borrowing from banks, since the numerator of $ROA(y)$ is nonnegative.

Second, Assumption 2 guarantees that (7) defines $\Lambda(y_{-i})$ with no ambiguity: $\Lambda(y_{-i}) = \{y_L, y_H - c\}$ if all firms in the network are owned by entrepreneurs and have debt contracts that satisfy (5), and $\Lambda(y_{-i}) = \{y_L, y_L - c\}$ otherwise.

2. *Bank's Optimality*

Given $\{r_t, V_t, (D_t, R_{t+1}), y_{it}\}_{t=0}^{\infty}$, the bank chooses liquidation or loan rollover to maximize its expected rate of return when a debtor defaults. Thus

$$Q_{t+1} = \arg\max_{Q \in \Psi_t} ROA^b(Q), \tag{11}$$

where Q_{t+1} is the market value of a defaulted firm, which is determined as a result of the bank's choice of liquidation or loan rollover:

$$Q_{t+1} \in \Psi_t \equiv \{V_{t+1} - z, \beta_{t+1} p y_L - 1 + \beta_{t+1} Q_{t+2}\}, \tag{12}$$

where $\beta_{t+1} = \frac{1}{1+r_t}$, and

$$ROA^b(Q) = \frac{p\tilde{R}_{t+1} + (1-p)\tilde{S}_{t+1}}{D_t}, \tag{13}$$

where

$$\tilde{R}_{t+1} = \begin{cases} R_{t+1} & \text{if } R_{t+1} \leq y_{it} + V_{t+1} \\ y_{it} + Q & \text{otherwise,} \end{cases} \tag{14}$$

and

$$\tilde{S}_{t+1} = \begin{cases} R_{t+1} & \text{if } R_{t+1} \leq V_{t+1} - c(y_{it}) \\ Q - c(y_{it}) & \text{otherwise.} \end{cases} \tag{15}$$

Since $ROA^b(Q)$ is an increasing function of Q, the optimal choice by bank implies

$$Q_{t+1} = \max\{V_{t+1} - z, \beta_{t+1} p y_L - 1 + \beta_{t+1} Q_{t+2}\}, \tag{16}$$

which defines $\{Q_{t+1}\}_{t=0}^{\infty}$ recursively. If $Q_{t+1} = V_{t+1} - z$, then the bank chooses liquidation for the defaulted debtor.

3. *Equilibrium Condition*

The equilibrium $\{r_t, V_t, (D_t, R_{t+1}), y_{it}\}_{t=0}^{\infty}$ must satisfy the participation constraints of entrepreneurs and banks:

$$ROA(y_{it}) \geq 1 + r_t, \tag{17}$$

$$ROA^b(Q_{t+1}) \geq 1 + r_t. \tag{18}$$

Arbitrage in the asset market imposes the following condition for the equilibrium prices:

$$V_t = \frac{p}{1+r_t}\{y_{it} + V_{t+1} - z \cdot d_t(0)\} + \frac{1-p}{1+r_t}\{(V_{t+1} - c(y_{it})) \cdot (1 - d_t(1)) + (Q_{t+1} - c(y_{it})) \cdot d_t(1)\}, \tag{19}$$

where $d_t(\omega) = 1$ if the firm defaults and $d_t(\omega) = 0$ if the firm repays R_{t+1} to the bank, and $\omega = 1$ if the idiosyncratic shock hits the firm and $\omega = 0$ otherwise.

2.4 Optimal Equilibrium

In this subsection, we show the existence of the optimal stationary equilibrium where firms always invest and banks always choose liquidation when their debtors default. We also show that this equilibrium is unique, given that only entrepreneurs, not banks, buy the firms at the initial period (time 0).

We set the following assumption for the parameter values:

$$\beta p^{n-1}\{p(y_H - y_L) - c\} > z. \tag{20}$$

This condition is shown to be the sufficient condition for the existence and uniqueness of the optimal equilibrium. Before describing the optimal equilibrium, let us establish one observation:

Lemma 1 *The debt contracts that satisfy (5) become dominant in any equilibrium as the result of competition among banks.*

See Appendix 1 for the proof.

Next, we assume the following for simplicity of exposition:

$$r_t = r \quad (t = 0, \cdots, \infty) \tag{21}$$

Under this constant market rate of interest, we can construct a stationary equilibrium where the market price of a firm is also constant: $V_t = V$ for all t.

Existence of Stationary Equilibrium The existence of the optimal equilibrium is shown by construction. Define V_H by

$$V_H \equiv \frac{\beta(py_H - c - (1-p)z) - 1}{1-\beta}. \tag{22}$$

Suppose that $V_t = V_H$ for all $t \geq 0$. Assuming that $Q_{t+1} < \infty$ for all t, it is easily shown from assumption (20) that

$$Q_{t+1} = \max\{V_H - z,\ \beta p y_L - 1 + \beta Q_{t+2}\} = V_H - z, \tag{23}$$

where $\beta = \frac{1}{1+r}$. See Appendix 2 for the proof of (23). Thus banks always choose liquidation when a debtor defaults. Given $V_t = V_H$, if the debt contract (D_t, R_{t+1}) satisfies

$$\begin{aligned} &y_L + V_H \leq R_{t+1} < y_H - c + V_H \\ &pR_{t+1} + (1-p)(V_H - c - z) = (1+r)D_t, \end{aligned} \tag{24}$$

then the participation constraint for banks is satisfied, and the entrepreneur always invests as long as all firms in the network have the same debt contract. Since we assume $D_t < V_H + 1$ (see (10)), the entrepreneur will use his or her own money $(V_H + 1 - D_t)$ to buy a firm and 1 unit of input. Given that $V_t = V_H$ for all t and that all firms in the same network invest, the expected return for an entrepreneur who accepts the debt contract (D_t, R_{t+1}) satisfying (24) and implements the relation-specific investment is

$$ROA(y_H - c) = \frac{p(y_H - c + V_H - R_{t+1})}{V_H + 1 - D_t} = 1 + r.$$

Thus the participation constraint for entrepreneurs is also satisfied. Given the debt contract that satisfies (24), there is no room for Pareto improvement for the entrepreneur and the bank. Therefore, both banks and entrepreneurs under perfect competition are willing to accept the debt contract satisfying (24).

Given that the firm always invests, that the default occurs only when the idiosyncratic shock hits the firm, and that the bank always sells the defaulter, the equilibrium condition for the market value of a firm is the following:

$$V_t = \beta p(y_H + V_{t+1} - c) + \beta(1-p)(V_{t+1} - c - z) - 1,$$

which is satisfied by $V_t = V_{t+1} = V_H$.

In summary, the optimal equilibrium where the risk-free rate of interest r is a given constant is described as follows. The market value of a firm is V_H; entrepreneurs and banks who are under perfect competition agree on the debt contract (D_t, R_{t+1}) that satisfies (24); firms always choose to invest; and banks always choose to sell any defaulted firm. In this optimal equilibrium, the per capita output is large $(py_H - c - (1-p)z)$ and the asset price, i.e., the market value of a firm (V_H), is high compared with the bad equilibrium described in Subsection 2.5.

Uniqueness We can prove the following claim: If all firms are bought by entrepreneurs at time 0, then the optimal equilibrium is the unique competitive equilibrium.

Note that the optimal debt contract (D_t, R_{t+1}) satisfying (5) becomes dominant in any equilibrium (Lemma 1). Thus, in any competitive equilibrium, banks and entrepreneurs agree on the debt contract that guarantees that all firms invest.

The question, therefore, is whether there exists an equilibrium in which banks choose to roll loans over. If banks always choose liquidation in an equilibrium, the equilibrium must be the only optimal one (uniqueness). We will show by contradiction that banks will always choose liquidation. Given the sequence $\{V_t\}_{t=0}^{\infty}$, the condition for banks to choose liquidation at time 1 is $V_1 - z > Q_1$. Since all firms are owned by the entrepreneurs at time 0, ratio $1-p$ of the total firms are taken over by banks at time 1, since (5) guarantees that firms default if and only if they are hit by idiosyncratic shocks. We

consider the choice faced by a bank at time 1. Suppose that all the other banks choose the loan-rollover option. Then, the condition $V_1 - z > Q_1$ is rewritten as

$$\beta(p^n(y_H - y_L) + py_L - p^{n-1}c + pV_2 + (1-p)Q_2) - z > \beta(py_L + Q_2), \tag{25}$$

which is satisfied if (20) holds. (Note that the equilibrium condition for the market price of a firm implies $Q_2 \leq V_2$, since a firm sold in the market, whose value is V_2, can produce at least py_L, while a firm taken over and operated by a bank, whose value is Q_2, can produce at most py_L.)

Result (25) implies that a rational bank will choose liquidation even if all the other banks roll loans over. Therefore, in any equilibrium where all N firms are initially bought by the entrepreneurs at time 0, the banks always choose to sell off defaulted firms. The uniqueness is proved.

2.5 Unexpected Macroeconomic Shock and Emergence of Stagnant Equilibrium

Suppose that the economy is in the optimal equilibrium initially and that a temporary macroeconomic shock hits it unexpectedly at time τ (> 0). The macroeconomic shock changes the parameter p to P only at time τ where $1 - P$ is close to 1. We assume that the shock is temporary and that the original value of parameter p is restored from $\tau + 1$ on. Therefore, the output of $(1-P)N$ firms are destroyed at time τ before the repayment to the banks, and all $(1-P)N$ firms are taken over by banks at time τ.[13]

Given that $(1-P)N$ firms are taken over by banks at time τ and parameter P satisfies (27) below, there exist two equilibria. One is the optimal equilibrium described in Subsection 2.4. Given that $V_t = V_H$ for all $t \geq \tau$, the optimal choice for banks is liquidation, and the economy stays in the optimal equilibrium from τ on.

[13]We assume that the PN firms that are not hit by the shock are sold in the market at price V_H at time τ. Only after the PN firms are sold and the $(1-P)N$ firms are taken over by banks do we assume that asset price V_τ at time τ is revised abruptly as the result of the macroeconomic shock. At that point entrepreneurs buy the firms in the market, and banks determine whether to choose liquidation or loan rollover on the basis of a firm's price V_τ, which may not be equal to V_H.

In the other equilibrium banks will always choose loan rollover to defaulted debtors. We define V_t^L for $t \geq \tau$ recursively by

$$V_t^L = \beta\{Y_t + pP(t)V_{t+1}^L + (1 - pP(t))Q\} - 1 \text{ for } t \geq \tau, \tag{26}$$

where $P(t) = P^{n-1}p^{(n-1)(t-\tau)}$, $Y_t = P(t)\{p(y_H - y_L) - c\} + py_L$, and $Q = \frac{\beta p y_L - 1}{1-\beta}$. It is easily shown that the sequence $\{V_t^L\}_{t=\tau}^{\infty}$ is a monotonically decreasing sequence that converges to Q as t goes to infinity. We assume that the parameter P is so small that

$$P^n < \min\left\{1 - \frac{(1-p)z}{p(y_H - y_L) - c}, \frac{z}{\beta\{p(y_H - y_L) - c\}}\right\} \tag{27}$$

is satisfied, while it is easily shown that there exist sets of parameters $(n, \beta, y_H, y_L, c, p, z)$ and P that satisfy both (20) and (27). If (27) is satisfied, it is easily shown that

$$V_\tau^L - z < Q.$$

Therefore, if the market value of firms becomes $\{V_t^L\}_{t=\tau}^{\infty}$, then the optimal choice for banks when their debtors default is to roll their loans over. The recursive difference equation (26) equals the equilibrium condition for the market value of firm V_t, given that banks always choose loan rollover.

Given that banks always choose loan rollover, entrepreneurs and banks can design the optimal debt contract (D_t, R_{t+1}) for $t(\geq \tau)$ as follows so that a firm owned by an entrepreneur always invests if and only if all the other $n-1$ firms in the same group are owned by entrepreneurs:

$$\begin{aligned} &y_L + V_{t+1}^L \leq R_{t+1} < y_H - c + V_{t+1}^L, \\ &(1+r)D_t = P(t)\{pR_{t+1} + (1-p)(Q-c)\} + (1 - P(t))(py_L + Q). \end{aligned} \tag{28}$$

Recall that n firms form a group by random matching. If a bank-owned firm is included in the group, Assumption 1 and the debt contract imply that the entrepreneur-owned firm will be indifferent whether to make a relation-specific investment (c) or not. Thus we can simply assume that the firm will not invest in such a case.

It is easily observed that under the debt contract (28), the expected rate of return for banks and entrepreneurs is the same as the market rate of return. Thus banks and entrepreneurs under perfect competition agree on debt contract (28).

We have confirmed the following claim. In the case where parameter values satisfy (27) and the market rate of interest is a given constant, $r_t = r$ for all $t \geq 0$,[14] the following stagnant equilibrium exists: The market value of a firm is V_t^L for $t \geq \tau$; entrepreneurs and banks agree on the debt contract (D_t, R_{t+1}) that satisfies (28); firms owned by entrepreneurs always choose to invest if and only if all the other $n-1$ firms in the same group are owned by entrepreneurs; and banks always choose rollover of bad loans when the debtors default.

This equilibrium is the stagnant one where per capita net output at time $t+1$ is $P^n p^{n(t-\tau)}\{p(y_H - y_L) - c\} + py_L$. It is obvious from (27) that this per capita net output is smaller than that of the optimal equilibrium $(py_H - c - (1-p)z)$. It can also be easily shown that the asset price V_τ^L is smaller than V_H and that $\{V_t^L\}_{t=\tau}^{\infty}$ decreases monotonically and converges to Q as t increases.

3 LITERATURE

In this section, we review our model in the light of existing literature.

Summary Existing finance literature deals with issues between banks and firms (or depositors): shortages of capital supply (credit crunch), moral hazards and asset dissipation by the managers of nonviable firms (soft budget), premature withdrawal (bank runs), and so forth. These deal with issues of information asymmetry, principal-agent problems, or incomplete contracts *between banks and firms*.

Our model deals with the inefficiency caused by complementarity in the activities of firms due to relation-specificity and incomplete contracts *among firms*. The complementarity among firms causes the coordination failure, which is triggered by debt problems.

[14] In the general equilibrium setting, the market rate of interest r_τ may jump up at time τ when a substantial amount of the output is destroyed by the macroeconomic shock, since $1 + r_t = \frac{u'(c_t)}{\rho u'(c_{t+1})}$ where the concave function $u(c)$ is the utility of the representative consumer, $0 < \rho < 1$ is the consumer's time-discount factor, and c_t is the consumption at time t, which must be equal to the output at t. We can generalize our model to take this change of interest rate into account, but the results do not differ qualitatively from those in our partial equilibrium model.

The main contribution of our model is to point out that the financial distress of some firms may cause the decline of *productivity growth* of all the other firms through externality. Macroeconomic inefficiency results not from a shortage of capital input but from lower productivity. This story seems relevant to the Japanese economy, since it is argued that there is little evidence of a credit crunch in the economy in the 1990s and that the demand for capital (bank loans) was weak in that period, implying the possible disappearance of productive projects in the corporate sector.

Financial Intermediation and Macroeconomy Finance theory has analyzed the function of financial intermediaries in the framework of agency problems under information asymmetry (Diamond [1984], Diamond and Dybvig [1983], Krasa and Villamil [1992], Dewatripont and Tirole [1993]).[15] Therefore, macroeconomic inefficiency caused by financial distress is usually modeled as the agency cost between banks and debtors. The agency problem limits the bank's supply of credit to the debtor, causing a shortage of capital accumulation in the economy. In line with this thought are works on debt-deflation theory (Fisher [1933]), financial accelerator models (Bernanke and Gertler [1989], Bernanke, Gertler, and Gilchrist [1996]), credit cycles (Kiyotaki and Moore [1997]), and excessive foreclosures (Shleifer and Vishny [1992], Diamond [2000]), which basically attribute inefficiency to a shortage of credit supply (credit crunch). A credit crunch propagates from the initially distressed firms to other firms through the fall of asset prices (or the liquidation value of a firm) or an impairment of bank capital that constrains the supply of credit, causing business investments to contract all over the economy.

While the credit crunch stories are concerned with the *ex ante* supply of credit, the agency problem between the lender and the debtor can cause an *ex post* inefficiency: debt overhang (Myers [1977], Hart [1995], Lang, Ofek, and Stulz [1995]). A firm whose existing debt obligations are too large will not be able to raise funds for productive new investments if no one will provide new money because the priority of the existing

[15]The form of debt has been proved to be the optimal solution for a certain class of principal-agent problems (Townsend [1978], Gale and Hellwig [1985]).

debt is senior. Thus, debt overhang can be another source of a shortage of capital input. (Lamont [1995] shows that simultaneous debt overhang of many firms will cause aggregate demand to shrink in a monopolistic competition economy.)

Bank Forbearance Although finance literature highlights the inefficiency caused by a supply shortage of credit or capital, data on the Japanese economy indicates that there was no contraction of total bank loans in the 1990s, at least until 1998 (Hoshi [2000]). Therefore, the possibility of inefficiency due to forbearance lending (the rollover of bad loans) by banks has begun to attract researchers' attention. Several empirical analyses show the existence of forbearance lending by Japanese banks in the 1990s (Sakuragawa [2001], Tsuru [2001], Kobayashi, Saita, and Sekine [2002], Sugihara and Fueda [2002]).

There are several explanations for why banks are willing to roll over nonperforming loans. Sunk costs under information asymmetry between the bank and the firm can cause a soft-budget constraint (Berglöf and Roland [1997], Dewatripont and Maskin [1995]); bank managers may be inclined to cover up the true financial state of their bank from the regulators (Aghion, Bolton, and Fries [1998], Mitchell [1998], Sakuragawa [2001]); the existence of deposit insurance may induce bank managers to gamble on the recovery of insolvent firms (Tsuru [2001]); bounded rationality that bank managers perceive today's losses more "saliently" than tomorrow's losses may induce procrastination (Hoshi [2000]); and banks may want to buy time if the option value of waiting before writing loans off is substantial (Baba [2001]). All these explanations formalize forbearance lending as (quasi-) rational behavior of banks in a restrictive informational environment, which is not socially optimal.[16]

These stories imply that forbearance lending can cause inefficiency in the real econ-

[16]Sugihara and Fueda (2002) offer a more affirmative idea for banks' procrastination. They show that disposals of nonperforming loan were countercyclical in the 1990s, and they claim that this finding indicates that banks have unsuccessfully tried to smooth over macroeconomic shocks. If Japanese banks have indeed tried to undertake the intertemporal smoothing of macroeconomic shocks (Allen and Gale [2000]), their action could have been socially optimal *ex ante*, though the observed results give this behavior the appearance of just procrastination *ex post*.

omy by the following mechanisms. First, when managers of debtor firms anticipate a soft-budget constraint, they do not exert necessary efforts to maximize the values of their firms (Berglöff and Roland [1997], Aghion, Bolton, and Fries [1998], Mitchell [1998]). Second, productive firms find they cannot raise fund for their business since bank credit is locked in inefficient sectors by forbearance lending (Berglöff and Roland [1997], Mitchell [1998], Hoshi [2000]). Since the former is basically a microeconomic problem, the latter is regarded to be the best macroeconomic candidate for explaining the stagnation. That is, loan rollovers for inefficient sectors crowd out the supply of capital to productive sectors.[17]

There are empirical analyses supporting this hypothesis. Saita and Sekine (2001) have shown using data from the *Tankan*, a quarterly survey by the Bank of Japan, that the mismatch between supply and demand of credit increased during the 1990s. Tsuru (2001) and Sugihara and Fueda (2002) analyzed bank lending and found that forbearance lending to the real estate industry (Tsuru) and to the construction industry (Sugihara and Fueda) were negatively correlated with bank lending to the manufacturing sector in the 1990s.

Low Productivity Growth The above arguments imply that the macroeconomic stagnation in Japan was caused by a shortage of credit supply to productive sectors resulting from either a credit crunch[18] or the misallocation of credit. One observation

[17]In the debate over Japanese monetary policy, it is pointed out that there are two transmission channels through which monetary easing by the Bank of Japan can influence real economic activity (See Hoshi [2000]). One channel is reduction of interest rates, which is standard in Keynesian literature. The other is expansion of bank credit (Bernanke and Blinder [1988]). Several authors argue that forbearance lending causes the credit channel of monetary policy to malfunction. This argument seems to assume implicitly that forbearance lending to inefficient sectors causes a shrinkage of credit supply to productive sectors.

[18]Motonishi and Yoshikawa (1999) found evidence of a credit crunch in 1997 and 1998. Ogawa and Kitasaka (2000) analyzed data for 1976–1995 and found that investments by small firms depend on bank loans and that bank loans to small and/or nonmanufacturing firms are dependent on real estate as collateral. Their findings imply the possibility of credit crunch for small firms in the 1990s, when land prices continued to fall.

that seems to contradict this explanation is that there have been huge amounts of idle money in the banking sector. Japanese banks doubled their holdings of Japanese government bond during the 1990s, from 28.7 trillion yen at the end of 1993 to 66.9 trillion yen at the end of 2001. Even if they had engaged in forbearance lending to inefficient sectors, they should still have been able to provide credit to other sectors if there had been productive borrowers in them. It was argued throughout the 1990s that corporate demand for bank loans was weak, especially in the manufacturing sector.[19] Observations implying the disappearance of productive lending opportunities suggest another cause of the stagnation: decline of productivity growth. Hayashi and Prescott (2002) argue that the stagnation in Japan must have been caused by low productivity growth, not by a credit crunch.

Many countries have experienced decade-long periods of stagnation (*great depressions*) in the 20th century (Kehoe and Prescott [2002], Bergoeing, Kehoe, Kehoe, and Soto [2002]). It is reported that the persistent depressions were usually associated with declines of productivity growth. Slow productivity growth in Japan may be caused by misallocation of credit due to forbearance lending, but then the existence of idle money is left unexplained. An alternative explanation for low productivity growth is a coordination failure among economic agents whose activities exhibit complementarity due to relation-specificity, information asymmetry, and/or incomplete contracts. Blanchard and Kremer (1997) point out that the output decline in the former Soviet countries can be explained by just this kind of coordination failure. They empirically confirmed that the complexity defined below by (30) was negatively correlated with the output in the former Soviet countries in the beginning of the 1990s.

Observations very similar to those being made in today's Japan were made in the United States during the Great Depression. Banks reduced the outstanding loans and invested idle funds in the long-term bonds of the federal government at a time when the observed interest rates were quite low. Bernanke (1983) argues that the deterioration

[19]Hoshi and Kashyap (1999) show that large manufacturing firms shifted to capital market financing as a result of deregulation.

of the banking sector protracted the recession through a nonmonetary channel, positing that the rush of bankruptcies elevated the cost of credit intermediation, which may be interpreted as a decrease in productivity. Ohanian (2001) argues that a decrease in organizational capital may account for the unexplained part of the productivity decline during this period. These arguments indicate that serious coordination problems might have reduced productivity and that the coordination problems might have been caused by the financial crisis. Our model is an attempt to explain the Japanese stagnation in line with this coordination failure story.[20]

4 EVIDENCE IN THE JAPANESE ECONOMY

Is the hypothesis of a complexity externality relevant to the persistent stagnation of the Japanese economy in the 1990s? Circumstantial evidence of the shrinkage of economic activities due to prevalent pessimism comes from the decrease of credit transactions in the economy. Figure 4 shows the total value of bill and check clearings and domestic fund transfers, and it indicates that business transactions contracted sharply in Japan. This may imply that supply networks and the division of labor among firms were damaged throughout the 1990s.

Figure 4. Values of Transactions in Payment Systems

Next, we conduct empirical analyses on industry-level data of the Japanese economy. The results show a negative correlation between output and the complexity of industries in the Japanese economy only in the 1990s. We also conducted identical analyses of the United States economy and compared the results. The comparison indicates that complexity had a negative effect on output only in Japan and only after the collapse of the asset-price bubble.

[20] Cooper and Ejarque (1995) also propose a model of the Great Depression, in which the strategic complementarity in financial intermediation causes the coordination failure. In their model, the coordination failure is associated with a shortage of credit supply.

4.1 Complexity and Output

We can easily confirm that the number of firms in a group n_i of industry i and per capita output y_i are negatively correlated when an economy is trapped in a bad equilibrium due to the complexity externality. If the economy is in the optimal equilibrium initially, per capita output is $y_i = py_H - c - (1-p)z$. If the economy shifts to the bad equilibrium at time τ, the expected value of per capita output at time $t+1$ $(t \geq \tau)$ becomes

$$Ey_{it+1} = P^{n_i} p^{n_i(t-\tau)}\{p(y_H - y_L) - c\} + py_L. \tag{29}$$

If there are many firms and many production chains in an industry, then we can regard Ey_{it+1} as the average per capita output of the industry. Therefore, the level of per capita output must be negatively correlated with n_i in the bad equilibrium, assuming that parameters (y_H, y_L, c, P, p) are common for all industries. The output growth of industry i is defined as $g_i = Ey_{it+1}/Ey_{it}$, which is also negatively correlated with n_i.

In the following subsections we introduce the *index of complexity* (c_i) as a proxy of n_i, and we empirically examine the relations between index c_i and output.

4.2 Data

Most of the data are from the input-output tables published every five years by the Management and Coordination Agency (MCA). We used the 1985-1990-1995 Connection Tables (93 Sector Classification). Our basic strategy was to implement empirical analyses on output using independent variables, which included the complexity index defined below, capital stock, labor, and materials input.

We used the following index of complexity c_i as a proxy of the number of firms n_i in a production network of sector i:

$$c_i = 1 - \sum_j (a_{ij})^2, \tag{30}$$

where a_{ij} is the share of input from sector j in the total input to sector i. Thus $\sum_j a_{ij} = 1$. The index c_i is introduced by Blanchard and Kremer [1997] to examine disorganization in the former Soviet countries. By construction, c_i is equal to zero when there is only

one input, and as the variety of input increases, c_i approaches 1. Thus c_i represents the complexity of input structure of sector i. As Blanchard and Kremer do, we assumed that the complexity of a production chain tends to become higher as the input structure of the sector grows more complex. Therefore, we regard c_i as a proxy of n_i in a production chain in sector i. Table 1 shows the resulting complexity indices for the different sectors.

Table 1. Complexity Indices of Sectors in 1990

Note that complexity c_i may be a technological constraint on the sector rather than a result of firms' effort to develop production chains, because the input structure may be determined by the production technology of the goods, not by the firms' behavior. High complexity may indicate that the technological character of a good necessitates a highly complex supply network. To see whether complexity is a technological constraint or not, we calculated the order correlation between the complexity in 1985, 1990, and 1995. The results are shown in Table 2. The order correlation between the complexity of 1990 and 1995 is larger than that between 1985 and 1990, showing that complexity in the 1990s did not change significantly despite the severe recession. This result implies that complexity is a technological constraint for the corresponding sector.

Table 2. Order Correlation of Complexities.

The other independent variables are durability, the debt burden, capital, labor, materials input, the trade factor, and the constant term. See Appendix 3 for details of the data construction.

Durability is a dummy variable that is equal to 1 if the good is durable, 0 otherwise. We used this variable since the production of durable goods is typically procyclical relative to the production of nondurables in the major developed countries (See Blanchard and Kremer [1997]).

The debt burden is the ratio of the debt outstanding to the annual operating surplus. This ratio is assumed to measure the credit constraint, which is expected to depress a firm's output. We conjecture that the coefficient of this ratio represents the negative effect of debt that is modeled in credit-crunch stories.

The trade factor is the ratio of net exports to the sum of gross exports and imports of an industry. We used this variable to capture the effect of changes in international trade. Many authors argue that one reason for the bad performance of the Japanese economy in the 1990s is the radical change in the international business climate at the end of the Cold War. We expected to detect the effect of changes in international trade by this variable.

4.3 Regression Results

Let us examine the relationship between the complexity index and the level of output. We assume the same Cobb-Douglas production function for all industries. The only difference between industries is the total factor productivity (TFP). Thus we assume that the output of industry i is

$$Y_i = A_i K_i^{\beta_K} L_i^{\beta_L} M_i^{\beta_M}, \tag{31}$$

where Y_i is the gross product of industry i, K_i is the capital input, L_i is the labor input (man $\times$ hour), M_i is the intermediate goods, and A_i is the TFP. We assume that β_K, β_L, and β_M have the same values across industries and do not vary over time. We assume that A_i is a function of complexity (c_i), durability (δ_i), the debt burden (db_i), and the trade factor (ex_i). Taking the logarithm, we have

$$\ln Y_i = C + \beta_c c_i + \beta_1 \delta_i + \beta_2 db_i + \beta_3 ex_i + \beta_K \ln K_i + \beta_L \ln L_i + \beta_M \ln M_i + u_i, \tag{32}$$

where C is the constant term. We conducted a Panel Data Analysis using data for 1985, 1990, and 1995 to estimate the production function. The model is

$$\ln Y_{it} = C + \beta_{85} x_{it}^{85} + \beta_{90} x_{it}^{90} + \beta_{95} x_{it}^{95} + \beta_X X_{it} + u_{it} \tag{33}$$

for three years ($t = 1985, 1990, 1995$) and 91 sectors, where $x_{it}^T = (0,0,0,0)$ if $t \neq T$, and $x_{it}^t = (c_{it}^t, \delta_{it}^t, db_{it}^t, ex_{it}^t)'$, where c_{it}^t is the complexity of industry i in the year t, $\beta_t = (\beta_{ct}, \beta_{1t}, \beta_{2t}, \beta_{3t})$, $\beta_X = (\beta_K, \beta_L, \beta_M)$, and $X_{it} = (\ln K_{it}, \ln L_{it}, \ln M_{it})'$. To specify the error term (u_{it}), we conducted a Hausman specification test and found that the

test statistic was 16.146, which is significant at the 5% level. Thus we adopted a fixed effect model. We conducted two estimations, one with the one-way fixed effect model and the other with the two-way fixed effect model. In the one-way fixed effect error component model, u_{it} is defined as $u_{it} = \mu_i + \nu_{it}$, where μ_i represents the fixed effect and ν_{it} represents the random error, which is i.i.d. over samples. In the two-way fixed effect error component model, u_{it} is defined as $u_{it} = \mu_i + \lambda_t + \nu_{it}$, where μ_i represents the fixed effect within an industry and λ_t represents the fixed effect within a year. This λ_t is expected to depict the trend of economic growth. The results of the one-way model and the two-way model were quite close with each other qualitatively and quantitatively. Thus we report only the results of the one-way model in this paper (See Table 3).

Table 3. Regression Results: Level of Output and Complexity

The coefficient of the complexity index is significantly negative only in 1995. The significance was at the 10% or 5% level. This result is robust for various combinations of independent variables and is consistent with our hypothesis that complexity is negatively correlated with the level of output in the pessimistic equilibrium. The coefficients of durability, the debt burden, and the trade factor were not significant, while the signs on durability and the debt burden were consistent with our prediction. The sign on durability was positive for 1990 and 1995 when the economy was expanding and negative for 1985 when it was contracting. The sign on the debt burden was always negative, implying a credit constraint due to information asymmetry.

We also undertook regressions without the complexity index. In these cases, durability, debt burden, and trade factor coefficients were not significant either, implying that our results for complexity are not a misspecification of other variables.

Although the results are robust, the 10% significance level of the results in Table 3 is not very high. We accordingly ran a regression for a modified model with industries divided into two categories according to the value of debt burden (db_{it}): a low-debt-burden group (d1) and a high-debt-burden group (d2). This assumes that the coefficient of complexity could be different for the two groups. The results are given in Table 4. The "Index85 d1" is the complexity index of the low-debt-burden group in the year 1985,

while the "Index85 d2" is that of the high-debt-burden group in the same year.

Table 4. More Significant Complexity in the High-Debt Group

Table 4 shows that the negative effect of complexity is more significant for the high-debt group than for the low-debt group. The 5% significance level for the high-debt group in 1995 holds true in any combination of independent variables. This result is consistent with our thinking that a serious bad-debt problem in an industry can trigger the emergence of a stagnant equilibrium in the industry.

Thus, we can conclude that it is highly probable that complexity began exerting a negative effect on the output of Japanese industries only in the 1990s, and also that the negative effect was more severe for the industries holding heavier debts.

4.4 Potential Criticisms

There are several potential criticisms of our results. The first is that our complexity misspecifies the effect of deterioration in the real estate market. It may be just a coincidence that the industries that made unproductive investments in the real estate market have high complexity. Thus the negative coefficient of complexity might have merely detected the inefficient real estate investments in Japan.

The second criticism is that the time-horizon of our analysis is too short to determine whether our results depict structural change within the economy or whether they misinterpret the effect of a long business cycle as the effect of the complexity externality.

The third criticism is that the negative effect of complexity may represent a common technological change, one that has occurred in most developed economies possibly because of the development of information technology.

To check the first point, we conducted a regression for a division of industries into two groups. One is (t2), a group of bubble-related industries that invested in real estate aggressively (i.e., (1) civil engineering, (2) building construction, (3) repair of construction, (4) commerce, and (5) real estate agencies and rental services). The other group is

(t1), all other industries. The results are shown in Table 5.

Table 5. Comparison of Bubble-related and Other Industries

The results show that not only in the bubble-related industries but also in the other industries complexity exhibited a negative effect on the output. We divided group t1 (the other industries) into a low-debt group (d1) and a high-debt group (d2). The right-hand side of Table 5 shows the regression results for this subdivision. They indicate that the negative effect of complexity could be observed in industries that were not directly affected by the collapse of the real estate market.

In order to deal with the second criticism, we ran a regression on the growth of output for a longer period using data for 1975, 1980, 1985, 1990, and 1995. We could not extend the analysis of the previous subsection to 1980 or 1975, however, because of difficulty in data construction. Since capital stock amounts are not reported in Japan's input-output tables, we had to construct figures for them to implement the analysis in the previous subsection. But while we could do this for 1985, 1990, and 1995, but could not do the same for 1975 and 1980, since their I-O tables use the 1968 SNA, not the 1993 SNA used in the 1985-1990-1995 I-O tables. But we do not need data on the level of capital stock to infer the *growth rate* of capital stock if we adopt a very rough approximation method (See Appendix 4 for the details). Using a rough estimate of the growth of capital, we implemented an ordinary least squares (OLS) regression for the following model:

$$g_i = \beta_0 + \beta_1 c_i + \beta_2 \delta_i + \beta_3 db_i + \beta_4 gk_i + \beta_5 gl_i + \beta_6 gm_i + \epsilon_i, \tag{34}$$

where g_i is the output growth in the periods of 1975–1980, 1980–1985, 1985–1990, and 1990–1995, and gk_i, gl_i, and gm_i are the growth rates of capital, labor, and materials input for the corresponding periods. The values of complexity (c_i), durability (δ_i), and debt burden (db_i) are those at the beginning of the corresponding period. The results are reported in Table 6. They show that complexity was significant at the 1% level in the 1990s but had no negative effect for the 15-year period before that, implying that the negative effect of complexity in the 1990s was not a cyclical phenomenon.

Table 6. Regression Results: Growth of Output and Complexity

For an international comparison, we conducted the same empirical analysis as in Subsection 4.3 on the U.S. economy. The construction method for the data set is described in Appendix 5, and the results are shown in Tables 7-1 and 7-2.

Table 7-1: Regression Results: Level of Output and Complexity in the United States

Table 7-2: Regression Results: Growth of Output and Complexity in the United States

In the regression of the output level (Table 7-1), the coefficient of complexity is significantly positive in 1987, while it is not significant in 1992 and 1996. The change in significance may indicate a structural change in the U.S. economy that must have taken place in the 1990s possibly due to the spread of the Internet, which might have decreased the relation-specificity of production chains in industries, neutralizing the positive effect of complexity on output. Meanwhile, the regression results for output growth (Table 7-2) show no significant effect from complexity. At the least, complexity did not have any negative effect on output in the U.S. economy in the sample periods. Thus, we can conclude that the negative externality from complexity seems to be a unique phenomenon to Japan in the 1990s.

5 CONCLUDING REMARKS

In this paper we proposed an explanation for three anomalies prevalent in the Japanese economy from the 1990s on: slow growth, declining asset prices, and procrastination in dealing with nonperforming loans. The simultaneous insolvency of many firms after asset prices collapsed may have triggered the emergence of a stagnant equilibrium in which the complexity externality lowered productivity and banks made a rational decision not to reorganize all the defaulted firms. The vicious circle of the complexity externality and forbearance lending may have trapped the economy in a state of persistent stagnation. The empirical evidence supports the emergence of such a vicious circle at the beginning of the 1990s.

Policy Implications If our thesis is correct, market competition alone cannot recover the optimal equilibrium unless people's expectations change simultaneously. Thus public policies become necessary once an economy is trapped in a stagnant equilibrium. There are two directions for policy prescriptions.

One cause of the inefficiency is banks' decision not to reorganize bad debtors. Liquidation of debtors to recover the optimal capital structure (or the optimal debt ratio) is necessary to restore the optimal equilibrium. Yet as discussed in Subsection 2.5, liquidation is not the optimal strategy for a bank if most other banks stick to the status quo. Thus *the reorganization of a substantial number of firms must be done simultaneously.*

The first policy prescription is coordination by the regulators, perhaps with mandatory measures, to synchronize moves by banks to write off NPLs. The simultaneous restructuring of bad debts may force banks to put aside a huge amount of reserves,[21] causing a shortage of bank capital. If bank capital becomes insufficient for disposal of NPLs, the taxpayer's money must be used to cover the shortfalls through the special procedures for bankruptcy of banks. Meanwhile, a sharp increase of corporate bankruptcies subsequent to simultaneous NPL disposals could cause a severe recession and a deflationary spiral. Recapitalization of the banking sector offers one effective way to avoid a deflationary spiral, since it can make the money supply expand if the Bank of Japan monetizes the taxpayer's costs of recapitalization.

There is, however, a serious weakness in this policy prescription: the possibility that bank loans are not being rigorously evaluated. While accurate asset assessment is the necessary basis for any kind of debt restructuring, the current assessment criteria are

[21] One major reason and result of forbearance lending is alleged to be the insufficient provision of reserves by banks. This, if true, is unlawful, since the Commercial Code demands that creditors put aside sufficient reserves immediately when the prospect of repayment is lost. Still, bank regulators are said to have given tacit consent to insufficient reserves in the 1990s because the provision of sufficient reserves would have caused banks to fail and resulted in intolerable confusion in the banking system. The government adopted a strategy to restore economic growth by Keynesian demand policies. It was hoped that an economic recovery would lighten the burden of nonperforming loans to the point where banks could dispose of them without any substantial failure of the banking system. This strategy, it is said, led the government to condone the rollover of loans for the time being.

said to leave room for discretionary decisions.[22] Although flexibility in decision making is useful in ordinary times when the credibility of asset assessment by banks and their regulators is maintained, once the credibility is lost and the economy becomes trapped in a bad equilibrium, discretionary regulation reinforces the complexity externality by amplifying suspicions. At such a time the criteria for asset assessments should be limited to strictly numerical criteria. Stringent evaluation of bank loans can be said to be the foremost prerequisite for reorganizing firms and restructuring bad debts.

The second policy prescription, which is more structural, is to reduce the coordination cost for banks when they sell off defaulted firms. This coordination cost z consists of various dead-weight losses involving reorganization procedures, in or out of court. For example, whereas the reorganization process in the United States under Chapter 11 of the Federal Bankruptcy Act takes two years on the average, reorganization in Japan takes more than ten years on the average. The Civil Rehabilitation Law was enacted in April 2000 in order to introduce a Chapter 11–type bankruptcy procedure in Japan and thereby make reorganization quicker and more efficient. The legal paradigm of bankruptcy is thus being reformed, but a number of problems in bankruptcy procedures and business customs still remain, and they reinforce the view that reorganization is too costly. For example, judges and appointed receivers have allegedly had comprehensive discretion over reorganization plans. It is said that the creditors of and investors in bankrupt firms have not had much say over reorganization plans. With everything left to the discretion of judges, they have faced uncertainty. In general the Japanese business community regards bankruptcy as the death of the firm, which means that banks and other stakeholders stop thinking about a firm the minute bankruptcy procedures begin. Nobody exerts serious efforts to resolve the problems or restart the business. Only after

[22]The loans to the Sogo group, which went bankrupt in July 2000, and to the Mycal group, which failed in September 2001, are alleged to have been classified as Class 2 by most of their creditor banks just before their bankruptcies. Under current regulations, the required rate of reserves for Class 2 loans is only 3%. As a result, many banks suffered heavy losses because they had not put aside sufficient reserves for the default by Sogo or Mycal. The two debtors had apparently been insolvent for years, but banks and/or the regulators had kept their asset rating unrealistically high.

the Civil Rehabilitation Law was enacted did Japanese banks began to perceive DIP finance[23] as a possible source of profits. No doubt the ongoing changes in the perception of bankruptcy will work to reduce the coordination cost of liquidation.

The development of the secondary market for bad loans would also be effective to reduce coordination cost z and restore macroeconomic confidence. But because bank loans were not traditionally tradable, there is still ambiguity in the legal and tax systems, and it is a source of risks and costs in loan trading. For example, practices for assessing taxes when corporate loans are traded have not been firmly established, and there is confusion about what kinds of transactions in corporate restructuring deals are taxable and to what extent. If the tax office reaches a judgment that is published as a "non-action letter" before a bank sells a loan to an investor, the two parties can undertake the transaction without ambiguity whether or not a tax may be imposed on it. Under the current tax code, however, the tax authorities do not have any obligation to arrive at a judgment *ex ante*, and usually they make a decision on taxability only after the transaction is over. Not only that, the judgments of tax offices are often made on an unpredictable, case-by-case basis, since there are few precedents for corporate loan trading. This lack of transparency exacerbates investors' uncertainty.

Establishing efficient market institutions and bankruptcy procedures is crucial for restoring and maintaining confidence. The reform of market institutions may therefore be judged to be imperative for removing the threat of future long-term slumps and depressions. Undeniably an economy can be thrown into a sharp recession if, when a large shock hits, banks rush to dispose of all their NPLs. In such a case, fiscal and monetary stimulation may be necessary to stop an economic contraction. Aggregate demand management alone, however, cannot put an economy back on the growth path unless macroeconomic confidence is restored through timely reorganization of failed firms using credible and unambiguous market institutions.

[23]DIP (debtor-in-possession) finance is the extension of loans to a bankrupt firm for the continuation of its operations during the process of reorganization.

Appendix 1

Proof of Lemma 1

Suppose that the equilibrium price is $\{\overline{V}_t, (\overline{D}_t, \overline{R}_{t+1})\}_{t=0}^{\infty}$ where $(\overline{D}_t, \overline{R}_{t+1})$ does not satisfy (5). We will show that a bank can offer a Pareto-improving debt contract (D_t, R_{t+1}) that satisfies (5). Let α_t denote the ratio of entrepreneur-owned firms in this equilibrium at time t. The number of bank-owned firms is $(1-\alpha_t)N$. Since Assumption 2 implies that all firms produce py_L on the average, the market price of firm $\overline{V}_t$ satisfies

$$\overline{V}_t \leq (\beta p y_L - 1)\{1 + \beta + \beta^2 + \beta^3 + \cdots\} = \frac{\beta p y_L - 1}{1-\beta} \equiv Q. \tag{35}$$

Since Q is the value that a bank can get by choosing loan rollover in all periods after the debtor defaults, banks must always choose to roll loans over in this equilibrium, and it must be the case that

$$\overline{V}_t = Q \text{ for all } t \geq 0. \tag{36}$$

In this case, Assumption 2 implies that the sum of the expected values of the remaining output and the firm at time $t+1$ is

$$\overline{E}_{t+1} = p y_L + Q. \tag{37}$$

Suppose that a bank offers another debt contract (D_t, R_{t+1}) that satisfies (5) and guarantees a higher rate of return to entrepreneurs than that of $(\overline{D}_t, \overline{R}_{t+1})$. Then all $\alpha_t N$ entrepreneurs will accept the contract,[24] and the sum of the expected values of the remaining output and the firm becomes

$$E_{t+1} = \alpha_t^{n-1}\{p y_H - c\} + (1 - \alpha_t^{n-1}) p y_L + Q, \tag{38}$$

since the bank chooses roll loans over when default occurs. Therefore, $E_{t+1} - \overline{E}_{t+1} = \alpha_t^{n-1}(p y_H - p y_L - c) > 0$. Since $E_{t+1} > \overline{E}_{t+1}$, a bank, anticipating all entrepreneurs will accept the new offer, can offer a debt contract that satisfies (5) and guarantees a higher rate of return. The higher rate of return is validated by the fact that all entrepreneurs accept the new offer and that the ratio α_t^n of them implement the relation-specific investment. (Q.E.D.)

[24] We assume that a bank can provide loans for all firms that accept the offer.

Appendix 2

Proof of (23)

We prove equation (23) by contradiction. Suppose that $\exists t'$ such that $Q_{t'} \neq V_H - z$. Since $Q_{t'} = \max\{V_H - z, \beta p y_L - 1 + \beta Q_{t'+1}\}$, it must be the case that

$$Q_{t'} = \beta p y_L - 1 + \beta Q_{t'+1} > V_H - z.$$

Then, the definition of V_H implies

$$\beta Q_{t'+1} > \beta\{p(y_H - y_L) - c - (1-p)z - \frac{1-\beta}{\beta}z\} + \beta \cdot (V_H - z).$$

The assumption (20) implies that

$$x \equiv p(y_H - y_L) - c - (1-p)z - \frac{1-\beta}{\beta}z > \{\frac{1}{\beta p^{n-1}} - \frac{1-p\beta}{\beta}\}z > 0.$$

Therefore, we have shown that if $\exists t'$ such that $Q_{t'} \neq V_H - z$, then $Q_{t'} > V_H - z$ and $Q_{t'+1} > x + V_H - z > V_H - z$. Thus, by induction, we have $Q_t > V_H - z$ for all $t \geq t'$.

In this case, $Q_t = \beta p y_L - 1 + \beta Q_{t+1}$ for all $t \geq t'$. Thus $Q_t = \frac{1-\beta^N}{1-\beta} \cdot (\beta p y_L - 1) + \beta^N Q_{t+N}$ for any positive integer N. Since we assumed $Q_t < \infty$, we have $\lim_{N\to\infty} \beta^N Q_{t+N} = 0$. Therefore,

$$Q_t = \frac{\beta p y_L - 1}{1-\beta} \text{ for all } t \geq t'.$$

Since the parameter values satisfy (20), it is easily shown that

$$Q_{t'} = \frac{\beta p y_L - 1}{1-\beta} < V_H - z,$$

which contradicts the definition $Q_{t'} = \max\{V_H - z, \beta p y_L - 1 + \beta Q_{t'+1}\}$.

Therefore, equation (23) holds for all $t \geq 0$. (Q.E.D.)

Appendix 3

Construction Method of Data Set

1. *Input-output tables:* We used the 1985-1990-1995 Connection Tables (93 Sector Classification). We changed the treatment of byproducts from the Stone method adopted in the original tables to the Transfer method. The outputs of corresponding sectors were adjusted accordingly.

2. *Labor:* Labor input was calculated as the product of the number of workers and the working hours per worker. The number of workers in each sector was obtained from the I-O tables. As for the working hours per worker in manufacturing and services, we used "working hours in a workplace of 30 workers or more" in the Monthly Labor Survey published by the Ministry of Labor. The working hours per worker in agriculture, forestry, fisheries, and public service were obtained from the Annual Labor Force Survey published by the Management and Coordination Agency (MCA).

3. *Capital:* Since amounts of capital stocks were not reported in the I-O tables, we constructed the capital stock of each sector by the perpetual inventory method.

(1) Since the fixed capital formation matrices in the I-O tables of 1985 and 1990 are not reported according to the 1993 SNA, we constructed the fixed capital formation matrix I_t for 1985 and 1990. $I_t = (I_t^{ij})$, where I_t^{ij} is the amount of capital good j that is invested in sector i. We adjusted the sector classification and made pro rata division of capital goods into sectors. We calculated $I_t^i \equiv \sum_j I_t^{ij}$ for each sector i in 1985 and 1990.

(2) Next, we constructed I_t^i for each year between 1985 and 1990, and between 1990 and 1995, by the following linear interpolation. For $1 \leq t \leq 4$, we calculated that $I_{1985+t}^i = I_{1985}^i + \frac{J_{1985+t}-J_{1985}}{J_{1990}-J_{1985}}(I_{1990}^i - I_{1985}^i)$, where J_t is the total domestic fixed capital formation of year t, which was obtained from the National Accounts published by the Economic Planning Agency.

(3) The depreciation rate for each sector was calculated as a weighted average of the depreciation rates of corresponding capital goods. We used the following values for the depreciation rates: 0.047 for nonresidential buildings, 0.0564 for structures, 0.09489 for machinery, 0.147 for transportation equipment, and 0.08838 for instruments and tools,

following Hayashi and Inoue (1991). The depreciation rate is 0.023 for trees, livestock, and land according to Miyagawa and Shiraishi (2000), and 0.315 for computer software according to Jorgenson and Stiroh (2000). The depreciation rate for each sector (δ_t^i) is the average of the depreciation rates for capital goods weighted by the shares in total investment of sector i at year t. We used δ_{1985}^i for 1986–1990 and δ_{1990}^i for 1991–1995.

(4) The capital stock of each sector K_t^i was calculated by the perpetual inventory method. Set $K_{1984}^i = \frac{I_{1985}^i}{g+\delta}$ where g is the average annual growth rate of domestic investment J_t from 1985 to 1989, and δ is the average of the depreciation rates. We calculated as $K_{1985}^i = I_{1985}^i + (1-\delta)K_{1984}^i$, $K_{1986}^i = I_{1986}^i + (1-\delta_{1985}^i)I_{1985}^i + (1-\delta)^2 K_{1984}^i$, $K_{1987}^i = I_{1987}^i + (1-\delta_{1985}^i)I_{1986}^i + (1-\delta_{1985}^i)^2 I_{1985}^i + (1-\delta)^3 K_{1984}^i$, $\cdots$, $K_{1995}^i = I_{1995}^i + (1-\delta_{1990}^i)I_{1994}^i + (1-\delta_{1990}^i)^2 I_{1993}^i + \cdots + (1-\delta_{1985}^i)^{10} I_{1985}^i + (1-\delta)^{11} K_{1984}^i$.

4. *Debt burden:* To calculate the debt burden of sector i, we can utilize the input from the financial sector to sector i, because it is proportional to the debt outstanding of sector i. According to the MCA, the input from the financial sector to sector i at the year t (F_{it}) is calculated by

$$F_{it} = \frac{\text{Debt outstanding of sector } i}{\text{Total debt outstanding (all sectors) at } t} \times \{\text{Total output of financial sector at } t\}.$$

We obtained F_{it} and the total output of the financial sector at t from the I-O tables. We calculated the total outstanding debt of all sectors by summing up the lending and bond holding of the financial institutions reported in the National Accounts (68SNA). To be more precise, F_{it} includes the input from nonlife insurance that is not proportional to the debt outstanding. We simply neglected the effect of nonlife insurance because the total input to all industries from nonlife insurance is just 7% of that from the financial sector as a whole.[25]

[25] In the estimation of the growth of output, we used the ratio of F_{it} to the operating surplus as a proxy for the debt burden. Since the estimation method for growth was OLS, both the total output of the financial sector and the total outstanding debt of all sectors could be treated as constant when we estimated each equation independently.

5. *Durability:* We set the value of the durability dummy at 1 for the following 22 industries: (1) timber and wooden products, (2) furniture and fixtures, (3) pig iron and crude steel, (4) steel products, (5) steel castings and forgings and other steel products, (6) nonferrous metals, (7) nonferrous metal products, (8) metal products for construction and architecture, (9) other metal products, (10) general industrial machinery, (11) special industrial machinery, (12) other general machines, (13) machinery for office and service industry, (14) household electric appliances, (15) electronic equipment and communication equipment, (16) heavy electrical equipment, (17) other electrical machinery, (18) motor vehicles, (19) ships and repair of ships, (20) other transportation equipment and repair of transportation equipment, (21) precision instruments, and (22) miscellaneous manufacturing products.

Appendix 4

Approximation for Growth of Capital Stock

To calculate the growth rate of capital input, we used the "depreciation of fixed capital" in the I-O tables. Assuming that the depreciation rate is invariant over time and over capital goods in the same sector, we can regard the growth rate of the depreciation of fixed capital as a close approximate of the growth rate of capital, since

$$\frac{\Delta_i K^i_{t+T} - \Delta_i K^i_t}{\Delta_i K^i_t} = \frac{K^i_{t+T} - K^i_t}{K^i_t},$$

where Δ_i is the depreciation rate of sector i and $\Delta_i K^i_t$ is the depreciation of fixed capital in period t. Therefore, we used the growth rate of the depreciation of fixed capital instead of the growth rate of capital input. We obtained values for the depreciation of fixed capital at current prices from the I-O tables. We approximated their real values by multiplication with the GDP deflator.

Appendix 5

Data Set for the U.S. Economy

1. The complexity index was calculated from the data in USE Matrix (Two-Digit SIC) of the 1987 benchmark I-O table, of the 1992 benchmark I-O table, and of the 1996 annual I-O table. The ratio of net exports to the sum of gross exports and imports was also calculated from the I-O tables.

2. The gross output, intermediate input, and labor input for each industry were obtained from the National Income and Product Accounts. The capital stock estimated by the Bureau of Economic Analysis was also available online.

3. Each variable was normalized as a quantity index set at 100 for 1996.

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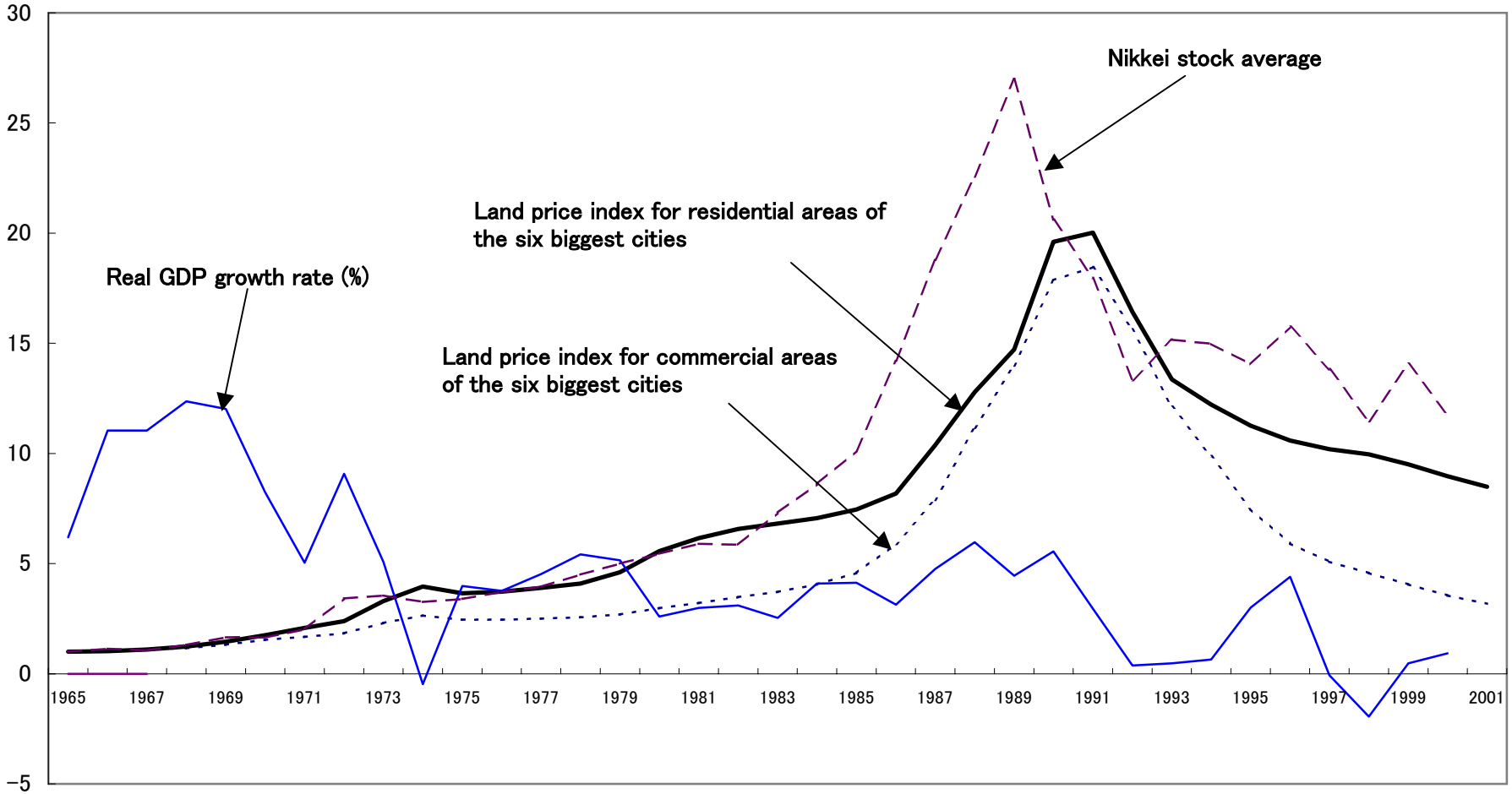
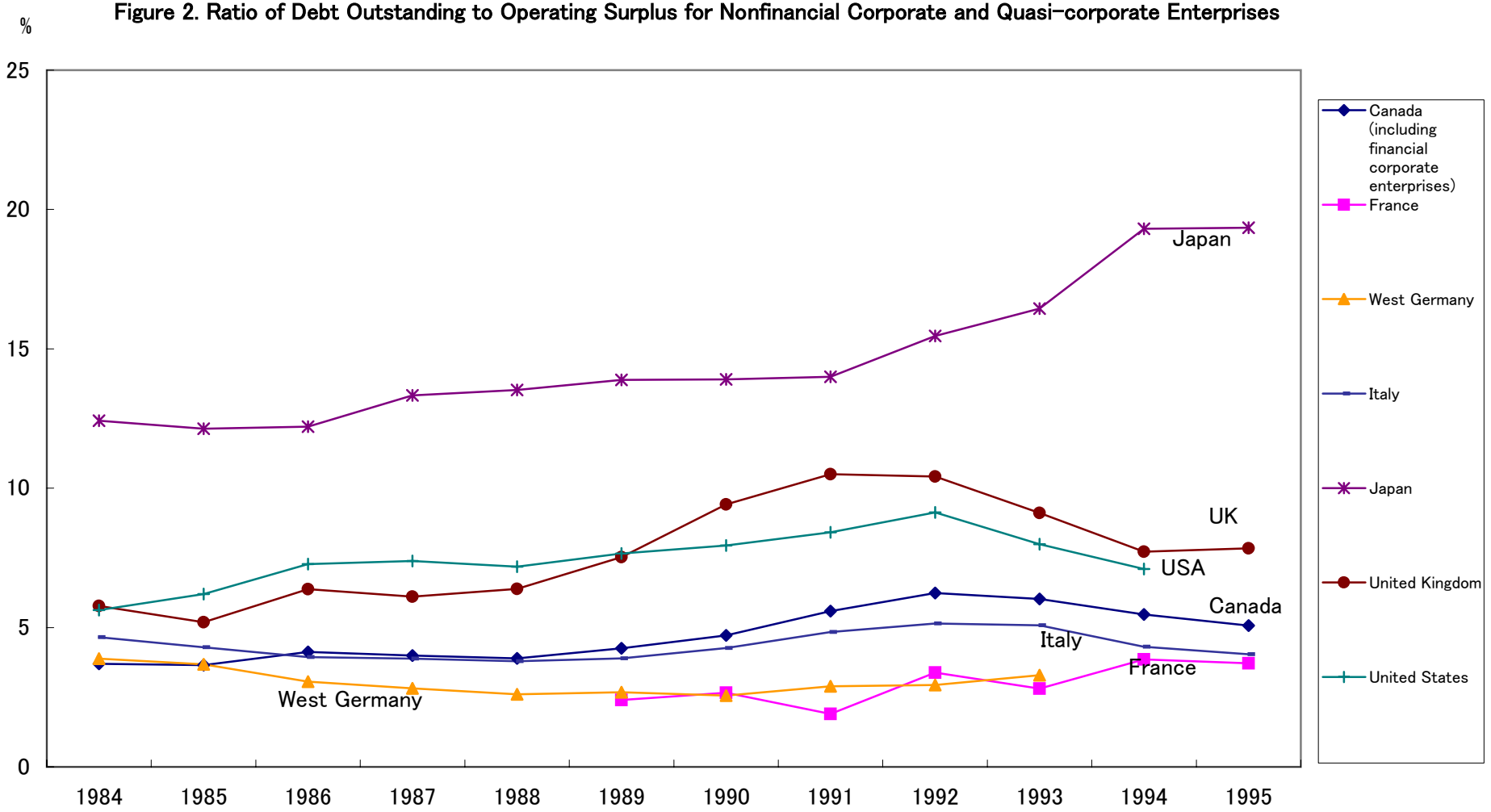
Figure 1. Growth Rate and Land and Stock Price Indices



Sources: Japan Real Estate Institute, Economy and Social Reserch Institute, and *Nihon Keizai Shimbun*

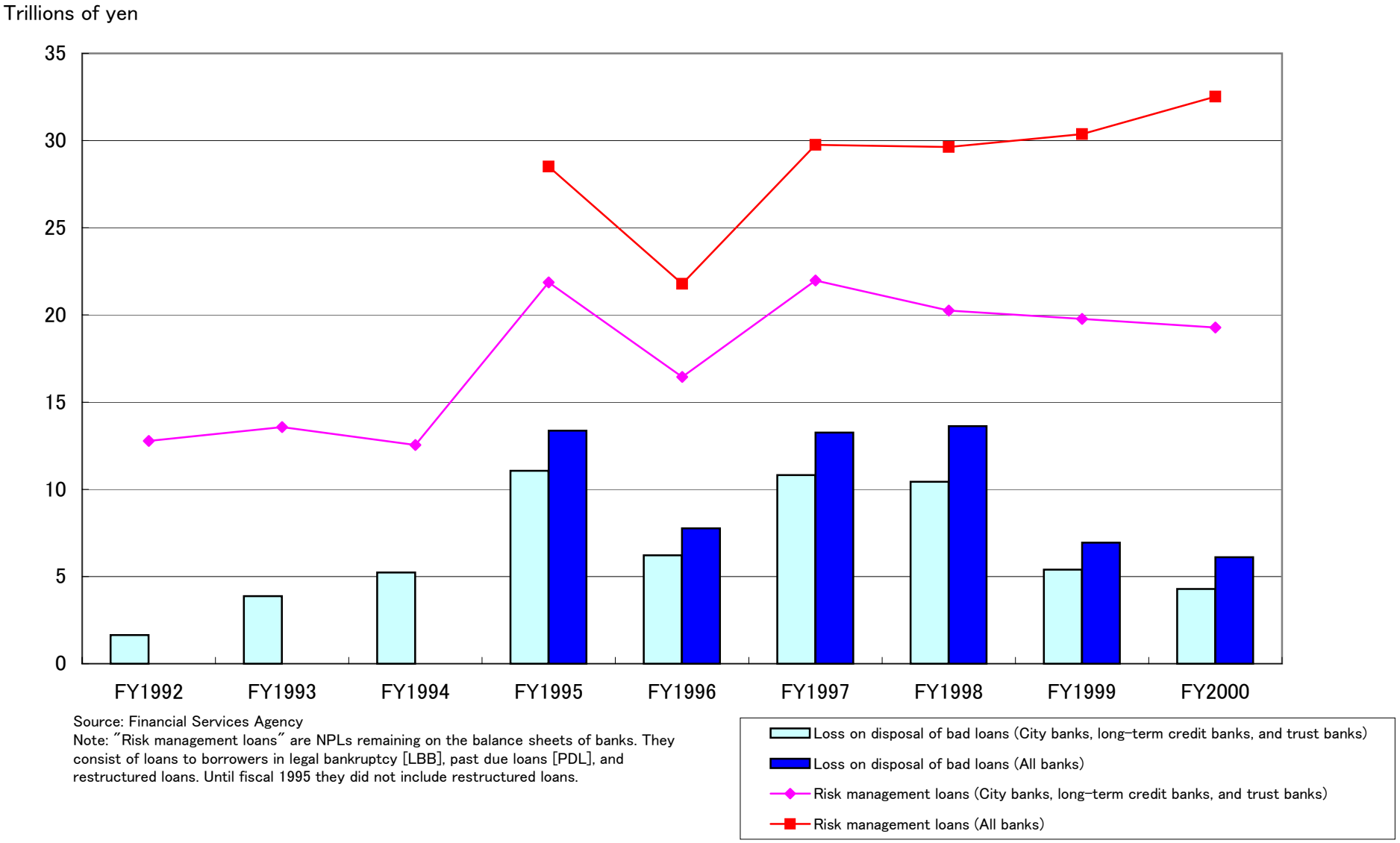
Note: The land price indices are as of March and are set at 1.0 in 1965. The Nikkei stock averages are annual averages of end-of-month prices. The GDP growth rates are for fiscal years (April to March).

Figure 2. Ratio of Debt Outstanding to Operating Surplus for Nonfinancial Corporate and Quasi-corporate Enterprises



Source : OECD、Financial Statements of Non-Financial Enterprises, National Accounts
Note: Debt outstanding of the United Kingdom does not include long-term liabilities before 1989.

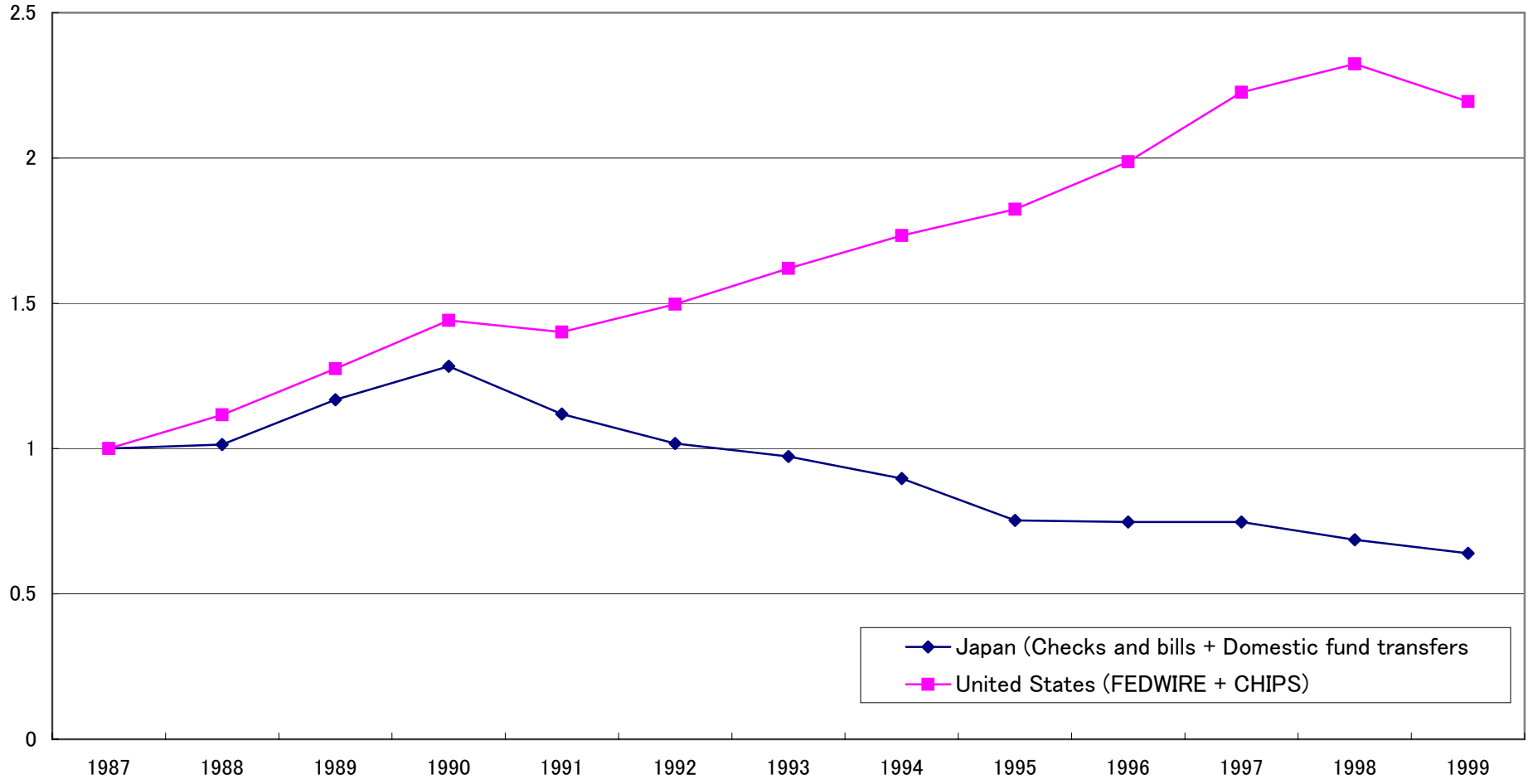
Figure 3. Nonperforming Loans Disposed of and Remaining



Source: Financial Services Agency
Note: "Risk management loans" are NPLs remaining on the balance sheets of banks. They consist of loans to borrowers in legal bankruptcy [LBB], past due loans [PDL], and restructured loans. Until fiscal 1995 they did not include restructured loans.

Index (1987 = 1.0)

Figure 4. Value of Transactions in Payment Systems



Sources: BIS, Statistics on Payment Systems in the Group of Ten Countries; Bank of Japan, Comparative Economic and Financial Statistics, Japan and Other Major Countries

Table1. Complexity Indices of Sectors in 1990

Social security	0.949125287	Chemical fertilizer	0.88661561
Public administration	0.948284368	Other business services	0.886581032
Miscellaneous manufacturing products	0.948206619	General industrial machinery	0.885518242
Other personal services	0.9474493	Gas and heat supply	0.878346201
Amusement and recreational services	0.947061265	Real estate agencies and rental services	0.876675536
Pottery, china, and earthenware	0.946387138	Other metal products	0.87512
Waste disposal services	0.945919155	Leather, fur skins, and miscellaneous leather products	0.8737509
Other ceramic, stone, and clay products	0.945282145	Road transport (except transport by private cars)	0.869094398
Glass and glass products	0.944312024	Machinery for office and service industry	0.867768386
Heavy electrical equipment	0.941390209	Finance and insurance	0.865554659
Education	0.938997281	Foods	0.860267595
Civil engineering	0.938627451	Storage facility services	0.854024788
Agricultural services	0.934489953	Eating and drinking places	0.848117044
Services relating to transport	0.933306158	Other transportation equipment and repair of transportation equipment	0.846426154
Building construction	0.929701945	Synthetic fibers	0.844215068
Repair of construction	0.927976461	Advertising, survey, and information services	0.843075933
Ships and repair of ships	0.927846843	Publishing and printing	0.830274106
Research	0.926680115	Textile products	0.823025306
Hotel and other lodging places	0.925444077	Goods rental and leasing services	0.801756478
Communication	0.922393865	Office supplies	0.799593017
Final chemical products	0.921958594	Medical service and health	0.792705761
Other general machines	0.919129356	Livestock and sericulture	0.783046035
Activities not elsewhere classified	0.917892283	Electronic equipment and communication equipment	0.782893517
Coal	0.917717098	Pulp, paper, paperboard, and processed paper	0.781140807
Commerce	0.917399745	Feeds and organic fertilizer	0.77249248
Crude petroleum and natural gas	0.916771799	Plastic products	0.770155426
Other public services	0.91671542	Broadcasting	0.763124833
Metallic ores	0.915784315	Nonferrous metals	0.762041491
Drinks	0.913716468	Coal products	0.74959776
Fisheries	0.912759811	Timber and wooden products	0.747808207
Crop cultivation	0.911123649	Petrochemical basic products and intermediate chemical products	0.745730673
Furniture and fixtures	0.909437872	Water transport	0.741216809
Freight forwarding	0.908569879	Wearing apparel and other textile products	0.741079586
Medicaments	0.908289132	Air transport	0.739785633
Repair of motor vehicles and machines	0.904542291	Pig iron and crude steel	0.738694219
Precision instruments	0.904520584	Railway transport	0.715948961
Household electric appliances	0.901111271	Tobacco	0.714483378
Electricity	0.899157403	Steel castings and forgings and other steel products	0.707625691
Rubber products	0.897417436	Paper products	0.693907866
Water supply	0.893251631	Steel products	0.684464532
Cement and cement products	0.892007667	Motor vehicles	0.668048557
Inorganic basic chemical products	0.891299465	House rent	0.636684823
Special industrial machinery	0.88932864	Forestry	0.5822088
Other electrical machinery	0.888970498	Nonferrous metal products	0.569753218
Nonmetallic ores	0.888552629	Synthetic resins	0.526768219
Metal products for construction and architecture	0.888547533	Petroleum refinery products	0.295907821

Table 2. Order Correlation of Complexities

Complexity	1985	1990	1995
1985	1		
1990	0.902933	1	
1995	0.834132	0.965661	1

Table 3. Regression Results: Level of Output and Complexity
Estimation method: One-way fixed effects model
Dependent variable: ln(Y) Sample size: 90

Variable	(1)	(2)	(3)	(4)	(5)
INDEX85	−0.444	−0.393	−0.452	−0.253	−0.169
	(0.397)	(0.408)	(0.400)	(0.394)	(0.408)
	(−1.118)	(−0.965)	(−1.131)	(−0.642)	(−0.413)
INDEX90	−0.598	−0.622	−0.596	−0.606	−0.594
	(0.393)	(0.405)	(0.396)	(0.387)	(0.400)
	(−1.523)	(−1.534)	(−1.507)	(−1.564)	(−1.484)
INDEX95	−0.934 *	−0.902 *	−0.933 *	−0.946 **	−0.902 *
	(0.476)	(0.488)	(0.482)	(0.477)	(0.490)
	(−1.963)	(−1.849)	(−1.937)	(−1.984)	(−1.841)
				[.049]	
ln(K)	0.104 ***	0.104 ***	0.105 ***	0.101 ***	0.104 ***
	(0.020)	(0.021)	(0.021)	(0.020)	(0.020)
	(5.108)	(5.078)	(5.119)	(5.047)	(5.104)
ln(L)	0.181 ***	0.183 ***	0.182 ***	0.159 ***	0.163 ***
	(0.029)	(0.029)	(0.029)	(0.029)	(0.030)
	(6.238)	(6.220)	(6.214)	(5.408)	(5.454)
ln(M)	0.646 ***	0.643 ***	0.642 ***	0.672 ***	0.665 ***
	(0.041)	(0.041)	(0.041)	(0.041)	(0.042)
	(15.803)	(15.570)	(15.468)	(16.341)	(15.832)
IMEX85		−0.046			−0.075
		(0.071)			(0.071)
		(−0.641)			(−1.052)
IMEX90		0.012			−0.020
		(0.074)			(0.075)
		(0.159)			(−0.261)
IMEX95		−0.030			−0.055
		(0.072)			(0.074)
		(−0.415)			(−0.743)
DURABLE85			−0.102		−0.111
			(0.190)		(0.187)
			(−0.540)		(−0.592)
DURABLE90			−0.096		−0.092
			(0.189)		(0.187)
			(−0.508)		(−0.490)
DURABLE95			−0.055		−0.051
			(0.190)		(0.187)
			(−0.291)		(−0.272)
Debt Burden85				−0.002 **	−0.002 **
				(0.001)	(0.001)
				(−2.393)	(−2.522)
Debt Burden90				−0.000 *	−0.000 *
				(0.000)	(0.000)
				(−1.709)	(−1.667)
Dept Burden95				0.000	0.000
				(0.000)	(0.000)
				(−1.280)	(−1.395)
Adjusted R-squared	0.974	0.974	0.974	0.975	0.975
Hausman test statistics	21.93 ***	22.525 ***	27.111 ***	24.899 ***	31.858 ***

Note:The first parentheses are standard errors, and the second ones are t-statistics.
Asterisks denote significance at the 10% level (*), the 5% level (**), or the 1% level (***).
IMEX = net exports/(imports + exports)

Table 4. More Significant Complexity in the High-Debt Group

Estimation method: One-way fixed effects model

Dependent variable: ln(Y) Sample size: 90

Variable	(1)	(2)	(3)	(5)
INDEX85 d1	−0.414	−0.372	−0.422	−0.381
	(0.389)	(0.400)	(0.392)	(0.403)
	(−1.063)	(−0.930)	(−1.078)	(−0.945)
INDEX85 d2	−0.577	−0.533	−0.589	−0.546
	(0.394)	(0.406)	(0.397)	(0.408)
	(−1.464)	(−1.315)	(−1.484)	(−1.336)
INDEX90 d1	−0.520	−0.555	−0.519	−0.552
	(0.388)	(0.399)	(0.390)	(0.403)
	(−1.341)	(−1.389)	(−1.328)	(−1.371)
INDEX90 d2	−0.626	−0.663 *	−0.626	−0.661
	(0.387)	(0.401)	(0.390)	(0.404)
	(−1.617)	(−1.655)	(−1.605)	(−1.636)
INDEX95 d1	−0.833 *	−0.807 *	−0.830 *	−0.804 *
	(0.468)	(0.480)	(0.474)	(0.486)
	(−1.778)	(−1.679)	(−1.752)	(−1.653)
INDEX95 d2	−0.991 **	−0.964 **	−0.989 **	−0.962 **
	(0.469)	(0.481)	(0.474)	(0.487)
	(−2.114)	(−2.004)	(−2.085)	(−1.975)
ln(K)	0.100 ***	0.100 ***	0.101 ***	0.101 ***
	(0.020)	(0.020)	(0.020)	(0.020)
	(4.972)	(4.920)	(4.998)	(4.946)
ln(L)	0.175 ***	0.176 ***	0.176 ***	0.177 ***
	(0.029)	(0.029)	(0.029)	(0.029)
	(6.104)	(6.060)	(6.085)	(6.040)
ln(M)	0.652 ***	0.650 ***	0.647 ***	0.645 ***
	(0.040)	(0.041)	(0.041)	(0.041)
	(16.214)	(15.982)	(15.875)	(15.642)
IMEX85		−0.037		−0.037
		(0.070)		(0.070)
		(−0.531)		(−0.525)
IMEX90		0.023		0.021
		(0.073)		(0.073)
		(0.320)		(0.291)
IMEX95		−0.025		−0.025
		(0.071)		(0.071)
		(−0.347)		(−0.349)
DURABLE85			−0.127	−0.127
			(0.186)	(0.188)
			(−0.685)	(−0.679)
DURABLE90			−0.096	−0.093
			(0.186)	(0.187)
			(−0.519)	(−0.499)
DURABLE95			−0.066	−0.066
			(0.186)	(0.187)
			(−0.353)	(−0.351)
Adjusted R-squared	0.975	0.975	0.975	0.975
Hausman test statistics	26.780 ***	27.270 ***	29.938 ***	31.663 ***

Note:The first parentheses are standard errors, and the second ones are t-statistics.
Asterisks denote significance at the 10% level (*), the 5% level (**), or the 1% level (***).
IMEX = net exports/(imports + exports)

Table 5. Comparison of Bubble-related and Other Industries

Estimation method: One-way fixed effects model Dependent variable: ln(Y)	Sample size: 90
Variable	
INDEX85 t1	−0.367 (0.407) (−0.901)
INDEX85 t2	−0.608 (0.423) (−1.440)
INDEX90 t1	−0.571 (0.398) (−1.436)
INDEX90 t2	−0.768 (0.427) (−1.798)
INDEX95 t1	−0.912 * (0.482) (−1.893)
INDEX95 t2	−1.126 ** (0.504) (−2.235)
ln(K)	0.087 *** (0.023) (3.740)
ln(L)	0.196 *** (0.031) (6.381)
ln(M)	0.649 *** (0.041) (15.825)
Adjusted R-squared	0.974
Hausman test statistics	33.351 **

Estimation method: One-way fixed effects model Dependent variable: ln(Y)	Sample size: 90
Variable	
INDEX85 t1 d1	−0.355 (0.403) (−0.880)
INDEX85 t1 d2	−0.469 (0.410) (−1.144)
INDEX85 t2	−0.645 (0.420) (−1.536)
INDEX90 t1 d1	−0.524 (0.396) (−1.322)
INDEX90 t1 d2	−0.598 (0.398) (−1.503)
INDEX90 t2	−0.741 * (0.424) (−1.748)
INDEX95 t1 d1	−0.850 * (0.479) (−1.774)
INDEX95 t1 d2	−1.009 ** (0.481) (−2.096)
INDEX95 t2	−1.086 ** (0.500) (−2.173)
ln(K)	0.084 *** (0.023) (3.628)
ln(L)	0.189 *** (0.031) (6.181)
ln(M)	0.652 *** (0.041) (15.982)
Adjusted R-squared	0.975
Hausman test statistics	40.946 ***

Note:The first parentheses are standard errors, and the second ones are t-statistics.
Asterisks denote significance at the 10% level (*), the 5% level (**), or the 1% level (***).

Table6. Regression Results: Growth of Output and Complexity

Estimation method: Ordinary least squares

	1975--1980	1980--1985	1985--1990	1990--1995
Coefficient	−0.071	0.229	−0.010	−0.206 ***
	(0.136)	(0.140)	(0.155)	(0.069)
	(−0.524)	(1.635)	(−0.062)	(−2.966)

Note: The regressors are the constant term, the complexity index, growth of capital, growth of labor, growth of intermediate goods, the durability dummy, and the debt burden.
The first parentheses are heteroskedastic-consistent standard errors corrected for the degrees of freedom according to Davidson and MacKinnon (1997).
The second parentheses are t-statistics.
Three asterisks (***) denote significance at the 1% level.

Table 7-1. Regression Results: Level of Output and Complexity in the United States
Estimation method: One-way fixed effects model
Dependent variable: ln(Y) Sample size: 47

Variable	(1)	(2)	(3)	(4)
INDEX87	0.999 ***	0.953 **	0.860 **	0.836 **
	(0.365)	(0.377)	(0.366)	(0.376)
	(2.737)	(2.528)	(2.350)	(2.224)
INDEX92	0.211	0.131	0.104	0.028
	(0.321)	(0.330)	(0.321)	(0.330)
	(0.656)	(0.398)	(0.323)	(0.085)
INDEX96	−0.105	−0.204	−0.235	−0.324
	(0.331)	(0.344)	(0.332)	(0.344)
	(−0.318)	(−0.592)	(−0.708)	(−0.940)
ln(K)	0.082 ***	0.085 ***	0.077 ***	0.081 ***
	(0.029)	(0.029)	(0.029)	(0.029)
	(2.843)	(2.899)	(2.698)	(2.777)
ln(L)	0.139 ***	0.146 ***	0.165 ***	0.169 ***
	(0.033)	(0.035)	(0.035)	(0.036)
	(4.161)	(4.152)	(4.681)	(4.634)
ln(M)	0.766 ***	0.753 ***	0.743 ***	0.732 ***
	(0.041)	(0.043)	(0.042)	(0.044)
	(18.822)	(17.420)	(17.596)	(16.496)
IMEX87		−0.005		−0.026
		(0.054)		(0.054)
		(−0.100)		(−0.479)
IMEX92		0.031		0.034
		(0.035)		(0.035)
		(0.879)		(0.977)
IMEX96		0.050		0.044
		(0.055)		(0.055)
		(0.908)		(0.808)
DURABLE87			−0.506 *	−0.564 *
			(0.282)	(0.292)
			(−1.794)	(−1.928)
DURABLE92			0.035	0.037
			(0.276)	(0.278)
			(0.127)	(0.135)
DURABLE96			−0.297	−0.270
			(0.199)	(0.204)
			(−1.491)	(−1.325)
Adjusted R-squared	0.974	0.974	0.975	0.976
Hausman test statistics	30.710 ***	34.836 ***	31.994 ***	33.887 ***

Note:The first parentheses are standard errors, and the second ones are t-statistics.
Asterisks denote significance at the 10% level (*), the 5% level (**), or the 1% level (***).
IMEX = net exports/(imports + exports)

Table 7-2. Regression Results: Growth of Output and Complexity in the United States
Estimation method: Ordinary least squares

	1987--1992	1990--1995
Coefficient	0.228	0.227
	(0.144)	(0.158)
	(1.585)	(1.434)

Note: The regressors are the constant term, the complexity index, growth of capital, growth of labor, growth of intermediate goods, and the durability dummy.
The first parentheses are heteroskedastic-consistent standard errors corrected for the degree of freedom according to Davidson and MacKinnon (1997).
The second parentheses are t-statistics.