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Productivity Slowdown in Japan's Lost Decades: How Much of It is Attributed to Financial Factors?*

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Abstract

The lost decades following the bubble burst in 1991 has been accompanied by slowdown of total factor productivity (TFP) growth in Japan. What has driven the TFP down, however, remains a puzzle. To address this question, we develop a New Keynesian sticky price model that is designed to investigate two suspects behind the TFP slowdown other than regression of technology; (i) malfunction of financial intermediation, and (ii) inter- and intra-sectoral misallocation of resources. Namely, our model consists of two goods producing sectors and financial intermediation and non-technology shocks endogenously alter the observed TFP through these channels. We use an estimated model based on the data from the 1980s to the 2010s to demonstrate that exogenous deteriorations of balance sheets of financial intermediaries and firms contributed a sizable portion of TFP decline by hampering financial intermediation. We also show that such shocks play the dominant role in generating persistent deflation during the lost decades.

Keywords: Lost Decades; Total Factor Productivity; Financial Intermediation; Input-Output Linkage; Financial Imbalances

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1 Introduction

Japanese economy has witnessed a long-lasting economic stagnation since the beginning of the 1990s, which is now called lost decades. While causes behind the lost decades has attracted a number of macroeconomists' attention, no consensus has yet to be reached. Along this line of research, the influential work by Hayashi and Prescott (2002) underscore importance of total factor productivity (hereafter TFP) in accounting for the first half of the lost decades. They demonstrate that TFP slowed down substantially in the 1990s and beyond and show that a simple growth model with such movements of TFP series can well reproduce output movements during the 1990s.[1] Figure 1 shows TFP series that is measured as the Solow residual from the 1980s to the 2000s.[2,3] TFP grew steadily during the bubble boom, deccelerated substantially around the early 1990s, and never reverted back to an original growth rate in the subsequent periods. Average TFP growth rate during the 1980s is 1.84% per year while those of the following two decades are 0.42% and 0.16% per year, respectively. Does this slowdown solely attributed to technological regression? Alternatively, do non-technological changes in economic environments play a role? Whatever the causes are, accounting for this TFP growth slowdown is needed to portray a comprehensive picture of the lost decades.

We explore why TFP growth has slowed down by investigating two suspects other than technological regression: malfunction of financial intermediation and inefficient allocation of resources in goods production. As the lost decades includes two episodes of large financial crises, the bubble burst in February 1991 and the outset of the banking crisis in November 1997, a good number of studies underline importance of financial intermediaries (hereafter FIs) in economic activities during the era. For instance, Bayoumi (2001), based on a vector-autoregressions, stresses that a disruption of financial intermediation originating from interaction of falling asset prices and decreasing banks' lendings is the key driver of the stagnation in the 1990s.[4] While connections between financial intermediation and TFP in an economy has not been much studied in the existing literature, we show below that malfunction of financial intermediation causes a lower TFP in a quantitatively substantial manner.[5]

The second suspect is inefficient allocation of resources in goods production within and across sectors that arises due to factor market distortions. When efficient allocations of production

[1] Hayashi and Prescott (2002) also point out the importance of institutional changes that have reduced the working hours in explaining the output downturns during the same periods. See also Otsu (2011) for the role played by a labor wedge in Japanese economy during this period.

[2] Similarly to Hayashi and Prescott (2002), the TFP growth series is computed from output growth less weighted average of labor input and capital input growth. Our TFP series is, however, slightly different from that of Hayashi and Prescott (2002) partly because of the difference in model structure; (*i*) we do not conduct National Income Accounts Adjustments made by Hayashi and Prescott (2002) and output series in our paper is GDP series of National Income Account, (*ii*) we incorporate effects of variations in capacity utilization of the capital stock when calculating the capital input, and (*iii*) we assume that households' residential asset and foreign asset are not included in the capital stock.

[3] Admittedly, there are several alternative ways of defining TFP. In what follows, TFP stands for the Solow residual unless otherwise noted.

[4] Relatedly, Kwon (1998) empirically documents that contractionary effects of monetary policy tightening in the early 1990s on output were amplified through endogenous price movements of lands that were commonly used as collateral in financial contracts. See also Ogawa et al. (1996) for empirical evidence for contributions of financial constraints in output decline after the bubble burst.

[5] From different perspective from ours, Hoshi and Kashyap (2004, 2010) and Caballero, Hoshi, and Kashyap (2008), discuss that banks' prolonged lendings to unproductive zombie firms have caused lower productivities in the corresponding industry and macroeconomic stagnation. See also Ogawa (2007) for the linkages between financial activity and TFP through R&D investment during the lost decades.

inputs are hindered by various types of frictions, TFP varies depending on type and degree of the frictions. For instance, Basu (1995) uses a one-sector model with imperfect intermediate inputs market with nominal price rigidity to show that a rise in degree of market imperfection lowers TFP through inefficient factor input allocation between intermediate inputs and primary inputs within the sector. From inter-sectoral point of view, Syrquin (1986) employs a multi-sector model to demonstrate that aggregate productivity may change with degree of factor mobility across sectors. Nakakuki et al. (2004), focusing Japanese economy, report that -0.5% out of -3.6% of difference in GDP growth rate between the 1980s and the 1990s is attributed to the resource misallocation across sectors.

In order to investigate the roles played by two suspects as well as technological regression behind the TFP decline both qualitatively and quantitatively, we incorporate three ingredients into otherwise standard New Keynesian sticky price model: (1) financial intermediation conducted by FIs, (2) intermediate input usage in goods productions, and (3) disaggregation of economy into non-durables and durables sector. Financial intermediation in our model is build upon a chained-credit contract model developed by Hirakata, Sudo, and Ueda (2011 hereafter HSU). In this setting, FIs and entrepreneurs that belong to goods producing sectors, are both credit constrained. FIs lend their own net worth and borrowings from households to the entrepreneurs, and the entrepreneurs conduct investment projects making use of their own net worth and borrowings from FIs. Because informational frictions prevail in the credit contracts, the borrowing rates that are applied to the borrowing contracts are negatively related with net worth of FIs and entrepreneurs.

Setting of our model regarding the intermediate input usage is borrowed from Basu (1995) and extended to two sector model following Bouakez, Cardia, and Ruge-Murcia (2009), Petrella and Santoro (2011), and Sudo (2012). The two goods producing sectors are subject to nominal price rigidity and hire intermediate inputs as well as primary inputs in producing goods. Products of goods producing sectors serve as intermediate inputs as well as as final goods. Goods markets are monopolistically competitive and factor mobility across sectors are imperfect in the short-run. Consequently, efficiency of resource allocations in goods productions both across and within sector is affected by degree of such distortions.[6]

In our model, non-technological shocks vary TFP through three channels. First, when financial intermediation activities becomes costly as a result of occurrence of a non-technological shock, TFP drops. Similarly to Bernanke, Gertler and Gilchrist (1999, hereafter BGG), financial intermediation involves monitoring of borrowers' creditworthiness and the cost of monitoring varies in response to changes in economic environments, such as conditions of FIs' balance sheet. Other things being equal, with higher monitoring costs, less resource is left for consumption and output, leading to a smaller TFP. Second, when intra-sectoral allocation of factor inputs, particularly that between usages of intermediate inputs and primary inputs, changes, TFP varies. For instance, a positive markup shock to goods producing sector dampens TFP. Because such shock makes the intermediate goods prices more expensive compared with wages and rental costs of capital, goods producing sectors reduce usages of intermediate inputs relative to those of primary inputs, leading to a lower TFP. Similarly, as discussed in Basu (1995), provided that nominal rigidity of goods price is quantitatively large, an endogenous increase in the markups driven by adverse demand shocks also reduce TFP. Third, imperfect mobility of factor inputs between non-durables and durables sector gives a rise to a change in TFP. Because of frictions associated with factor price adjustments and capital mobility, marginal productivity of capital and labor may differ across sector in the

[6]Similarly to Basu (1995), because intermediate goods market are monopolistically competitive, usage of intermediate inputs in goods producing sectors is too small relative to that of primary inputs at the steady state in our model.

short-run. As a result, efficient inter-sectoral allocation of these inputs is not achieved, lowering TFP.

Admittedly, in addition to these three channels above, our model consists of conventional two sources behind TFP variations. The first source is a technology shock itself. Because of sectoral interdependence originating from input-output structure, however, not only aggregate technology changes but also sectoral technology changes affect TFP.[7] The second source is variations in capacity utilization of capital inputs. Although Hayashi and Prescott (2002) abstracts from the endogenous capacity utilization, as addressed by Basu et al. (2001), it is important to disentangle the role played by capacity utilization in accounting for TFP movements from other sources. To do this, we allow the capacity utilizations to endogenously vary and investigate both TFP series adjusted for the capacity utilization and the series that is not unadjusted during the lost decades.

Based on the Japanese data from 1980Q2 to 2011Q4, we estimate our model. We then quantitatively explore the model's equilibrium response to various types of structural shocks using the estimated model. We show that TFP endogenously responds to non-technological shocks such as shocks to price markups and net worth of FIs and entrepreneurs in goods producing sectors, as they affect cost of financial intermediation, intra- and inter-sectoral resource allocation in goods production, or both. Next, we decompose time path of macroeconomic variables, including TFP, into underlying structural shocks and quantitatively explore which of these shocks are the dominant sources behind the long-lasting TFP growth slow down since the early 1990s.

From the quantitative exercise, two types of shocks emerge as important drivers of TFP movements: shocks to technology and shocks to net worth. While contributions of net worth shocks are quantitatively less important than technology shocks, their impacts play the prominent role in TFP variations around the period of the bubble burst and the banking crisis. Negative shocks to the net worths of FI and goods producing sectors drive TFP and GDP down through all of the three above-mentioned channels. First, as such shocks reduce borrowers' net worths, a larger portion of borrowers default, increasing monitoring costs associated with financial intermediation. Consequently, TFP falls. Second, borrowers with the deteriorated net worth reduce borrowing, causing weaker demand for investment and generating a deflationary pressure to the economy. As prices of intermediate inputs fall slower than those of primary inputs, goods producing sectors hire more of primary inputs, leading to a TFP decline. Finally, while the shocks brings about disproportionately large effects to the durables sector, nominal frictions and capital immobility hamper efficient allocation of production inputs across sectors, lowering TFP further. Among the three channels, we find that monitoring cost channel is quantitatively the most important. Our result is therefore consistent with earlier works that stress the importance of financial malfunction in accounting for the lost decades. Because impacts of these net worth shocks on TFP are in general translated to GDP variations, the net worth shocks contribute importantly to the GDP slow down in the early 1990s as well. In addition to the variations in real variables, net worth shocks played a sizable role in inflation dynamics during the lost decades. While inflation rate was steadily positive up to the early 1990s, adverse net worth shocks occurred during the early 1990s, particularly those to FI sector, substantially lowered inflation rate in the subsequent periods by the mechanism discussed above. Deflationary pressure originating from these shocks were long-lived and remained effective until the early 2000s.

This paper is organized into four sections. Section 2 describes our model. Section 3 estimates our model using the Japanese data to demonstrate quantitatively how our model responds to a various macroeconomic shocks and show relative significance of these shocks and channels in

[7] See Dupor (1999) and Basu et al. (2012) for the detailed discussion about transmission of sectoral productivity shocks to aggregate economic activities.

accounting for TFP variations during the lost decades. Section 4 draws a conclusion.

2 The economy

Figure 2 describes our model structure. The economy consists of five sectors: the household sector, the financial intermediary (FI) sector, the non-durables sector, the durables sector, and the government sector. The household sector consists of two agents, the representative household and the investors. The representative household supplies labor inputs to the goods-producing sectors, earn wage, make deposit to the investors, and receive repayment in return. The investors collect deposits from the household and lend them to the FI sector by making credit contracts called IF contracts with the FIs. The FIs raise the external fund from the investor through the IF contracts and lend it to the goods-producing sectors by making credit contracts with each of the sectors. We call each of the contracts, the FEC and the FED contract, respectively. Each goods-producing sector consists of three agents, the entrepreneurs, the capital goods producer, and the goods producers. The entrepreneurs raise external fund from the FIs, purchase capital goods from the capital goods producers using the fund, and provide the capital goods to the goods producers. They then earn the rental price of the capital goods in return, accumulating the earnings as the net worth. The capital goods producer purchases investment goods from the durables sector and produce the capital goods. The goods producers produce goods from labor input, capital goods, and intermediate goods. Government sector consists of the government and the central bank. The government collects tax from the household sector and spends the tax revenue for the government purchase. The central bank adjusts the nominal interest rate so as to stabilize the inflation rate.

2.0.1 Credit Contracts

The FIs make three credit contracts with other sectors. The first contract is the credit contract with the investors (the IF contract). The second and the third contract are the credit contract with the non-durables sector and the durables sector (the FEC contract and the FED contract, respectively). Similarly to BGG (1999) and HSU (2011), setting of the credit contracts are built upon costly state verification problem. The outline of the three credit contracts are shown in Figure 3.

2.0.2 FEC and FED Contract

Basic Setting

The FEC and FED contract are made between a specific type of FI and a continuum of the entrepreneurs that are attached to the FI in the two goods-producing sectors. In period t, each type i FI offers a loan contract to an infinite number of group j_{i_ξ} entrepreneurs in sector ξ for $\xi = c, x$.[8][9] An entrepreneur in group j_{i_ξ} owns net worth $N_{j_{i_\xi}}(s^t)$ and purchases capital of $Q_\xi(s^t) K_{j_{i_\xi}}(s^t)$, where s^t is the whole history of states until period t, $Q_\xi(s^t)$ is the price paid per unit of capital and $K_{j_{i_\xi}}(s^t)$ is the quantity of capital purchased by the group j_{i_ξ} entrepreneur. Since the net worth

[8] We hereafter utilize the subscript $\xi = c$ to denote non-durable sector and $\xi = x$ to denote the durables sector.

[9] Following HSU (2011), we assume that the monitoring cost that arises in the credit contracts between a type i FI and group $j_{i^*_\xi}$ entrepreneurs for $i_\xi \neq i^*_\xi$ is high so that group $j_{i^*_\xi}$ cannot raise external fund from a type i FI. By the similar assumption, a direct credit contract between the investors and the entrepreneurs is left out from our analysis.

$N_{j_{i_\xi}}(s^t)$ of the entrepreneurs is smaller than the amount of the capital purchase $Q_\xi(s^t) K_{j_{i_\xi}}(s^t)$, the entrepreneur raises the rest of the funds $Q_\xi(s^t) K_{j_{i_\xi}}(s^t) - N_{j_{i_\xi}}(s^t)$ from the type i FI.

The return to the capital received by an entrepreneur in group j_{i_ξ} is a product of two elements: an aggregate return to capital $R_\xi(s^{t+1})$ that is specific to sector ξ and an idiosyncratic productivity shock $\omega_{j_{i_\xi}}(s^{t+1})$, that is specific to the entrepreneur.[10] There is informational asymmetry between lenders and borrowers and the FI i cannot observe the realization of the idiosyncratic shock $\omega_{j_{i_\xi}}(s^{t+1})$ without paying the monitoring cost μ_ξ. Under this costly state verification environment, the FEC and FED contract specify:

- amount of debt that the group j_{i_ξ} entrepreneur borrows from a type i FI, $Q_\xi(s^t) K_{j_{i_\xi}}(s^t) - N_{j_{i_\xi}}(s^t)$, and
- cut-off value of idiosyncratic productivity shock $\omega_{j_{i_\xi}}(s^{t+1})$, which we denote by $\overline{\omega}_{j_{i_\xi}}(s^t)$, such that the group j_{i_ξ} entrepreneur repays its debt if $\omega_{j_{i_\xi}}(s^{t+1}) \geq \overline{\omega}_{j_{i_\xi}}(s^t)$ and declares the default if otherwise.[11]

Entrepreneurs' participation constraint in goods-producing sector ξ

A group j_{i_ξ} entrepreneur joins the FEC or FED contract only when the return from the credit contract is at least equal to the opportunity cost. The contracts state that if entrepreneurs do not default, *ex post,* they receive the net return to its capital holdings:

$$\left(\omega_{j_{i_\xi}}(s^{t+1}) - \overline{\omega}_{j_{i_\xi}}(s^t)\right) R_\xi(s^{t+1}) Q_\xi(s^t) K_{j_{i_\xi}}(s^t).$$

The entrepreneurial loan rate is therefore given by

$$r_{j_{i_\xi}}(s^{t+1}) \equiv \frac{\overline{\omega}_{j_{i_\xi}}(s^t) R_\xi(s^{t+1}) Q_\xi(s^t) K_{j_{i_\xi}}(s^t)}{Q_\xi(s^t) K_{j_{i_\xi}}(s^t) - N_{\xi, j_{i_\xi}}(s^t)}. \tag{1}$$

Instead of participating in the contracts, a group j_{i_ξ} entrepreneur can purchase capital goods using only its own net worth $N_{j_{i_\xi}}(s^t)$. In this case, *ex ante,* the entrepreneur expects to receive the earning $R_\xi(s^{t+1}) N_{j_{i_\xi}}(s^t)$, and *ex post* it receives the earning $\omega_{j_{i_\xi}}(s^{t+1}) R_\xi(s^{t+1}) N_{j_{i_\xi}}(s^t)$. The FEC and FED contract is agreed by a group j_{i_ξ} entrepreneurs therefore only when the following inequality is expected to hold:

$$\begin{aligned} \sum_{s^{t+1}} \Pr(s^{t+1}) \; R_\xi(s^{t+1}) Q_\xi(s^t) K_{j_{i_\xi}}(s^t) \left(\int_{\overline{\omega}_{,j_{i_\xi}}(s^t)}^{\infty} \left(\omega_\xi - \overline{\omega}_{j_{i_\xi}}(s^t)\right) dF_\xi(\omega_\xi) \right) \\ \geq \sum_{s^{t+1}} \Pr(s^{t+1}) \, R_\xi(s^{t+1}) \, N_{j_{i_\xi}}(s^t) \;\text{ for } \forall j_{i_\xi}. \end{aligned} \tag{2}$$

Note that $\Pr(s^{t+1})$ is probability weight attached to state s^{t+1}.

[10] Here, the idiosyncratic productivity shock is a unit mean, lognormal random variable distributed independently over time and across entrepreneurs in sector ξ. We express its density function by $f_\xi(\bullet)$ and its cumulative distribution function by $F_\xi(\bullet)$.

[11] The cut-off value of the FEC and the FED contracts are dependent only on the entrepreneurial net worth of the two goods-producing sector in period t, and invariant to the aggregate state in period $t+1$.

FIs' profit from the credit contracts with the goods-producing sectors

From FIs' perspective, equation (2) states their expected earnings from the FEC and FED contract are given by

$$\sum_{s^{t+1}} \Pr\left(s^{t+1}\right) \left[\sum_{\xi=c,x} \int_{j_{i_\xi}} R_\xi\left(s^{t+1}\right) \Phi_{\xi_i}\left(s^t\right) Q_\xi\left(s^t\right) K_{j_{i_\xi}}\left(s^t\right) dj_{i_\xi}\right],$$

where

$$\Phi_{\xi_i}\left(s^t\right) \equiv \int_{\overline{\omega}_{j_{i_\xi}}(s^t)}^{\infty} \overline{\omega}_{j_{i_\xi}}\left(s^t\right) dF_\xi\left(\omega_\xi\right) + \left(1-\mu_\xi\right) \int_0^{\overline{\omega}_{j_{i_\xi}}(s^t)} \omega_\xi dF_\xi\left(\omega_\xi\right), \text{ for } \xi = c, x. \tag{3}$$

Note that term associated with μ_ξ accounts for the *ex post* monitoring cost that a type i FI pays when a group j_{i_ξ} entrepreneur in sector ξ declares the default.

The type i FI makes a contract with a infinite number of group j_{i_ξ} entrepreneur in sector ξ with the same size of cut-off value $\overline{\omega}_{j_{i_\xi}}$. This is because as discussed in HSU (2011), the cut-off value is dependent on the ratio of amount of capital purchase over the entrepreneurial net worth which is identical across j_{i_ξ}. Consequently, the FI's expected total return from both the FEC and the FED contract can be expressed by

$$\sum_{s^{t+1}} \Pr\left(s^{t+1}\right) \sum_{\xi=c,x} \Phi_{\xi_i}\left(s^t\right) R_\xi\left(s^{t+1}\right) Q_\xi\left(s^t\right) K_{i_\xi}\left(s^t\right), \tag{4}$$

where

$$K_{i_\xi}\left(s^t\right) \equiv \int_{j_{i_\xi}} K_{j_{i_\xi}}\left(s^t\right) dj_{i_\xi}, \text{ for } \xi = c, x.$$

For the convenience of analysis below, we define the total amount of net worth held by the group j_{i_ξ} entrepreneur in sector ξ.

$$N_{\xi,i}\left(s^t\right) \equiv \int_{j_{i_\xi}} N_{j_{i_\xi}}\left(s^t\right) dj_{i_\xi}, \text{ for } \xi = c, x.$$

2.0.3 IF Contract

Basic setting

The IF contract is made between an investor and a continuum of the FIs. As discussed above, in period t, each type i FI, holding the net worth $N_{F,i}\left(s^t\right)$, makes loans to group j_{i_ξ} entrepreneurs in sector ξ at an amount of $Q_\xi\left(s^t\right) K_{\xi,i}\left(s^t\right) - N_{\xi,i}\left(s^t\right)$. Since the FI i's net worth is smaller than its loans to the entrepreneurs in the two sectors, it borrows the funds $\sum_{\xi=c,x}\left[Q_\xi\left(s^t\right) K_{\xi,i}\left(s^t\right) - N_{\xi,i}\left(s^t\right)\right]$ $- N_{F,i}\left(s^t\right)$ from the investor. The FI are also hit by an idiosyncratic productivity shock $\omega_{F,i}\left(s^{t+1}\right)$ that represents technological differences across the FIs, for example, those associated with risk management, maturity mismatch control, and loan securitization. Consequently, *ex post,* the FI's net receipt is given by[12]

[12] Similarly to the entrepreneurial idiosyncratic productivity shock, the FIs' idiosyncractic productivity shock is a unit mean, lognormal random variable distributed independently over time and across FIs i. Its density function and its cumulative distribution function are given by $f_F(\bullet)$ and $F_F(\bullet)$, respectively.

$$\omega_{F,i}\left(s^{t+1}\right)\left[\sum_{\xi=c,x}\Phi_{\xi_i}\left(s^t\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_{i_\xi}\left(s^t\right)\right].$$

There is informational asymmetry between the investors and the FIs. The investors can observe the realization of the idiosyncratic shock only by paying the monitoring cost μ_F. Under this environment, the IF contract specifies:

- amount of debt that a type i FI borrows from the investor, $\sum_{\xi=c,x}\left[Q_\xi\left(s^t\right)K_{\xi,i}\left(s^t\right)-N_{\xi,i}\left(s^t\right)\right]-N_{F,i}\left(s^t\right)$, and
- cut-off value of idiosyncratic shock $\omega_{F,i}\left(s^{t+1}\right)$, which we denote by $\overline{\omega}_{F,i}\left(s^t\right)$, such that the FI repays debt if $\omega_{F,i}\left(s^{t+1}\right)\geq\overline{\omega}_{F,i}\left(s^{t+1}|s^t\right)$ and declares the default if otherwise.[13]

According to the IF contracts, a portion of the FIs $\int_{\overline{\omega}_{F,i}(s^{t+1}|s^t)}^{\infty}dF_F\left(\omega_F\right)$ do not default and the rest of them default. *Ex post,* a default FI i receives none and a non-default FI i receives earnings:

$$\left(\omega_{F,i}\left(s^{t+1}\right)-\overline{\omega}_{F,i}\left(s^{t+1}|s^t\right)\right)\left(\sum_{\xi=c,x}\Phi_{\xi_i}\left(s^t\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_{i_\xi}\left(s^t\right)\right).$$

The FIs' loan rate confronting the non-default FI i is therefore given by

$$r_F\left(s^{t+1}|s^t\right)\equiv\frac{\overline{\omega}_{F,i}\left(s^{t+1}|s^t\right)\left(\sum_{\xi=c,x}\Phi_{\xi_i}\left(s^t\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_{i_\xi}\left(s^t\right)\right)}{\sum_{\xi=c,x}\left[Q_\xi\left(s^t\right)K_{\xi,i}\left(s^t\right)-N_{\xi,i}\left(s^t\right)\right]-N_{F,i}\left(s^t\right)}.\tag{5}$$

Investors' participation constraint

Investors participate in the IF contracts only when it is better off. Given the risk-free rate of return in the economy $R\left(s^t\right)$, the investor's net receipt from the IF contracts must at least equal the return from the risk-free investment. That is

$$\left[\Phi_{F,i}\left(s^{t+1}|s^t\right)\left[\sum_{\xi=c,x}\Phi_{\xi_i}\left(s^t\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_{i_\xi}\left(s^t\right)\right]\right]$$

$$\geq R\left(s^t\right)\left[\sum_{\xi=c,x}\left[Q_\xi\left(s^t\right)K_{\xi,i}\left(s^t\right)-N_{\xi,i}\left(s^t\right)\right]-N_{F,i}\left(s^t\right)\right]\text{ for }\forall i,s^{t+1},\tag{6}$$

where

$$\Phi_{F,i}\left(s^{t+1}|s^t\right)\equiv\int_{\overline{\omega}_{F,i}(s^{t+1}|s^t)}^{\infty}\overline{\omega}_{F,i}\left(s^{t+1}|s^t\right)dF_F\left(\omega_F\right)+\left(1-\mu_F\right)\int_0^{\overline{\omega}_{F,i}\left(s^{t+1}|s^t\right)}\omega_F dF_F\left(\omega_F\right).\tag{7}$$

[13] Similarly to BGG (1999), we assume that the contents of the FI contracts are contingent on aggregate states so that participating constraint regarding the investors hold with equality for all of the states in $t+1$.

2.0.4 Optimal Credit Contract chosen by the FI

Given the structure of the FEC, FED, and IF contract, a type i FI optimally chooses capital goods purchased from capital goods producing sectors, the cut-off value in the three classes of contracts, respectively. As shown in HSU (2011), since all types of FIs are identical in terms of Φ_{ξ_i},the expected profit of a type i FI is given by

$$\sum_{s^{t+1}} \Pr\left(s^{t+1}\right)\left[\int_{\overline{\omega}_F(s^{t+1}|s^t)}^{\infty}\left(\omega_F - \overline{\omega}_F\left(s^{t+1}|s^t\right)\right)dF_F\left(\omega_F\right)\right]\left[\sum_{\xi=c,x}\Phi_\xi\left(s^{t+1}|s^t\right)R_\xi\left(s^{t+1}|s^t\right)Q_\xi\left(s^t\right)K_{i_\xi}\left(s^t\right)\right] \tag{8}$$

The FI then maximizes the term (8), subject to the investor's participation constraint (6) and entrepreneurial participation constraint (2) for $\xi = c, x$.

2.0.5 Dynamic Behavior of Net Worth

The main sources of net worth accumulation of the FIs and the entrepreneurs in the goods-producing sector are the earnings from the credit contracts discussed above. In addition, there are two other sources of earnings. First, FIs and entrepreneurs inelastically supply a unit of labor to the goods-producing sectors and receive labor income $W_\zeta\left(s^t\right)$ for $\zeta = F$, c, and x.[14] Second, each of them is subject to an exogenous disturbance and varies in response to the shock. Their aggregate net worths are then given by

$$N_F\left(s^{t+1}\right) = \gamma_F V_F\left(s^{t+1}\right) + \sum_{\xi=c,x}\frac{W_{F_\xi}\left(s^t\right)}{P_{CPI}\left(s^t\right)} + \varepsilon_{N_F}\left(s^t\right), \tag{9}$$

$$N_\xi\left(s^{t+1}\right) = \gamma_\xi V_\xi\left(s^{t+1}\right) + \frac{W_\xi\left(s^t\right)}{P_{CPI}\left(s^t\right)} + \varepsilon_{N_\xi} \text{ for } \xi = c, x, \tag{10}$$

with

$$\begin{aligned} V_F\left(s^{t+1}\right) &\equiv \left(1-\Gamma_F\left(\overline{\omega}_F\left(s^{t+1}|s^t\right)\right)\right)\sum_{\xi=c,x}\left[\Phi_\xi\left(\overline{\omega}_\xi\left(s^t\right)\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_\xi\left(s^t\right)\right], \\ V_\xi\left(s^{t+1}\right) &\equiv \left(1-\Gamma_\xi\left(\overline{\omega}_\xi\left(s^t\right)\right)\right)R_\xi\left(s^{t+1}\right)Q_\xi\left(s^t\right)K_\xi\left(s^t\right), \text{ for } \xi = c, x. \end{aligned}$$

Note that each FIs and entrepreneurs in the goods-producing sectors survive to the next period with probability γ_ζ, and those who are in business in period t and fail to survive in period $t+1$ consume $\left(1-\gamma_\zeta\right)V_\zeta\left(s^t\right)$ for $\zeta = F, c, x$. The exogenous net worth disturbances represented by $\varepsilon_{N_\zeta}\left(s^t\right)$ for $\zeta = F, c, x$, are i.i.d. and orthogonal to the earnings from the credit contracts. These shocks capture an "asset bubble," "irrational exuberance," or an "innovation in the efficiency of credit contracts," hitting the FI sector or the goods-producing sectors.[15]

[14] See BGG (1999), Christiano, Motto, and Rostagno (2008) and HSU (2011) for the technical reason for introducing inelasitc labor supply from the FIs and the entrepreneurs.

[15] The setting of these net worth shocks is borrowed from Gilchrist and Leahy (2002). See also CMR (2008) and Nolan and Thoenissen (2009) for the interpretation of these net worth shocks under credit market imperfection. In these studies, the exit ratio of entrepreneurs γ_ζ obeys the stochastic law of motion, generating an unexpected change in the entrepreneurial net worth.

2.1 Households

Set up

Household h is an infinitely-lived representative agent with preference over the non-durables consumption, $C\left(h,s^t\right)$, service from the stock of durables, $D\left(h,s^t\right)$, and work effort, $L_\xi\left(h,s^t\right)$ for $\xi = c, x$, as described in the expected utility function, (11)

$$U_0 \equiv \sum_{t=0}^{\infty} \sum_{s^t} \Pr\left(s^t\right) \beta^t \left[\log\left(C^{\psi_c}\left(h,s^t\right) D^{\psi_d}\left(h,s^t\right)\right) - \varphi \frac{\left(\sum_{\xi=c,x} L_\xi\left(h,s^t\right)\right)^{1+v}}{1+v} \right], \tag{11}$$

where $\beta \in (0,1)$ is the discount factor, $v > 0$ is the inverse of the Frisch labor-supply elasticity, and φ is the weighting assigned to leisure. The parameter $\psi_\xi \in (0,1)$ for $\xi = c, d$ represents relative weights on utility from consuming each goods. The budget constraint for household h is given by

$$\sum_{\xi=c,x} P_\xi\left(s^t\right) \xi\left(h,s^t\right) + S\left(i,s^t\right) \leq \left[\begin{array}{l} \sum_{\xi=c,x} W_\xi\left(h,s^t\right) L_\xi\left(h,s^t\right) \\ -\sum_{\xi=c,x} \frac{\kappa_{w_\xi}}{2} \left(\frac{W_\xi\left(h,s^t\right)}{W_\xi\left(h,s^{t-1}\right)} - 1 \right)^2 W_\xi\left(s^t\right) L_\xi\left(s^t\right) \\ +R\left(s^{t-1}\right) S\left(h,s^{t-1}\right) + \Omega\left(h,s^t\right) + \tau\left(h,s^t\right) \end{array} \right], \tag{12}$$

where $P_\xi\left(s^t\right)$ denotes nominal prices of goods ξ, $S\left(h,s^{t-1}\right)$ is the saving, $R_s\left(s^t\right)$ is the nominal rate on deposit, $\Omega\left(h,s^t\right)$ is the nominal profit returned to the household, and $\tau\left(s^t\right)$ is the lump-sum nominal transfer from the government. $W_\xi\left(h,s^t\right)$ is the nominal wage and $W_\xi\left(s^t\right)$ is aggregate indices of the nominal wage in sector ξ. The second term in the right hand side of the equation stands for the nominal cost associated with adjusting nominal wage $W_\xi\left(h,s^t\right)$, and κ_{w_ξ} is parameter that governs the size of the cost.

Labor supply decision

Household h has the monopolistic power in its differentiated labor input $L_\xi\left(h,s^t\right)$ in sector ξ. The demand of the differentiated labor is given by

$$L_\xi\left(h,s^t\right) = \left(\frac{W_\xi\left(h,s^t\right)}{W_\xi\left(s^t\right)} \right)^{-\theta_{W_\xi}\left(s^t\right)} L_\xi\left(s^t\right) \text{ for } \xi = c, x, \tag{13}$$

where $L_\xi\left(s^t\right)$ is aggregate indices of labor input in sector ξ that is defined as

$$L_\xi\left(s^t\right) = \left[\int_0^1 L_{\xi,t}\left(h,s^t\right)^{\left(\theta_{W_\xi}\left(s^t\right)-1\right)/\theta_{W_\xi}\left(s^t\right)} dh \right]^{\theta_{W_\xi}\left(s^t\right)/\left(\theta_{W_\xi}\left(s^t\right)-1\right)} \quad \text{for } \xi = c, x,$$

where $\theta_{Wc}\left(s^t\right)$ and $\theta_{W_x}\left(s^t\right) \in (1,\infty)$ deliver time-varying elasticity of labor demand for differentiated labor input with respect to wages.

Durables accumulation

The law of motion for the stock of durable is given by

$$D\left(h,s^t\right) = (1-\delta_d) D_{t-1}\left(h,s^{t-1}\right) + \left(1 - \frac{\kappa_{dd}}{2} \left(\frac{X_t\left(h,s^t\right)}{X_{t-1}\left(h,s^{t-1}\right)} - 1 \right)^2 \right) X_t\left(h,s^t\right), \tag{14}$$

where $\delta_d \in (0,1)$ is the depreciation rate of the durables stock, and κ_{dd} is the parameter associated with durable stock adjustment.

2.2 Goods Producers

Set up

The economy consists of two distinct sectors of production: the non-durables sector and the durables sector. Following the specification of the model described by Huang et al. (2004), we assume that both sectors contain a continuum of firms, each producing differentiated products, as indexed by $l \in [0,1]$, $m \in [0,1]$, respectively. We use $C_g(s^t)$ to denote a gross output of composite of differentiated non-durables $\{C_g(l,s^t)\}_{l\in[0,1]}$, and $X_g(s^t)$ to denote a gross output of composite of differentiated durables $\{X_g(m,s^t)\}_{m\in[0,1]}$. The production functions of the two composites are

$$C_g(s^t) = \left[\int_0^1 C_g(l,s^t)^{1-(\theta_{P_c}(s^t))^{-1}} dl\right]^{\frac{\theta_{P_c}(s^t)}{\theta_{P_c}(s^t)-1}}, \; X_g(s^t) = \left[\int_0^1 X_g(m,s^t)^{1-(\theta_{P_x}(s^t))^{-1}} dm\right]^{\frac{\theta_{P_x}(s^t)}{\theta_{P_x}(s^t)-1}},$$

where $\theta_{P_\xi}(s^t) \in (1,\infty)$ denotes the time-varying elasticity of substitution between products in sector ξ. The composite products are produced in an aggregation sector that faces perfect competition. The demand functions for the non-durables firm l and for the durables firm m are derived from the optimization behavior of the aggregation sector, represented by

$$C_g(l,s^t) = \left[\frac{P_c(l,s^t)}{P_c(s^t)}\right]^{-\theta_{P_c}(s^t)} C_g(s^t) \text{ and } X_g(m,s^t) = \left[\frac{P_x(m,s^t)}{P_x(s^t)}\right]^{-\theta_{P_x}(s^t)} X_g(s^t), \tag{15}$$

where $P_\xi(s^t)$ is the prices of the composite of goods produced in sector ξ. These prices are related to the prices of the non-durables $\{P_c(l,s^t)\}_{l\in[0,1]}$ and the durables $\{P_x(m,s^t)\}_{m\in[0,1]}$ by

$$P_c(s^t) = \left[\int_0^1 P_c(l,s^t)^{1-\theta_{P_c}(s^t)} dl\right]^{\frac{1}{1-\theta_{P_c}(s^t)}} \text{ and } P_x(s^t) = \left[\int_0^1 P_x(m,s^t)^{1-\theta_{P_x}(s^t)} dm\right]^{\frac{1}{1-\theta_{P_x}(s^t)}}.$$

In our economy, the composites serve either as final goods, such as consumption goods and investment goods, or as intermediate production inputs. The allocation of the gross output of the non-durables is

$$\begin{aligned} C_g(s^t) &= C(s^t) + G_c(s^t) + \int_0^1 \Psi_c(l,s^t)\,dl + \int_0^1 \Psi_d(m,s^t)\,dm \\ &+ \sum_{\xi=c,x}\left[\mu_\xi\left(\int_0^{\overline{\omega}_\xi} \omega_\xi dF_\xi(\omega_\xi)\right) R_\xi(s^t)\,Q_\xi(s^{t-1})\,K_\xi(s^{t-1})\right] \\ &+ \sum_{\xi=c,x}\left[\mu_F\left(\int_0^{\overline{\omega}_F} \omega_F dF_F(\omega_F)\right) \Phi_\xi(\overline{\omega}_\xi(s^t))\,R_\xi(s^t)\,Q_\xi(s^{t-1})\,K_\xi(s^{t-1})\right] \\ &+ \sum_{\xi=c,x,F}(1-\gamma_\xi)\,V_\xi(s^t). \end{aligned} \tag{16}$$

where $\{\Psi_c(l,s^t)\}_{l\in[0,1]}$ are intermediate production inputs used by firm l in the non-durables sector, and $\{\Psi_d(m,s^t)\}_{m\in[0,1]}$ are intermediate production inputs used by firm m in the durables sector. In addition, as shown in the forth and fifth terms, we assume that non-durable is used by the FIs in monitoring for defaulted FIs and entrepreneurs. The similar equation holds for a composite of durables $X_g(s^t)$ and intermediate production inputs $\{\Gamma_c(l,s^t)\}_{l\in[0,1]}$, $\{\Gamma_d(m,s^t)\}_{m\in[0,1]}$. The gross output of the durables is used as final consumption goods and intermediate production inputs but also as investment goods and government purchase:

$$X_t^g(s^t) = X(s^t) + \int_0^1 \Gamma_c(l,s^t)\,dl + \int_0^1 \Gamma_x(m,s^t)\,dm + \sum_{\xi=c,x} I_\xi(s^t) + G_x(s^t) \tag{17}$$

Production function

The inputs used by firms in each sector are labor, capital and intermediate inputs. The production function of firm l in the non-durables sector is given by

$$C_g(l,s^t) = \begin{array}{l} Z(s^t)\,A(s^t)\,\Psi_c(l,s^t)^{\gamma_{11}}\,\Gamma_c(l,s^t)^{\gamma_{21}}\left[L_c(l,s^t)^{\alpha}\right]^{1-\gamma_{11}-\gamma_{21}} \\ \times\left[\left[K_c(l,s^t)\,U_c(l,s^t)\right]^{1-\alpha-\alpha_E-\alpha_{FI}}\right]^{1-\gamma_{11}-\gamma_{21}} - F_c \end{array} \tag{18}$$

Similarly, the production function of firm m in the durables sector is given by

$$X_g(m,s^t) = \begin{array}{l} Z(s^t)\,Z_x(s^t)\,A(s^t)\,A_x(s^t)\,\Psi_x(m,s^t)^{\gamma_{12}}\,\Gamma_x(m,s^t)^{\gamma_{22}}\left[L_x(m,s^t)^{\alpha}\right]^{1-\gamma_{12}-\gamma_{22}} \\ \times\left[\left[K_x(m,s^t)\,U_x(l,s^t)\right]^{1-\alpha-\alpha_E-\alpha_{FI}}\right]^{1-\gamma_{12}-\gamma_{22}} - F_x. \end{array} \tag{19}$$

Here, $Z(s^t)$, $Z_x(s^t)$, are non-stationary component of technology that is common to the goods-producing sectors and that is specific to the durables producing sector respectively. $A(s^t)$ and $A_x(s^t)$ are stationary component of technology that is common to the goods-producing sectors and that is specific to the durables producing sector respectively. The parameters $\gamma_{\xi\hat{\xi}}$ for $\xi,\hat{\xi}=1,2$ denote the cost share of total expenditure on inputs in sector ξ due to the purchase of intermediate inputs from sector $\hat{\xi}$. We assume that the values of $\gamma_{\xi\hat{\xi}}$ are identical across firms in the same sector. $\{L_c(l,s^t),\ L_x(m,s^t)\}$, $\{K_c(l,s^t),\ K_x(m,s^t)\}$, and $\{U_c(l,s^t),\ U_x(m,s^t)\}$ are labor inputs, capital inputs, and capital utilization rate in firm l and firm m. α is the labor share of primary inputs in the two sectors. F_c and F_x are fixed costs that are identical for all firms[16].

Firms l and m in the two goods producing sectors are price-takers in the input markets. In this set-up, the cost-minimization problem of firm l in the non-durables sector and firm m in the durables sector yield the following marginal cost function:

$$\begin{aligned} MC_c(l,s^t) &= \frac{\bar{\phi}_c P_c(s^t)^{\gamma_{11}}\,P_x(s^t)^{\gamma_{21}}}{A(s^t)\,Z(s^t)}\left[\begin{array}{l} W_c(s^t)^{\alpha}\,W_{E_c}(s^t)^{\alpha_{E_c}}\,W_{E_d}(s^t)^{\alpha_{E_d}} \\ \times W_{F_c}(s^t)^{\alpha_F}\,\tilde{R}_c(s^t)^{1-\alpha-\alpha_E-\alpha_F} \end{array}\right]^{1-\gamma_{11}-\gamma_{21}}, \\ MC_d(m,s^t) &= \frac{\bar{\phi}_d P_c(s^t)^{\gamma_{12}}\,P_x(s^t)^{\gamma_{22}}}{A(s^t)\,A_d(s^t)\,Z(s^t)\,Z_d(s^t)}\left[\begin{array}{l} W_d(s^t)^{\alpha}\,W_{E_c}(s^t)^{\alpha_{E_c}}\,W_{E_d}(s^t)^{\alpha_{E_d}} \\ \times W_{F_d}(s^t)^{\alpha_F}\,\tilde{R}_d(s^t)^{1-\alpha-\alpha_E-\alpha_F} \end{array}\right]^{1-\gamma_{12}-\gamma_{22}} \end{aligned} \tag{20}$$

where $\bar{\phi}_\xi$ is constant and $\tilde{R}_\xi(s^t)$ is nominal gross return to capital usage, $K_c(l,s^t)\,U_c(l,s^t)$ and $K_x(m,s^t)\,U_x(m,s^t)$, in sector ξ. We assume that a capital utilization rate is determined by

[16] F_c and F_x are set so that there is no incentive for a firm in one sector to enter into the market of other products. This condition implies that the profits from operating in either of the two sectors are zero at the steady state (Huang et al., 2004).

entrepreneurs in sector ξ for $\xi = c, x$, and choosing capital utilization $U_\xi\left(s^t\right)$ incurs the real cost of

$$\frac{\kappa_U K_\xi\left(s^t\right) U_\xi\left(s^t\right)^{\Upsilon_U+1} - 1}{\Upsilon_U + 1},$$

where κ_U and Υ_U are parameters that govern capital utilization rate. The nominal gross returns to capital in the goods-producing sectors then are expressed by the aggregate returns by the following equations.

$$R_\xi\left(s^{t+1}|s^t\right) = \frac{\frac{U_\xi\left(s^t\right)\tilde{R}_\xi\left(s^t\right)}{P_{CPI}\left(s^t\right)} - \frac{Q\left(s^t\right)\left(\kappa_U U_\xi\left(s^t\right)^{\Upsilon_U+1}-1\right)}{\Upsilon_U+1} + (1-\delta)\, Q_\xi\left(s^t\right)}{Q_\xi\left(s^{t-1}\right)}, \text{ for } \xi = c, x$$

where $P_{CPI}\left(s^t\right)$ is the aggregate CPI.

Price setting

Firm l in the non-durables sector are monopolistic competitors in the products market where they set prices for their products $P_c\left(l, s^t\right)$ in reference to the demand given by (15). It can reset the prices solving the following problem:

$$\max_{\{P_c(l,s^t)\}} \sum_{q=0}^{\infty} \sum_{s^{t+q}} \Pr\left(s^{t+q}\right) \frac{\Lambda_{t,t+q}}{\Lambda_{t,t}} \frac{\Pi_c\left(l, s^{t+q}\right)}{P_c\left(s^{t+q}\right)} \tag{21}$$

$$s.t.\ \Pi_c\left(l, s^{t+q}\right) = \begin{array}{l} P_c\left(l, s^{t+q}\right) C_g\left(l, s^{t+q}\right) - MC_c\left(l, s^{t+q}\right)\left(C_g\left(l, s^{t+q}\right) + F_c\right) \\ -\frac{\kappa_{pc}}{2}\left(\frac{P_c\left(l,s^{t+q}\right)}{P_c\left(l,s^{t+q-1}\right)} - 1\right)^2 P_c\left(s^{t+q}\right) C_g\left(s^{t+q}\right) \end{array}$$

where $\Lambda_{t,t+q}$ is the Lagrange multiplier associated with budget constraint (12), and κ_{p_c} is the parameter associated with non-durables price adjustment. The price setting of the durables sector is conducted in the similar way.

2.3 Capital Goods Producer

Capital goods producers in sector ξ for $\xi = c, x$ converts investment goods $I_\xi\left(s^t\right)$ purchased from durables sector to capital goods $K_\xi\left(s^t\right)$, using technology $F_{I_\xi}\left(s^t\right)$, and sell it to the entrepreneurs with price $Q_\xi\left(s^t\right)$. The capital goods producers' problem is to maximize the profit function given below:

$$\max_{I_\xi(s^t)} \sum_{q=0}^{\infty} \sum_{s^{t+q}} \Pr\left(s^{t+q}\right) \Lambda_{t,t+q} \left[Q_\xi\left(s^{t+q}\right)\left(K_\xi\left(s^{t+q}\right) - (1-\delta) K_\xi\left(s^{t+q-1}\right)\right) - \frac{P_x\left(s^t\right) I_\xi\left(s^{t+q}\right)}{P_{CPI}\left(s^t\right)}\right],$$

where F_{I_ξ} is defined as follows:

$$F_{I_\xi}\left(I_\xi\left(s^{t+q}\right), I_\xi\left(s^{t+q-1}\right), \kappa_{I_\xi}\left(s^{t+q}\right)\right) \equiv \frac{\kappa_{I_\xi}\left(s^{t+q}\right)}{2}\left(\frac{I_\xi\left(s^{t+q}\right)}{I_\xi\left(s^{t+q-1}\right)} - 1\right)^2,$$

where $\kappa_{\xi}\left(s^{t+q}\right)$ is a time-varying parameter that is associated with investment adjustment cost in sector ξ.[17] As capital depreciates in each period, the evolvement of total capital is given by

$$K_{\xi}\left(s^{t}\right)=\left(1-F_{I_{\xi}}\left(I_{\xi}\left(s^{t}\right),I_{\xi}\left(s^{t-1}\right)\right)\right)I_{\xi}\left(s^{t}\right)+\left(1-\delta\right)K_{\xi}\left(s^{t-1}\right). \tag{22}$$

where $\delta\in(0,1)$ is the depreciation rate of the capital stock.

2.4 Defining Aggregate Variables

The real GDP Y_t is defined as the weighted average of value-added components:

$$Y\left(s^{t}\right)\equiv\left[C\left(s^{t}\right)+G_{c}\left(s^{t}\right)\right]^{\psi_{Y_c}}\left[X\left(s^{t}\right)+G_{x}\left(s^{t}\right)+\sum_{\xi=c,x}\left[I_{\xi}\left(s^{t}\right)\right]\right]^{\psi_{Y_x}}, \tag{23}$$

where ψ_{Y_ξ} is the steady-state expenditure share for the value-added produced by sector ξ over the total expenditure. The inflation of GDP deflator and CPI, $\pi\left(s^{t}\right)$ and $\pi_{CPI}\left(s^{t}\right)$, are defined by

$$\pi\left(s^{t}\right)=\prod_{\xi=c,x}\left(\frac{P_{\xi}\left(s^{t}\right)}{P_{\xi}\left(s^{t-1}\right)}\right)^{\psi_{Y_\xi}}\text{ and }\pi_{CPI}\left(s^{t}\right)=\prod_{\xi=c,x}\left(\frac{P_{\xi}\left(s^{t}\right)}{P_{\xi}\left(s^{t-1}\right)}\right)^{\psi_{PCE_\xi}}, \tag{24}$$

where ψ_{PCE_ξ} is the steady-state share of the consumption expenditure for goods produced from sector ξ over the total consumption expenditure. The real interest rate is given by the Fischer equation that connects the nominal interest rate set by the government sector $R_n\left(s^{t}\right)$ and the expected inflation:

$$R\left(s^{t}\right)=\frac{R_{n}\left(s^{t}\right)}{\sum_{s^{t+1}}\Pr\left(s^{t+1}\right)\pi\left(s^{t+1}|s^{t}\right)}.$$

2.5 Government Sector

The government collects a lump-sum tax $\tau\left(s^{t}\right)$ from the household to finance government purchase $P_{\xi}\left(s^{t}\right)G_{\xi}\left(s^{t}\right)$ whose amount is exogenously given. We assume that a balanced budget is maintained in each period t as follows:

$$\sum_{\xi=c,x}P_{\xi}\left(s^{t}\right)G_{\xi}\left(s^{t}\right)=\tau\left(s^{t}\right)$$

The central bank adjusts policy rate according to the following Taylor rule:

$$R_{n}\left(s^{t}\right)=R_{n}\left(s^{t-1}\right)^{\rho}\pi\left(s^{t}\right)^{(1-\rho)\varphi}\exp\left(\epsilon_{R_n}\left(s^{t}\right)\right). \tag{25}$$

Here, $\rho\in(0,1)$ is the persistency parameter of the monetary policy rule, $\varphi>1$ is the policy weight attached to the inflation rate and $\epsilon_{R_n}\left(s^{t}\right)$ is an i.i.d. shock to the rule.

[17] A term for used capital $K_{\xi}\left(s^{t}\right)$ sold by the entrepreneurs at the end of the period $t-1$ does not appear in the equation. This is because, following BGG (1999), we assume that the price of capital that the entrepreneurs sell back to the capital goods producers, say $\overline{Q}_{\xi}\left(s^{t}\right)$, is close to the price of newly produced capital $Q_{\xi}\left(s^{t}\right)$ around the steady state.

2.6 Shock Process

The exogenous variables, the permanent technology common in the goods-producing sectors $Z(s^t)$, the permanent technology specific to the durables sector $Z_x(s^t)$, the exogenous components in net worth variations in borrowing sector $\varepsilon_{N_F}(s^t)$, $\varepsilon_{N_c}(s^t)$, $\varepsilon_{N_x}(s^t)$, the government spending $G_\xi(s^t)$, the investment adjustment cost $\kappa_{I_\xi}(s^t)$, the price markup $\theta_{P_\xi}(s^t)$, and the wage markup $\theta_{W_\zeta}(s^t)$ in goods-producing sector ξ, and the technology of capacity utilization of capital inputs $Z_U(s^t)$ evolve according to the equation below:

$$
\begin{aligned}
\ln Z\left(s^t\right) &= \ln Z\left(s^{t-1}\right) + u_Z\left(s^t\right),\ u_Z\left(s^t\right) = \rho_Z u_Z\left(s^{t-1}\right) + \epsilon_Z\left(s^t\right), \\
\ln Z_x\left(s^t\right) &= \ln Z_x\left(s^{t-1}\right) + u_{Z_x}\left(s^t\right),\ u_{Z_x}\left(s^t\right) = \rho_{Z_x} u_{Z_x}\left(s^{t-1}\right) + \epsilon_{Z_x}\left(s^t\right), \\
\varepsilon_{N_\zeta}\left(s^t\right) &= \rho_{N_\zeta}\varepsilon_{N_\zeta}\left(s^{t-1}\right) + \epsilon_{N_\zeta}\left(s^t\right),\ \text{for } \zeta = F, c, \text{ and } x, \\
\ln G_\xi\left(s^t\right) &= \left(1-\rho_{G_\xi}\right)\ln G_\xi + \rho_{G_\xi}\ln G_\xi\left(s^{t-1}\right) + \epsilon_{G_\xi}\left(s^t\right),\ \text{for } \xi = c, x, \\
\ln \kappa_{I_\xi}\left(s^t\right) &= \left(1-\rho_{I_\xi}\right)\ln \kappa_{I_\xi} + \rho_{I_\xi}\ln \kappa_{I_\xi}\left(s^{t-1}\right) + \epsilon_{I_\xi}\left(s^t\right),\ \text{for } \xi = c, x, \\
\ln \theta_{P_\xi}\left(s^t\right) &= \left(1-\rho_{P_\xi}\right)\ln \theta_{P_\xi} + \rho_{P_\xi}\ln \theta_{P_\xi}\left(s^{t-1}\right) + \epsilon_{P_\xi}\left(s^t\right),\ \text{for } \xi = c, x, \\
\ln \theta_{W_\xi}\left(s^t\right) &= \left(1-\rho_{W_\xi}\right)\ln \theta_{W_\xi} + \rho_{W_\xi}\ln \theta_{W_\xi}\left(s^{t-1}\right) + \epsilon_{W_\xi}\left(s^t\right),\ \text{for } \xi = c, x, \\
\ln Z_U\left(s^t\right) &= \left(1-\rho_U\right)\ln Z_U + \rho_U\ln Z_U\left(s^{t-1}\right) + \epsilon_U\left(s^t\right),
\end{aligned}
$$

where $\rho_Z, \rho_{Z_x}, \rho_{N_F}, \rho_{N_c}, \rho_{N_x}, \rho_{G_c}, \rho_{G_x}, \rho_{I_c}, \rho_{I_x}, \rho_{P_c}, \rho_{P_x}, \rho_{W_x}, \rho_{W_c}$ and $\rho_U \in (0,1)$ are the autoregressive root of the corresponding shocks, and $\epsilon_Z(s^t)$, $\epsilon_{Z_x}(s^t)$, $\epsilon_{N_F}(s^t)$, $\epsilon_{N_c}(s^t)$, $\epsilon_{N_x}(s^t)$, $\epsilon_{G_c}(s^t)$, $\epsilon_{G_x}(s^t)$, $\epsilon_{K_c}(s^t)$, $\epsilon_{K_x}(s^t)$, $\epsilon_{P_c}(s^t)$, $\epsilon_{P_x}(s^t)$, $\epsilon_{W_c}(s^t)$, $\epsilon_{W_x}(s^t)$, and $\epsilon_U(s^t)$, are the exogenous i.i.d. shocks that are normally distributed with mean zero.

2.7 Equilibrium

An equilibrium consists of a set of prices, for $\xi = c, x$, $\{P_\xi(s^t), W_\xi(s^t), R_\xi(s^t), \tilde{R}_\xi(s^t), R(s^t), Q_\xi(s^t)\}_{t=0}^\infty$, and the allocations $\{C(s^t), C_g(s^t), C_g(l, s^t), \Psi_c(l, s^t), \Psi_x(m, s^t), X(s^t), X_g(s^t), X_g(m, s^t), \Gamma_c(l, s^t), \Gamma_x(m, s^t), I_\xi(s^t), L_c(l, s^t), L_x(m, s^t), K_c(l, s^t), K_x(m, s^t), U_c(l, s^t), U_x(m, s^t)\}_{t=0}^\infty$, for all $l, m \in [0,1]$, for given government policy $\{G(s^t), \tau(s^t), R_n(s^t)\}_{t=0}^\infty$, realization of exogenous variables $\{\epsilon_Z(s^t), \epsilon_{Z_d}(s^t), \epsilon_{R_n}(s^t), \epsilon_A(s^t), \epsilon_{A_c}(s^t), \epsilon_{N_F}(s^t), \epsilon_{N_\xi}(s^t), \epsilon_{G_\xi}(s^t), \epsilon_{K_\xi}(s^t), \epsilon_{P_\xi}(s^t), \epsilon_{W_\xi}(s^t), \epsilon_U(s^t)\}_{t=0}^\infty$, and initial conditions $\{N_F(s^{-1})\}$, $\{N_\xi(s^{-1})\}\}$ such that for all t, the following conditions are satisfied.

(i) each household h maximizes her utility given the prices;

(ii) each FI i maximizes its profits given the prices and the net worths;

(iii) each entrepreneurs j_{i_c} and j_{i_x} maximizes its profits given the prices and the net worth;

(iv) goods producer l in the non-durables sector and goods producer m in the durables sector maximize their profits given the prices;

(v) capital goods producers in the two goods-producing sectors maximize their profit given prices;

(vi) the government budget constraint holds;

(vii) the central bank sets a policy rate following the Taylor rule; and

$(viii)$ markets clear.

2.8 Endogenous Development of TFP through Three Channels

Defining TFP

In contrast to a standard growth model where TFP movements are fully attributed to exogenously driven technology shocks, TFP in our model varies with non-technology shocks as well. To see this, we define aggregate TFP $\lambda(s_t)$ following a conventional treatment:

$$\lambda(s_t) \equiv \frac{Y(s^t)}{\left(\sum_{\xi=c,x} L_\xi(s^t)\right)^{\psi_L} \left(\sum_{\xi=c,x} K_\xi(s^{t-1})\right)^{1-\psi_L}}, \tag{26}$$

where ψ_L is the steady state labor share of income. Similarly, we define the sectoral TFP $\lambda_\xi(s_t)$ as follows:

$$\lambda_c(s_t) \equiv \frac{C(s^t)+G_c(s^t)}{(L_c(s^t))^{\psi_L}(K_c(s^{t-1}))^{1-\psi_L}}, \text{ and } \lambda_x(s_t) \equiv \frac{X(s^t)+\sum_{\xi=c,x} I_\xi(s^t)+G_x(s^t)}{(L_x(s^t))^{\psi_L}(K_x(s^{t-1}))^{1-\psi_L}} \tag{27}$$

In addition, to see the role of capacity utilization of capital stock, we define aggregate TFP adjusted for capacity utilization $\lambda_{adj}(s_t)$ as follows:

$$\lambda_{adj}(s_t) \equiv \frac{Y(s^t)}{\left(\sum_{\xi=c,x} L_\xi(s^t)\right)^{\psi_L} \left(\sum_{\xi=c,x} K_\xi(s^{t-1})\, U_\xi(s^t)\right)^{1-\psi_L}}. \tag{28}$$

Monitoring costs and TFP

There are three channels through which non-technological shocks affect TFP. First, the financial intermediation in our model incurs monitoring costs and wastes the value-added of the non-durables that otherwise serves for the use of households' consumption. The size of the monitoring costs are given in the fifth and sixth terms in the equation (16). Other things being equal, the total monitoring costs spent in the economy increase with the three cut-off values of the credit contracts $\overline{\omega}_c$, $\overline{\omega}_x$, and $\overline{\omega}_F$. As shown in the equation (1) and (5), rise, the cut-off values increase when borrowing rates are high. With higher cut-off values, therefore, a larger portion of borrowers default and more resources are spent for monitoring the output of defaulting borrowers. TFP falls because less non-durables are left for final goods.[18]

Intersectoral resource misallocation of factor inputs and TFP

Second, incomplete intersectoral mobility of primary inputs gives a rise to TFP variations. In the model, capital stock is attached to each sector and the rental price of capital goods in the two sectors may temporarily diverge. Labor mobility across sectors is also not insured because of the nominal friction associated with prices and wages. Consequently, primary input prices are not equalized across sectors, giving a rise for intersectoral inefficiency of resource allocation in goods production.

To see this, we arrange the equations (18) and (27), and derive the following expression:

[18] In addition to the monitoring costs, as discussed in Basu, Fernald, and Shapiro (2001), certain types of adjustment costs, including those of price and wage adjustment, incur similar class of real cost and reduce TFP. Because these adjustments incur zero cost at the steady state, however, they give no first-order effect on the resource constraint in economic dynamics in our model. By contrast, the monitoring costs are positive at the steady state and maintain nonzero quantitative impacts on the resource allocation in economic dynamics. In the quantitative exercise below, we concentrate our analysis on the first-order approximation of the model around the non-stochastic steady state.

$$\lambda(s_t) = (\lambda_c(s_t))^{\psi_{Y_c}} (\lambda_x(s_t))^{\psi_{Y_x}} \left(\frac{(L_c(s^t))^{\psi_{Y_c}} (L_x(s^t))^{\psi_{Y_x}}}{\sum_{\xi=c,x} L_\xi(s^t)} \right)^{\psi_L} \left(\frac{(K_c(s^{t-1}))^{\psi_{Y_c}} (K_x(s^{t-1}))^{\psi_{Y_x}}}{\sum_{\xi=c,x} K_\xi(s^{t-1})} \right)^{1-\psi_L}. \tag{29}$$

The equation indicates that even when sectoral TFPs $\lambda_c(s_t)$ and $\lambda_x(s_t)$ are unchanged, the aggregate TFP may vary if composition of primary inputs usages in the goods-producing sectors changes. According to the functional forms associated with the last two terms, sectoral usages of primary inputs are compliments to each other. Any shocks that makes the primary input usages of one sector disproportionately large compared with other sector lower TFP.

Intra-sectoral resource misallocation of factor inputs and TFP

Third, as shown in equations (18) and (19), since the goods producers substitute production inputs between intermediate inputs and primary inputs depending on the relative prices, intra-sectoral changes of production inputs affect TFP. For instance, if, as a result of adverse shock, the intermediate input price rises relative to primary inputs and the goods producers employ more of primary inputs and reduce intermediate inputs, TFP falls so far as output declines.

To see this channel analytically, based on several simplifying assumptions[19], we employ equation (16) and (27) and express the TFP in the non-durables sector $\lambda_c(s_t)$ by the ratio of intermediate inputs over gross output in the non-durables sector $\left(\int_0^1 \Psi_c(l, s^t)\, dl\right)/C_g(s^t)$, as below:

$$\lambda_c(s_t) \approx \left[Z(s^t) A(s^t)\right]^{\frac{1}{1-\gamma_{11}}} \times \left[\left(\int_0^1 \Psi_c(l, s^t)\, dl\right)/C_g(s^t)\right]^{\frac{\gamma_{11}}{1-\gamma_{11}}} \times \left[1 - \left(\int_0^1 \Psi_c(l, s^t)\, dl\right)/C_g(s^t)\right]. \tag{30}$$

The equation indicates that a marginal increase in intermediate usage ratio in a sector generates two opposing effects on the TFP in the same sector. Each of the two effects are captured by the second and the third bracket in the equation, respectively; (i) the first effect is positive, reflecting the increased productivity of primary input as the intermediate input is compliment to primary inputs as shown in production function (18) and (19), (ii) the second effect is negative reflecting the reduction of value-added by the increased usage of goods as the intermediate inputs. Quantitatively, the first effect dominates the second effect whenever the intermediate input usage is small. In our model, similarly to Basu (1995), intermediate input usages at the steady state are smaller than efficient level, reflecting the monopolistic competition of goods markets, and the first effect quantitatively dominates the second effect.

3 Quantitative Analysis

In this section, we investigate quantitative implication of our model, including working mechanism that drives TFP growth down. Based on the Japanese data, we first estimate the model's parameters and extract seventeen structural shocks; the permanent technology shock in the two goods-producing sectors $\epsilon_Z(s^t)$, the permanent technology shock to the durables sector $\epsilon_{Z_x}(s^t)$, the monetary policy shock $\epsilon_{R_n}(s^t)$, the temporal technology shock to the two goods producing sector $\epsilon_A(s^t)$, the temporal technology shock to the durables sector $\epsilon_{A_c}(s^t)$, the net worth shock in

[19] For illustrative purpose, we put extreme assumptions that parameters γ_{12}, γ_{21}, α_E, and α_F as well as monitoring costs are sufficiently small.

the FI sector $\epsilon_F(s^t)$, the net worth shock in the non-durables sector $\epsilon_{N_c}(s^t)$, the net worth shock in the durables sector $\epsilon_{N_x}(s^t)$, the government spending shock to sector ξ $\epsilon_{G_\xi}(s^t)$, the investment adjustment cost shock in sector ξ $\epsilon_{K_\xi}(s^t)$, the price markup shock in sector ξ $\epsilon_{P_\xi}(s^t)$, the wage markup shock in sector ξ $\epsilon_{W_\xi}(s^t)$, and the technology shock to capacity utilization of capital inputs $\epsilon_U(s^t)$ using the Bayesian technique. We then explore the model's equilibrium response to these exogenous shocks. In particular, we discuss how TFP responds to non-technological shock. Next, we explore the quantitative contribution of each shocks in explaining variations of macroeconomic variables, including the TFP, GDP, and inflation in Japanese economy.

3.1 Data

Our benchmark dataset includes eleven time series from 1980Q2 to 2011Q4: (1) real gross domestic output, corresponding to $Y(s^t)$, (2) real investment expenditure, corresponding to $I_c(s^t)+I_x(s^t)$, (3) deflator of real consumption expenditure, corresponding to $P_c(s^t)$, (4) deflator of investment expenditure, corresponding to $P_x(s^t)$, (5) nominal wage per hour, corresponding to weighted average of $W_c(s^t)$ and $W_x(s^t)$, (6) working hours, corresponding to $L_c(s^t)+L_x(s^t)$, (7) capacity utilization rate of capital stock, corresponding to weighted average $U_c(s^t)$ and $U_x(s^t)$, (8) the over night call rate, corresponding to $R_n(s^t)$, (9) Solow residual, corresponding to $\lambda(s^t)$, (10) real net worth of the FIs, corresponding to $N_F(s^t)\,P_{CPI}(s^t)^{-1}$ in the model, and (11) real net worth of the entrepreneurs in the non-durables and the durables sector, corresponding to $(N_c(s^t)+N_x(s^t))\,P_{CPI}(s^t)^{-1}$.

The series (1) to (8) are displayed in Figure 4, the series (9) is displayed in Figure 1, and the series (10) and (11) are displayed in Figure 5. Data source of these series from SNA released from Cabinet Office unless otherwise noted. The series (2) consists of the real residential investment, non-residential investment, and households expenditure on the durable goods. The series (3) is the deflator for the non-durable consumption expenditure that consists of the households expenditure on service, non-durables, and semi durables. The series (4) is the deflator series corresponding to the series (2). The series (5) is constructed from compensation of employees based on SNA divided by the number of employees based on the Labour Force Survey times hours worked index based on the Monthly Labour Survey.

In estimating the model, we take first difference for all of the series other than the series (8). To convert nominal series into the quantity term, we make use of the GDP deflator. We also divide all of the quantity series by the number of population over 15 reported in the Labor Force Survey to obtain the per-capita series.

3.2 Prior and Posterior Distribution of the Parameters

Following Christensen and Dib (2008), we calibrate some of the parameters using values adopted in the existing studies and the Japanese data. These include the discount factor β, the elasticity of substitution between differentiated products θ_{p_c} and θ_{p_x}, the elasticity of substitution between differentiated labor inputs θ_{w_c} and θ_{w_x}, depreciation rate of the capital stock δ, depreciation rate of the durables stock δ_d, the labor share α, the share of the entrepreneurial labor input and the FIs' labor input α_E and α_F, and utility weight on leisure ξ_h. The relative wight on the utility from consuming the non-durables and from the durables stock ψ_c and ψ_d, and the four elements of the input-output matrix, γ_{11}, γ_{12}, γ_{21}, and γ_{22}, are calibrated to the expenditure of the households and the input-output table in the Japanese data. See Table 1 for the values of these parameters.

In addition, following HSU (2011), using the Japanese data and partly following BGG (1999), we calibrate nine parameters regarding the credit contracts: the lenders' monitoring cost parameter in the IF contract μ_F, the lenders' monitoring cost parameter in the FEC and the FED contract μ_c and μ_x, the standard error of the idiosyncratic productivity shock in the FI sector σ_F, the standard error of the idiosyncratic productivity shock in the entrepreneurs in the non-durables and the durables sector σ_c and σ_x, the survival rate of FIs γ_F, and the survival rate of entrepreneurs in the non-durables and the durables sector γ_c and γ_x, so that the following nine equilibrium conditions are met at the steady state: (1) the annualized spread between the FIs' borrowing rate and the risk-free rate, $r_F - R$, is 56 bps; (2) the ratio of net worth held by FIs to capital, $N_F / (Q_c K_c + Q_x K_x)$, is 0.1; (3) and (4) the ratios of net worth held by entrepreneurs in the two goods producing sectors to capital, $N_c / Q_c K_c$ and $N_x / Q_x K_x$, are 0.6; (5) the annualized failure rate of FIs is 1%; (6) and (7) the annualized failure rate of entrepreneurs in the two goods producing sectors is 1%; and (8) and (9) the annualized spread between the FIs' loan rate and the FIs' borrowing rate, $r_c - r_F$ and $r_x - r_F$, equals 442 bps. Note that the numerical values other than those of (5), (6), and (7), for steady state calibrations are taken from the historical average of corresponding Japanese data. The numbers for (5), (6), and (7), are taken from BGG (1999).

We estimate the rest of parameters of the model using a Bayesian method. To calculate the posterior distribution and to evaluate the marginal likelihood of the model, the Metropolis-Hastings algorithm is employed. To do this, a sample of 400,000 draws was created, neglecting the first 200,000 draws. Those are shown in Table 2. The first to the third columns of Table 2 report the prior distribution of the estimated parameters. The last three columns in Table 2 display the posterior mean and the confidence intervals of the model parameters.

3.3 Model's Response to Exogenous Shocks

Using the estimated model, we now turn our focus to quantitative exercise. We examine how macroeconomic variables, including TFP, respond to various type of structural shocks.

Response to net worth shock of FI sector

Figure 6 shows that when FIs' net worth becomes scarce, the investors require a higher external finance premium in lending to FIs, widening the deposit spread and increasing FIs' borrowing rate. As described in the existing financial accelerator models including BGG (1999) and HSU (2011), because higher FIs' borrowing rate is reflected in the two lending spreads through the FEC and FED contract, entrepreneurs in the two goods producing sectors confront higher borrowing rates, reducing the borrowing from the FIs. As a result, the entrepreneurs in the two goods producing sectors reduce the capital goods supply to the goods producers, and the gross output in the two goods-producing sectors is reduced. Accompanied by the fall in production, the investment and GDP are dampened. As a result of weakening demand, inflation drops.

The reduction in the gross output in the two goods-producing sectors is amplified to the rest of the economy through the two channels; one through the endogenous developments of net worths in the borrowing sectors and the other through the input-output linkages of intermediate input supply. First, the deterred goods productions endogenously hamper the net worth accumulation in the FI and the two goods-producing sector, as the retained earnings in these sectors diminish as shown in equation (9) and (10). The deteriorated net worth bring about the second round effect to the economy by raising the external finance premium in the credit contracts. Consequently, investment falls, dampening the GDP further. Second, the fall in the supply of the intermediate goods and the investment goods in one sector adversely affects the production of other sector because of the interdependence stemming from the input-output structure. For instance, other things being equal, a decline in non-durables production leads to a decline in durables production as intermediate inputs supplied from the non-durable sector are reduced. This channel brings about the further decline of the GDP.

In response to the deterioration of FIs' net worth, aggregate TFP drops. The working mechanism behind the decline in TFP are seen in the dynamics of monitoring cost, loss of TFP originating from sectoral immobility, and markups of goods producing sectors. Here we discuss each of them in details. First, in the wake of the shock, monitoring cost paid by FIs and investors rise compared to the steady state, leading to a fall in TFP. After the net worth deterioration of the FIs, FIs' borrowing rate rise as shown in panel (11). With a higher cut-off value of the IF contracts, a larger portion of the FIs default and monitoring costs paid by the investors increase. In addition, since the net worth shock to FIs leads to endogenous deteriorations of the net worths in goods producing sectors, FIs' lending rate rises and a larger number of entrepreneurs default in the two sectors, enhancing the impacts of the channel through the monitoring costs further. In panel (14), we depict a response of a measure of monitoring cost expense defined by the total amount of monitoring cost paid in the economy divided by the total non-durable gross output. As shown in the panel, the measure of monitoring cost increases in response to the shock, indicating that less non-durables are available for households' consumption and government expenditure. Other things being equal, it results in a smaller TFP.

Second, inter-sectoal misallocation of production input increases in response to the net worth shock, reducing TFP. To capture a loss of TFP brought about by the immobility between non-durables and durables sector, we make use of equation (29) to extract a portion of TFP movements stemming from the compositional changes in sectoral allocation of inputs by following equation.

$$\log \lambda \left(s^t\right) - \psi_{Y_c} \log \lambda_c \left(s^t\right) - \psi_{Y_x} \log \lambda_x \left(s^t\right).$$

Note that this measure of inter-sectoral allocation is defined as the residual from the aggregate TFP less the weighted average of the sectoral TFP. As shown in panel (8), the measure of inter-sectoral allocation takes negative value after the shock, indicating that, in terms of deviation from the steady state, the aggregate TFP is smaller than the weighted average of sectoral TFPs, indicating that inter-sectoral misallocation helps decrease TFP.

Third, in response to the shock, the markups of goods producing sectors, defined by the price of non-durables and durables divided by the corresponding marginal costs (20), increase as shown in panel (5), reducing TFP. As documented in Table, our estimation results indicate that, in response to exogenous shocks, nominal wages adjust quicker than nominal prices. Consequently, the channel of intra-sectoral resource misallocation addressed in Basu (1995) is operative and markup rises whenever adverse deflationary shocks occur. In the wake of the increased markups brought about by the deflationary pressure stemming from the FIs' net worth disruption, hiring cost of labor inputs becomes relatively cheaper than that of intermediate input from view points of goods producing sectors. Because value-added declines as a consequence of the adverse shock and good producers employ more of primary inputs and reduce usage of intermediate inputs, TFPs fall.

Response to net worth of non-durables sector

We next discuss the economic response to an unexpected net worth disruption in the non-durables sector. While the shock occurs solely in the non-durables sector and primarily affects the FEC contract, its effect is not limited within the sector. As Figure 7 indicates, the net worth decline in the non-durables sector leads to widening of external finance premium in the IF contracts as well as in the FEC contract, amplifying the initial impact of the shock. As indicated in equation (6), this is because the credit contracts are chained and investors consider the aggregate leverage, which is given by total amount of debt $\sum_{\xi=c,x}\left[Q_{\xi}\left(s^{t}\right)K_{\xi}\left(s^{t}\right)-N_{\xi}\left(s^{t}\right)\right]-N_{F}\left(s^{t}\right)$ relative to the investment $\sum_{\xi=c,x}\left[Q_{\xi}\left(s^{t}\right)K_{\xi}\left(s^{t}\right)\right]$. The widenings in the spreads are then reflected to the two lending rates through the FEC and FED contract, resulting in the economic downturn and TFP decline through the mechanisms discussed above.

Response to the economy-wide permanent technology shock

Figure 8 displays the economic response to an unexpected decline in the technology growth rate. Because technology slow down directly lowers the productivity of goods production, GDP components together with TFP fall. As panel (5), (8), and (14) in the figure show, the proportion of the total TFP decline is attributed to the endogenous response of economy to the shock, suggesting that the exogenous technology slow down is quantitatively smaller than the observed TFP decline.

Response to the price markup shocks in non-durables sector

Figure 9 displays the economic response to an unexpected increase in the markup of the non-durables sector. In contrast to standard models where TFP is independent from the markup variations, the higher markup results in lower TFP in the current model. That is, facing a higher non-durables prices, goods producers substitute away from the usage of non-durables intermediate inputs and employ more of other inputs, including primary inputs, lowering TFP.

The higher markup also varies TFP through the other two channels. The contractionary response of the central bank to the inflation increase and the smaller usages of non-durables intermediate inputs lower output, deteriorate the net worths of borrowing sectors, and make the costs for financial intermediation higher. In addition, because a higher markup of the non-durables causes a large relative price change across two goods and dampens the demand for the non-durables disproportionately, usages of primary inputs across sectors become uneven.

3.4 Historical Decomposition

In this section, we decompose historical time path of TFP growth, GDP growth, and inflation rate during the sample period into structural shocks and examine which shock is important in accounting for time variations of these macroeconomic variables.[20]

Decomposition of the TFP growth

Figure 10 displays the evolvement of the TFP growth together with the underlying structural shocks on a quarterly basis (upper panel) and in ten-year average (lower panel). The TFP is unadjusted for capacity utilization rate of capital stock. The figure indicates that the two types of shocks are important in TFP movements from the 1980s to the 1990s: technology shocks and two net worth shocks. The technology shocks are the key driver of the TFP growth during the boom of the 1980s, and turn to dampen the TFP growth in the early 1990s substantially, accounting for a large portion of TFP slowdown at the period. Their contribution to the TFP growth does not last long and dies out shortly after the mid 1990s. The influence of two net worth shocks is

[20] In this section, we discuss only about TFP that is unadjusted for endogenous movements of capacity utilization rate of capital stock that is defined by equation (26). In Appendix, we show that much of the quantitative results are unchanged for TFP that is adjusted for the capacity utilization rate, defined by equation (28) . The key time series properties of unadjusted TFP growth, particularly the kink that occurred in the early 1990s, are maintained even when capacity utilization is adjusted in constructing TFP series. Timing of growth rate slow down is, however, slightly different between the two series. That is, while the unadjusted TFP slowed down about 1990, the adjusted TFP slowed down a few years later, indicating that variations in capacity utilization play a certain role in TFP slow down in the early 1990s.

moderately positive from the 1980s up until the mid 1990s when it starts to decrease the TFP growth. Its impacts last persistently during the 1990s and beyond. During the two financial crisis, the banking crisis in the late 1997 and the global financial crisis since the summer of 2007, the bulk of the accompanying TFP decline is accounted for by the decline in the net worth in the FI sector and the goods producing sectors.

Figure 11 depicts the evolution of the TFP level. To see how the net worth shocks affect the time path of TFP, in the upper panel, we plot the TFP series when all of the structural shocks are present (the left panel) and the hypothetical TFP series when all of the shocks other than two net worth shock are present (the right panel). The discrepancy between the two TFP series is accounted for by the economy's endogenous responses to exogenous net worth variations. Absent from such net worth shocks, the TFP grows quicker, demonstrating no kink in its time path around the early 1990s. Quantitative impacts of the net worth shocks are reported in the table. While TFP growth slows down by 1.42% from the 1980s to the 1990s, 0.99% is attributed to the negative net worth shocks. Which of the three channels discussed above plays the quantitative important tole? Figure 12 compares the hypothetical TFP in the economy where no monitoring costs are lost as a result of the net worth shocks together with the economy where no net worth shocks occur. Note that in the former economy, the TFP variations stemming from the two other channels than the monitoring cost channel are operating. The two time series move together closely, indicating that the bulk of contribution by the net worth shocks in lowering TFP is attributed to the resource loss associated with the monitoring cost.

Decomposition of the GDP growth

As shown in Figure 13, relative significance of each shock to TFP growth is translated to GDP growth. That is, technology regression remains the dominant source of GDP growth slow down since the early 1990s and deterioration of net worths remains important source of the slowdown. The estimated impacts of net worth shocks on GDP closely track the time path of financial position of private firms during the period. Figure 14 displays the developments of financial position of firms released from the Bank of Japan together with the model generated GDP series in an hypothetical economy where all of the structural shocks other than the net worth shocks are absent. The two series commove closely throughout the sample period. In particular, both tightening of the financial position and negative contribution of the net worth shocks to GDP variations become prominent during the three financial crisis, bubble burst in 1991, outset of banking crisis in 1997, and outbreak of global financial crisis in 2007.

Decomposition of the inflation rate

Figure 15 indicates that net worth shocks are the key shocks in development of inflation during the lost decades. The weakening inflation starting from the middle of the 1990s is mostly brought about by the deflationary pressure stemming from the negative FIs' net worth shocks. The monetary policy shocks are also important shock, giving the upward pressure from the 1990s to the 2000s. Compared to the net worth shocks and the monetary policy shocks, the role played by the technology growth shocks is minor in inflation dynamics. It contributes declining inflation in 1992 and 2008, but its quantitative role is limited.

4 Conclusive Remark

The GDP slowdown in Japan that has last since the beginning of the 1990s is accompanied by the simultaneous TFP slowdown. While a number of plausible hypothesis is proposed as to the cause of the TFP slowdown, such as the technology regression, the malfunction of the financial intermediation, and the resource misallocation across and within sectors, the existing studies do not agree on this issue.

In this paper, we explore the determinants of the TFP movement from the 1980s to the 1990s, based on the New Keynesian sticky price model that is carefully designed to quantitatively evaluate each of the existing hypothesis in a unified framework. Our model is a version of the multi-sector model with input-output matrix developed by Dupor (1999) and Basu et al. (2010) combined with the financial accelerator framework developed by Bernanke, Gertler and Gilchrist (1999) and extended by Hirakata, Sudo, and Ueda (2011). In our model, the non-technology shock cause a lower TFP through three channels; Increase in monitoring costs associated with the financial intermediation, inter-sectoral misallocation of production inputs, and intra-sectoral misallocation of production inputs.

Using the Japanese data from the 1980s to the 2000s, we estimate the model and distill the underlying structural shocks behind the TFP movements. We then investigate quantitative contribution of each structural shock in explaining variations of TFP growth, particularly around the beginning of the 1990s, where the TFP growth slows down substantially. We find that the net worth shocks to the FIs and goods producing sectors are important determinants of the TFP growth slow down during the periods. In particular, after the bubble burst and the outset of banking crisis, these shocks persistently reduce TFP through the three channels, particularly through the increase in monitoring costs associated with the financial intermediation. While the negative net worth shocks deteriorate the balance sheets of the FIs and goods producing sectors, financial intermediation becomes more costly, reducing resource that is otherwise allocated to value-added, dampening TFP.

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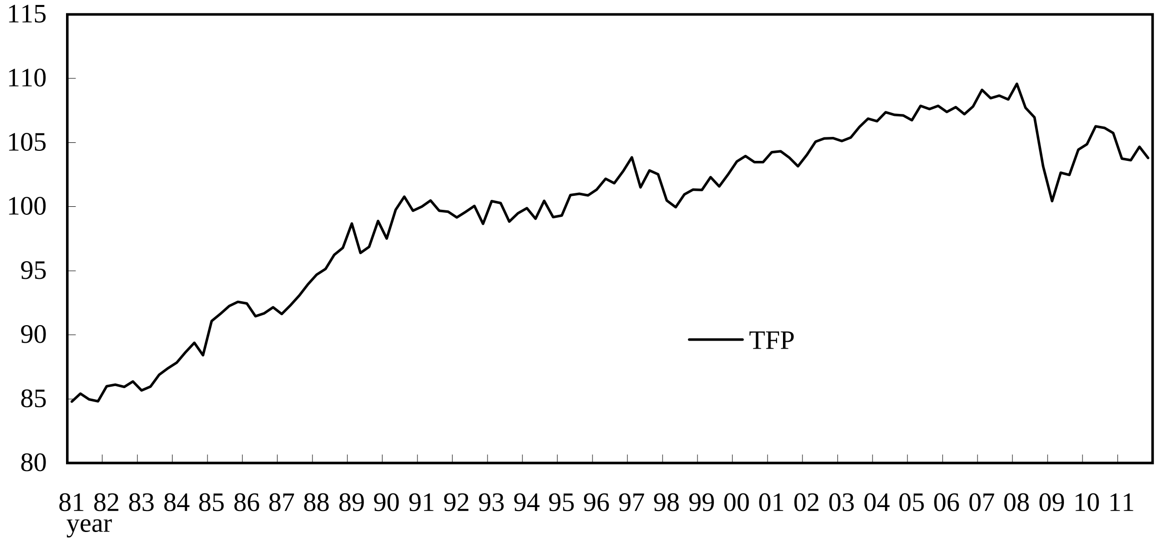
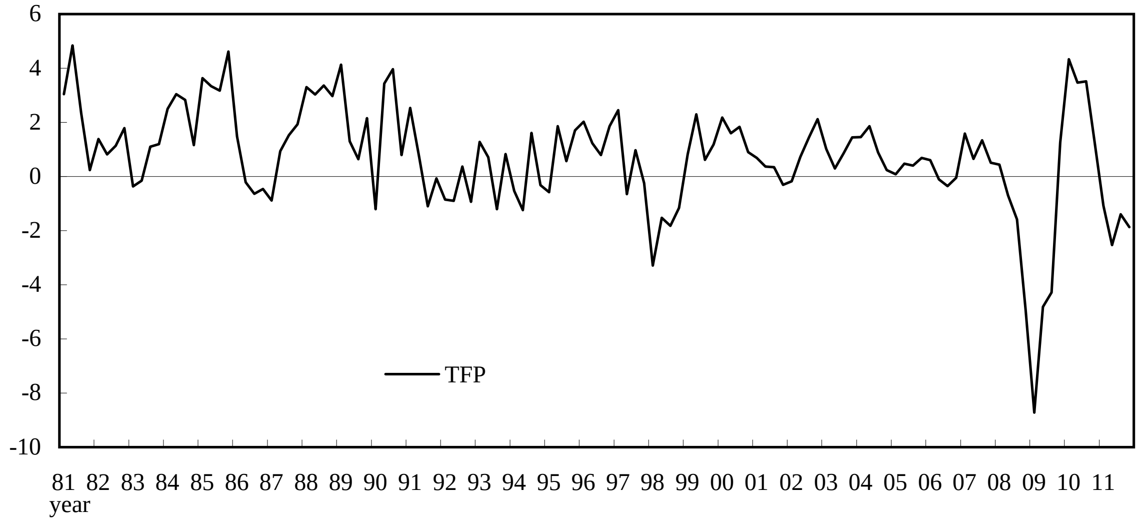
Figure 1: Total Factor Productivity

(1) Level (1991Q1=100)



(2) Growth Rate (year on year % change)



(3) Growth Rate (average of 10 years)

year on year % change

	1980s	1990s	2000 and beyond
TFP	1.84 *N/A*	0.42 *-1.42*	0.16 *-0.26*

Notes: Numbers reported below growth rates are changes in growth rates.

Sources: Cabinet Office, "National Accounts," Ministry of Health, Labour and Welfare, "Monthly Labour Survey"; Ministry of Internal Affairs and Communications, "Labour Force Survey";

Figure 2: Outline of the Model

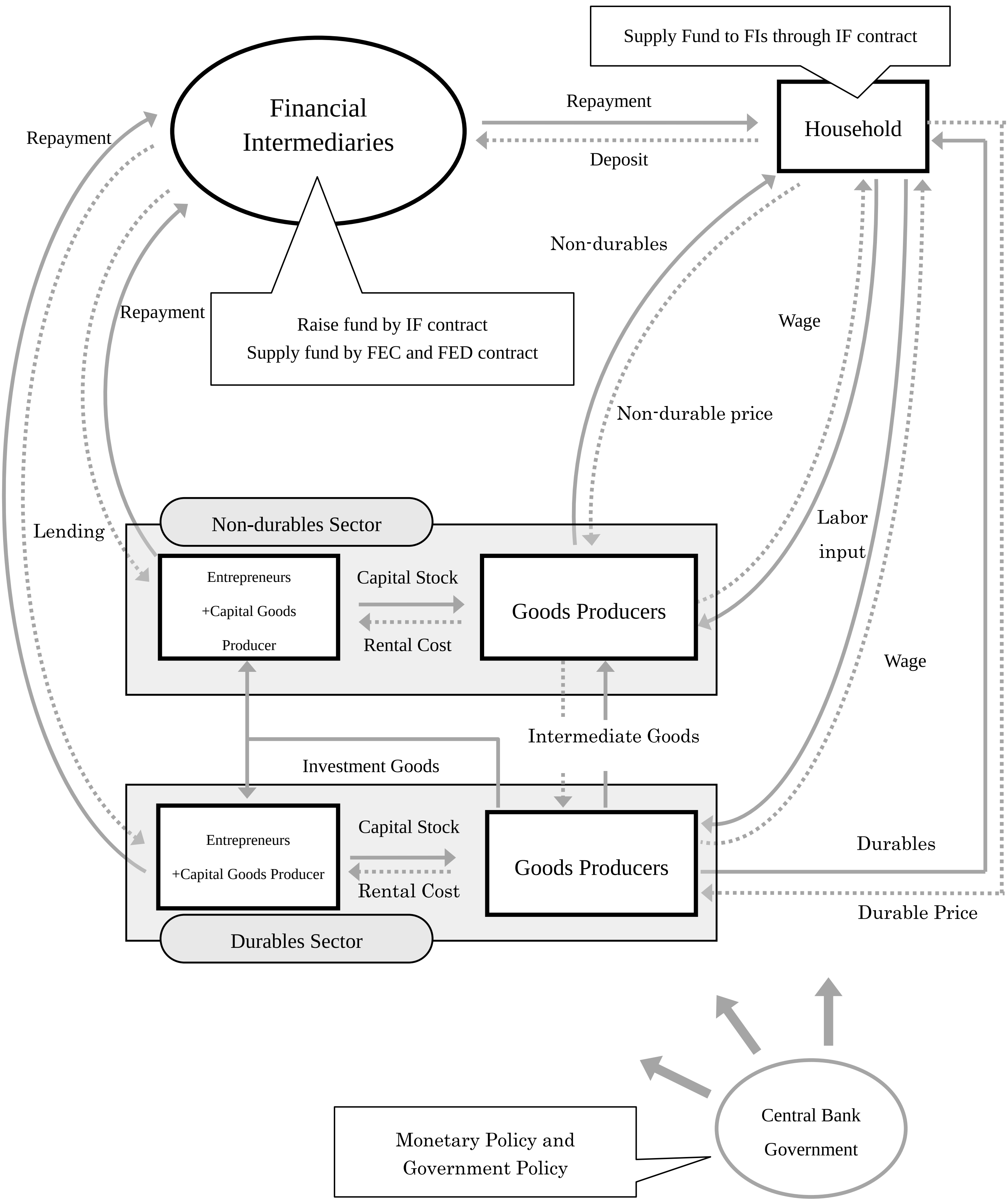


Figure 3: Chained Credit Contracts

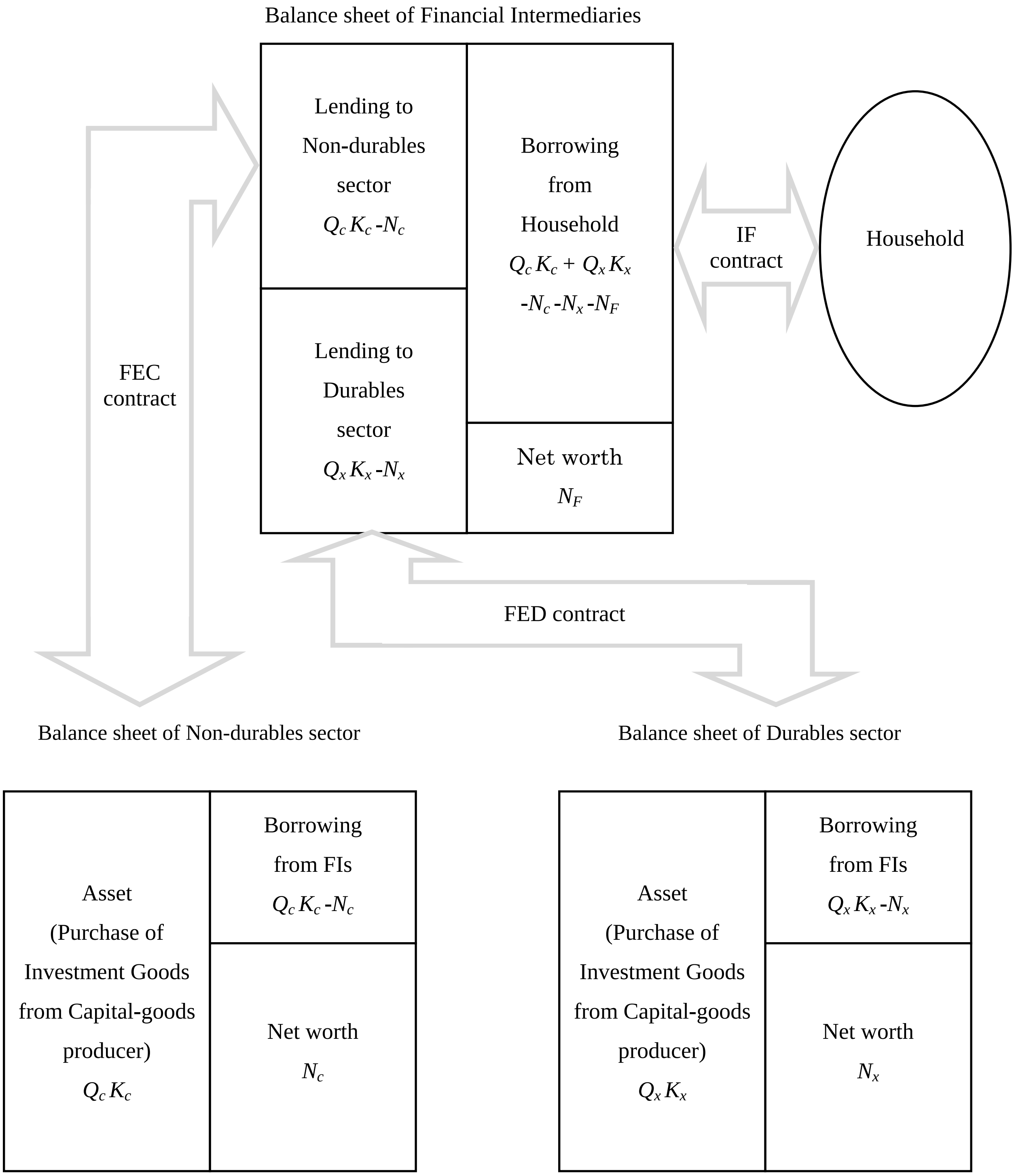
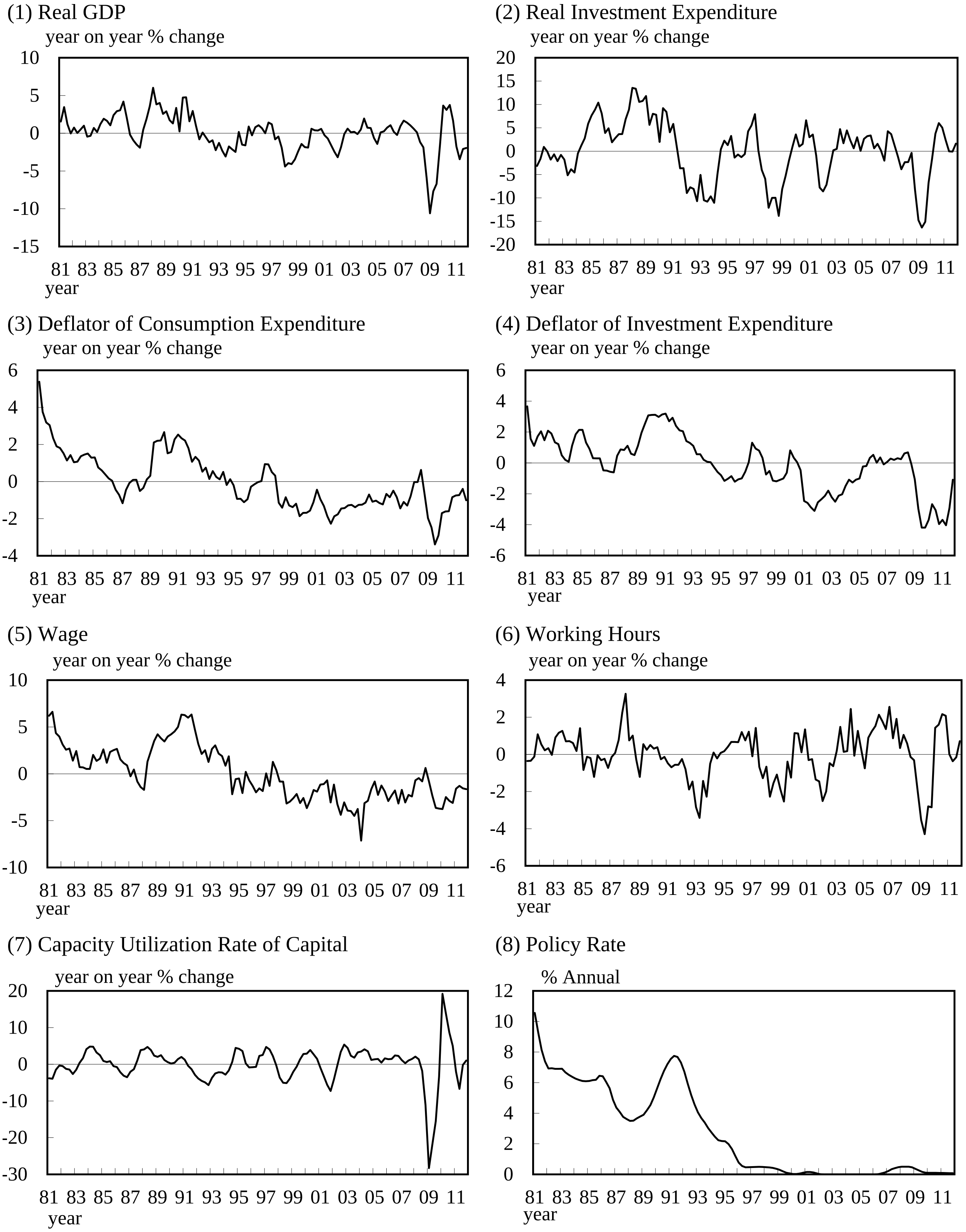


Figure 4: Data Used for Estimation



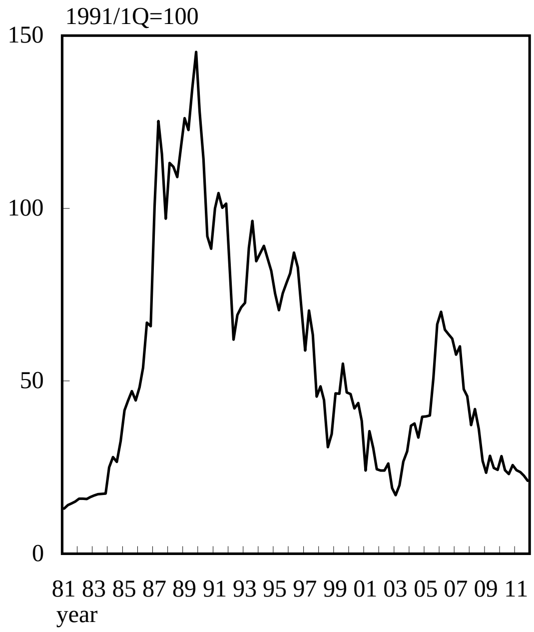
Notes: Series: (1), (2), and (6) are converted into per capita basis using population aged 15 and over.
All series other than the series (8) are demeaned.

Sources: Cabinet Office, "National Accounts," Ministry of Health, Labour and Welfare, "Monthly Labour Survey"; Ministry of Internal Affairs and Communications, "Labour Force Survey"; Ministry of Economy, Trade and Industry, "Indices of Industrial Production," and other statistics

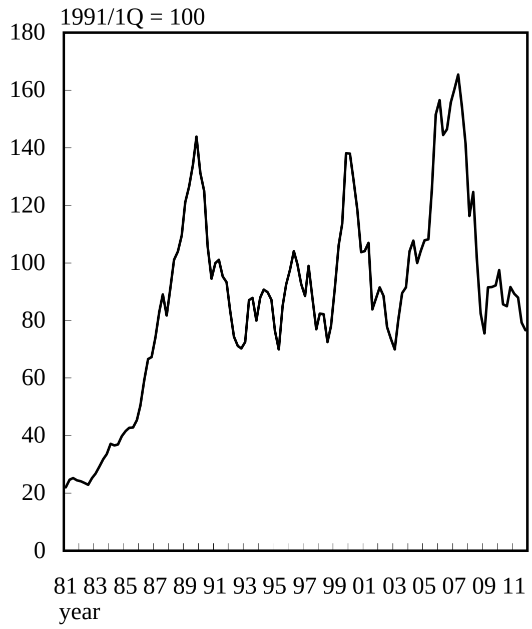
Figure 5: Net Worth of FIs and Goods Producing Sectors

(1) Level

FIs' Net Worth

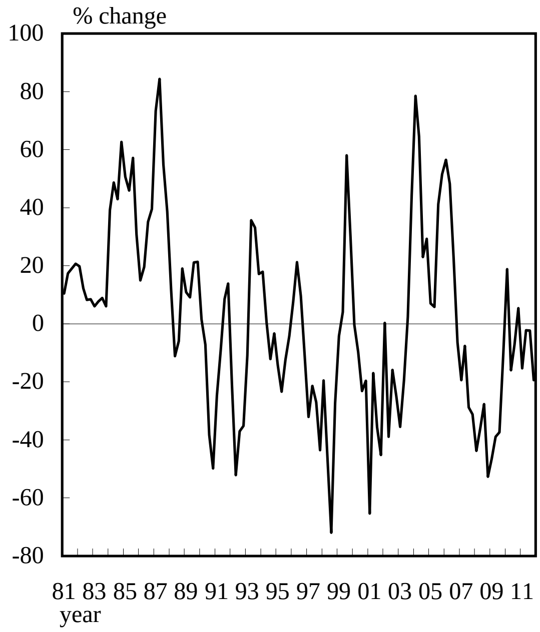


Goods Producing Sectors' Net Worth

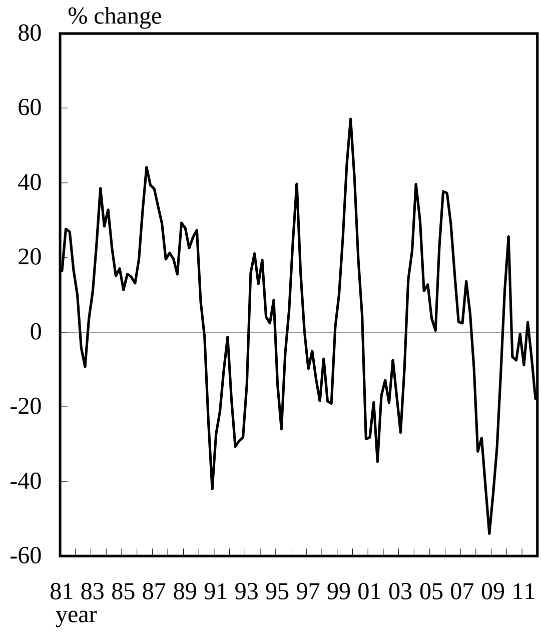


(2) Growth Rate (year on year % change)

FIs' Net Worth

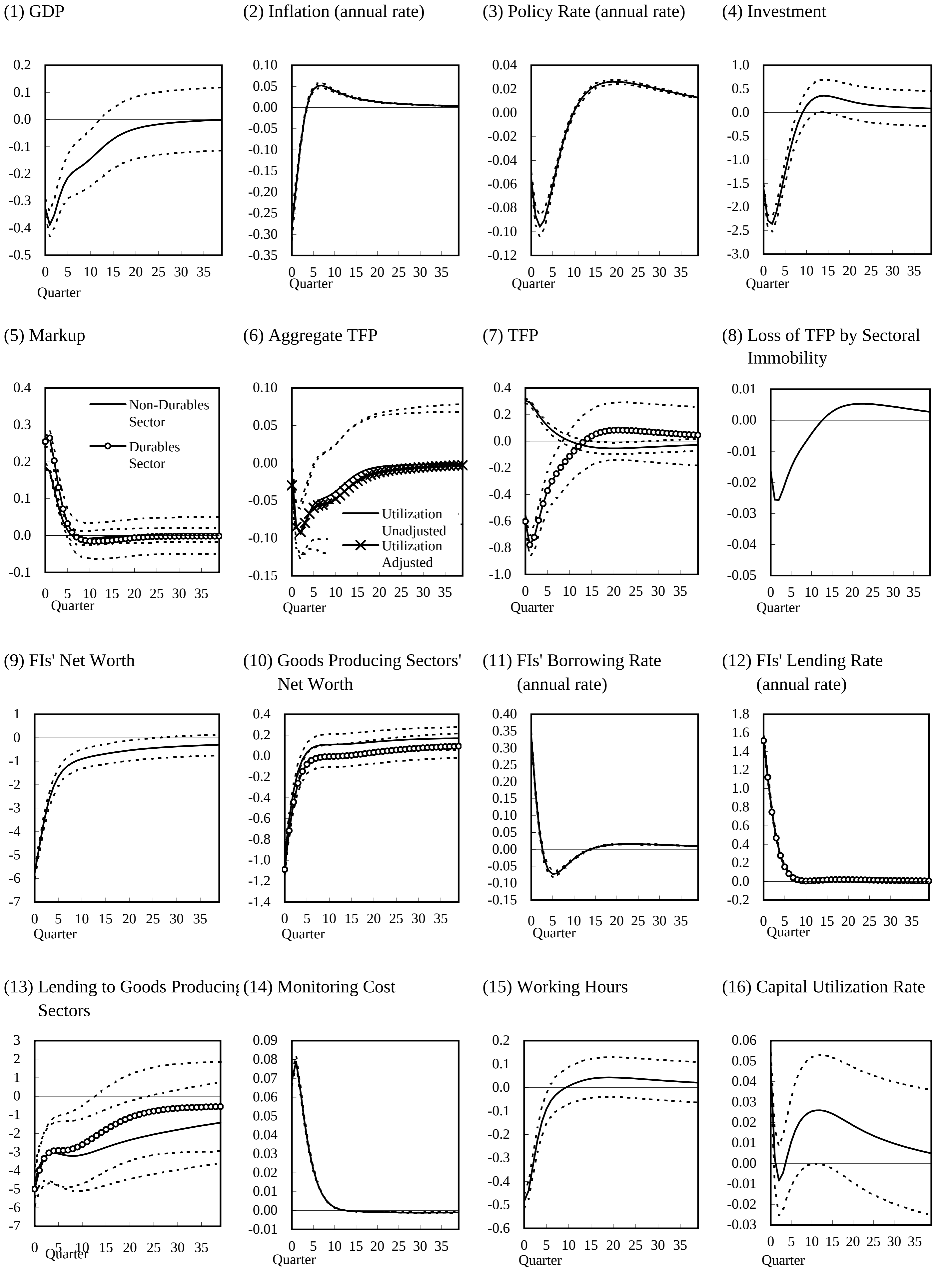


Goods Producing Sectors' Net Worth



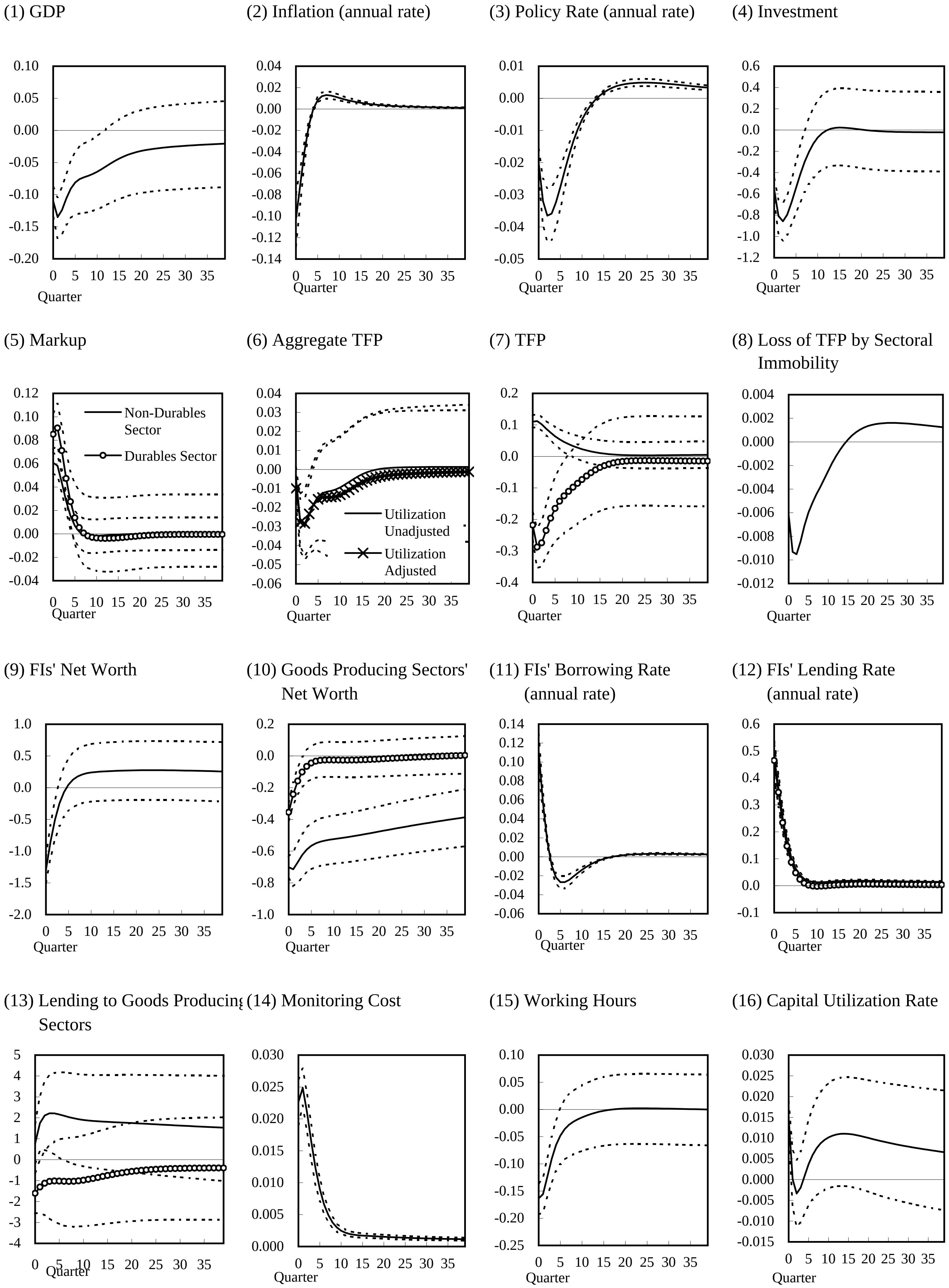
Sources: Tokyo Stock Exchange, "Market Capitalization"; Bank of Japan, "Flow of Funds Accounts."

Figure 6: Response to a Negative Shock to FIs' Net Worth



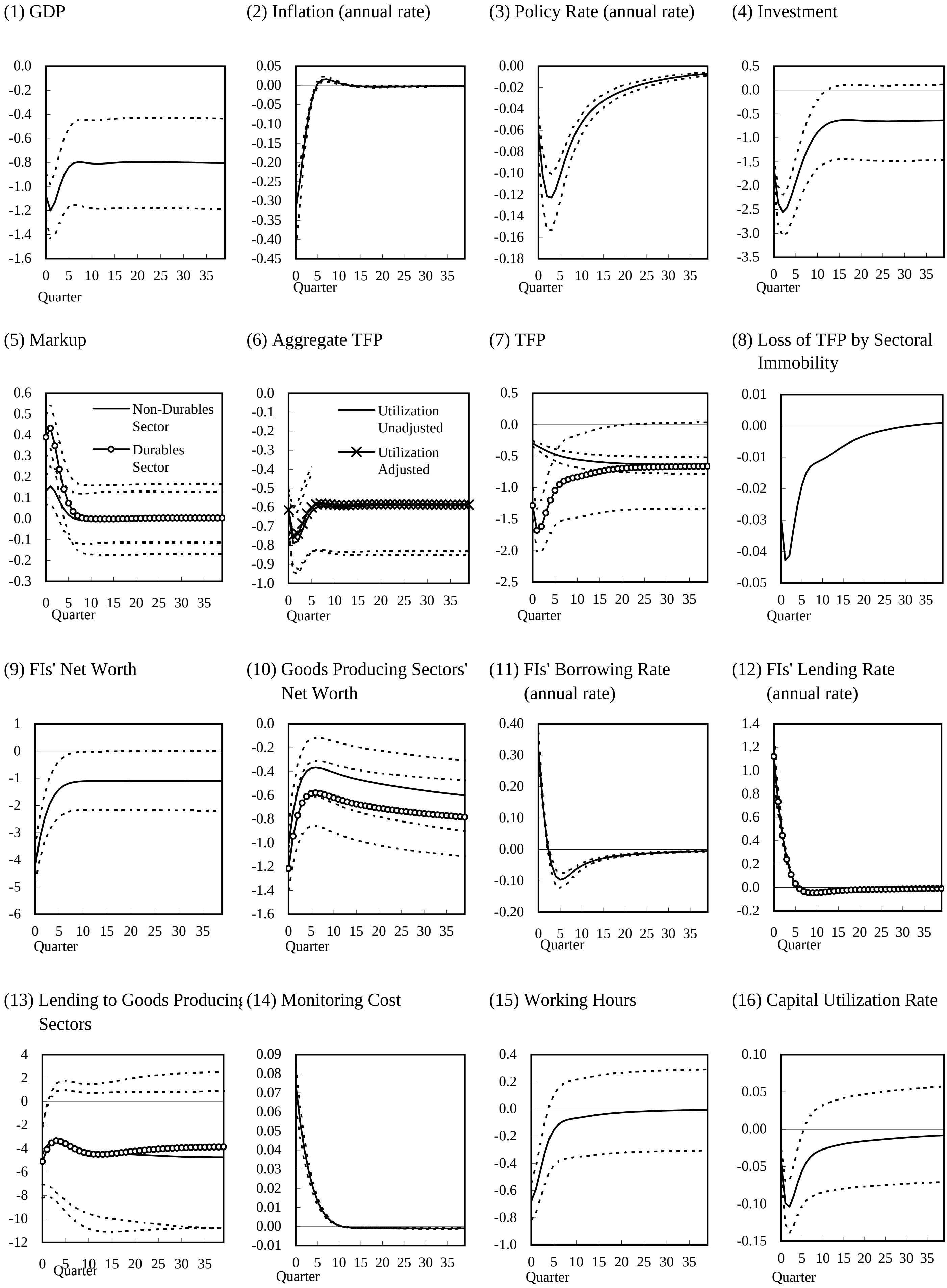
Notes: Interest rates, inflation, and markups are deviation from the non-stochastic steady state.
Others are percentage deviation from the non-stochastic steady state

Figure 7: Response to a Negative Shock to Non-Durables' Net Worth



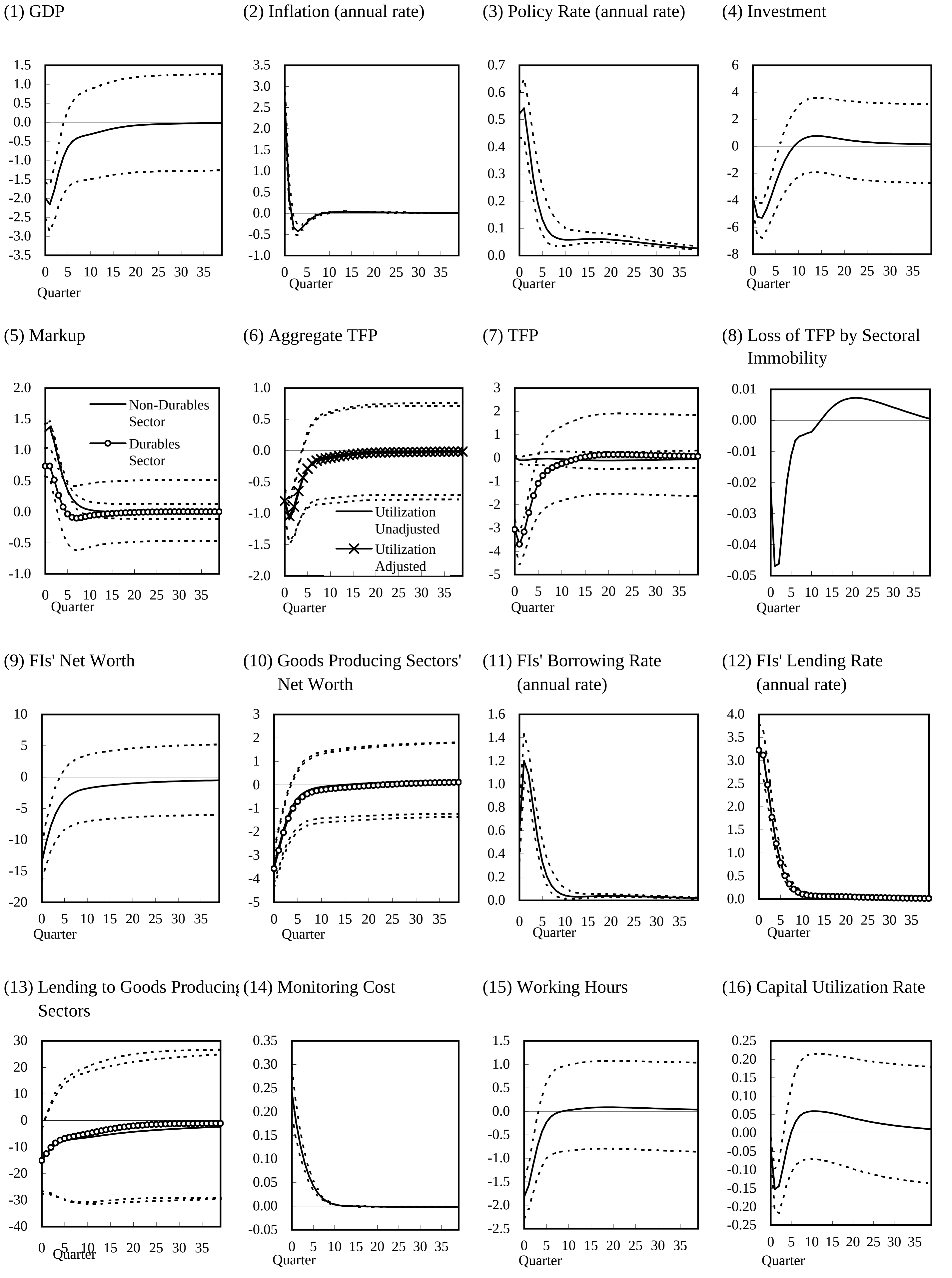
Notes: Interest rates, inflation, and markups are deviation from the non-stochastic steady state.
Others are percentage deviation from the non-stochastic steady state

Figure 8: Response to a Negative Shock to Common Technology Growth



Notes: Interest rates, inflation, and markups are deviation from the non-stochastic steady state.
Others are percentage deviation from the non-stochastic steady state

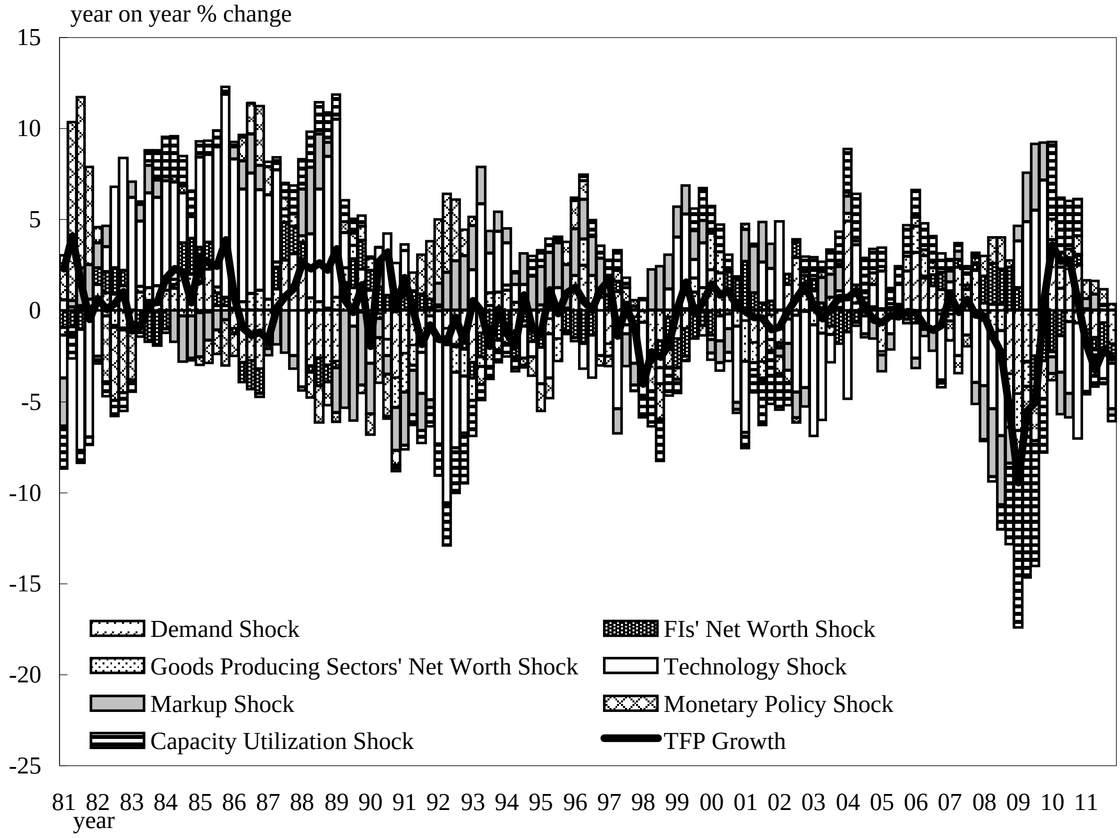
Figure 9: Response to the Markup Shock in the Non-Durables Sector



Notes: Interest rates, inflation, and markups are deviation from the non-stochastic steady state.
Others are percentage deviation from the non-stochastic steady state

Figure 10: Decomposition of TFP Growth (Capacility Utilization Unadjusted)

(1) Decomposition (Quarterly)



Notes: Contributions of other shocks and initial values are not shown in the Figure.

(2) Decomposition (Average of 10 years)

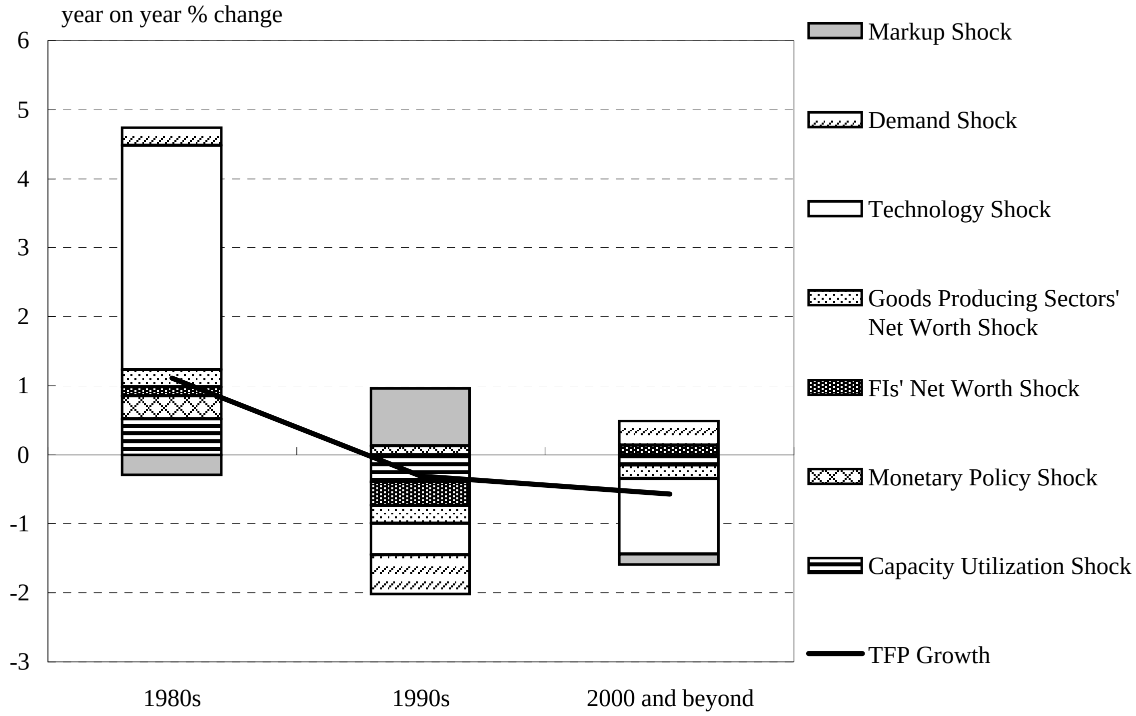
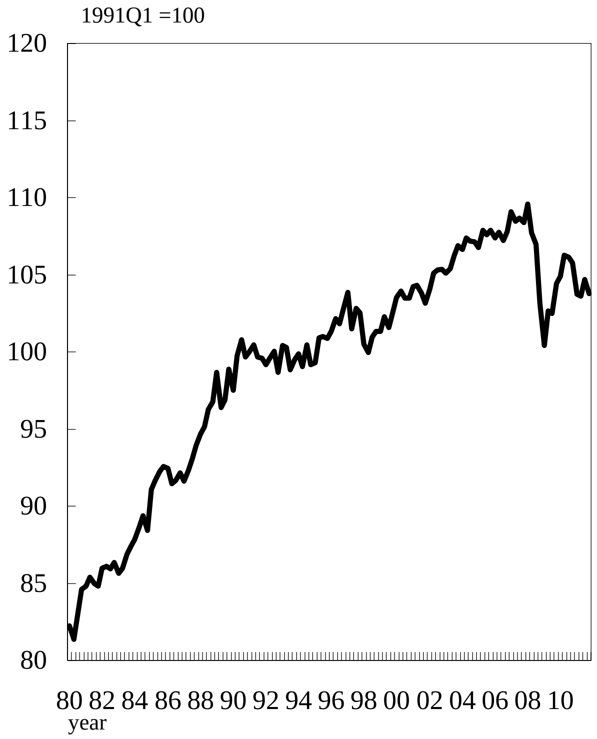


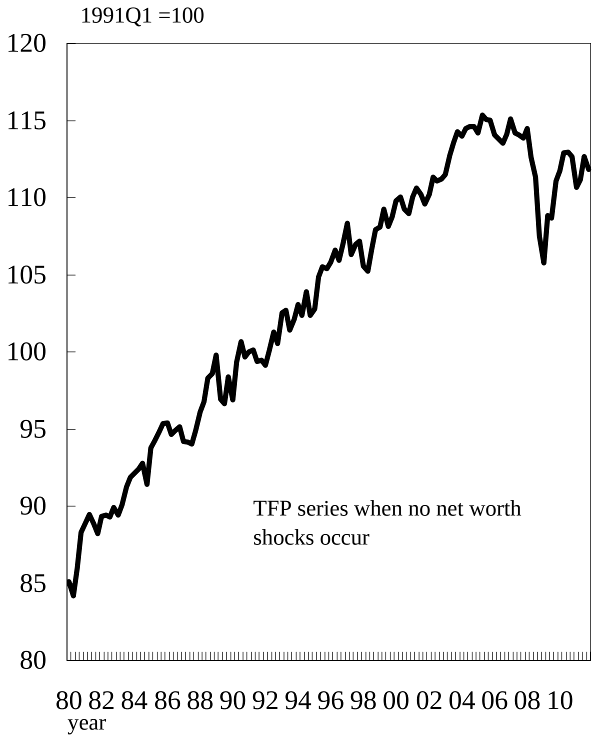
Figure 11: Counterfactual Simulation for TFP (Utilization Unadjusted)

(1) Level

Actual TFP



Model-generated TFP



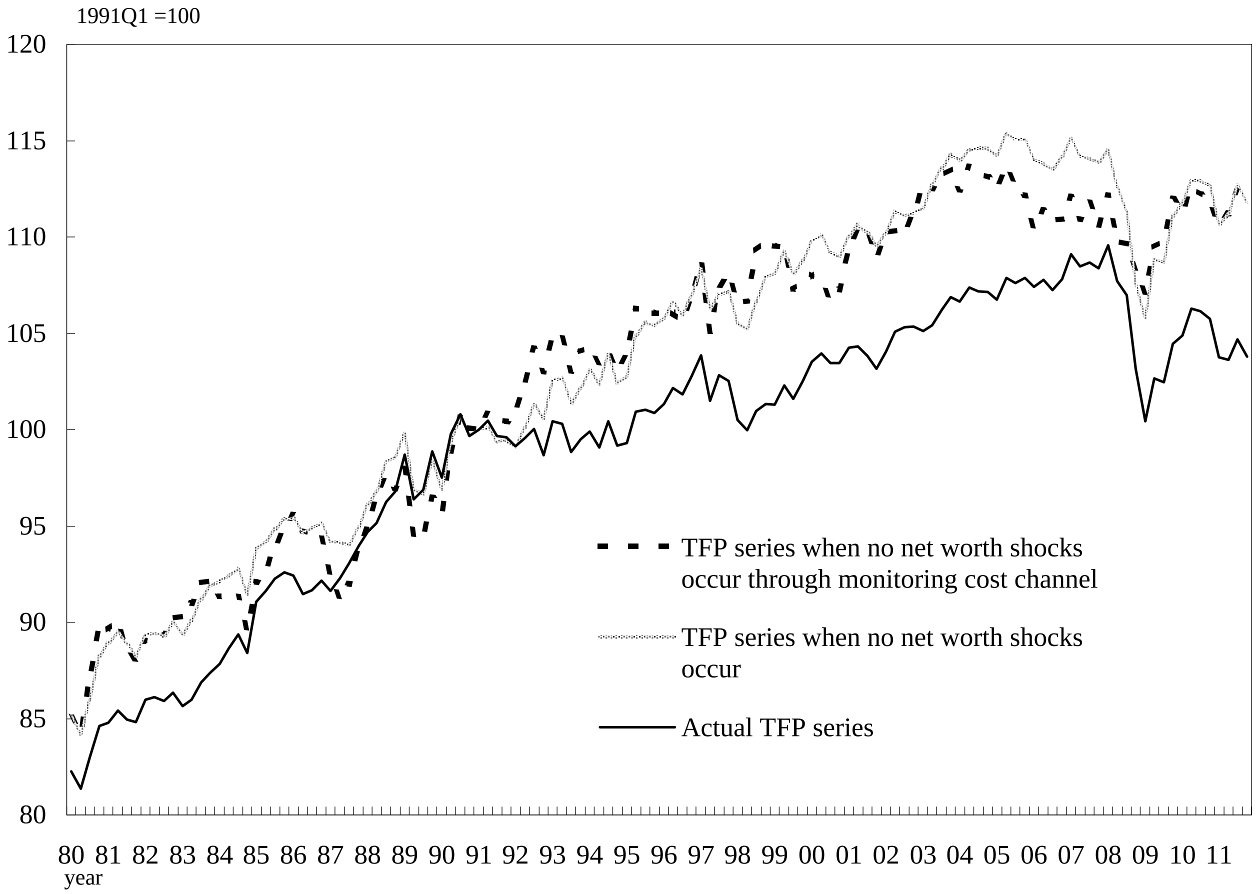
(2) Growth Rate (year on year % change)

year on year % change

	1980s	1990s	2000 and beyond
Actual TFP	1.84	0.42	0.16
	N/A	*-1.42*	*-0.26*
Model-generated TFP when net worth shocks are absent	1.46	1.03	0.23
	N/A	*-0.43*	*-0.80*

Notes: Numbers reported below growth rates are changes in growth rates.

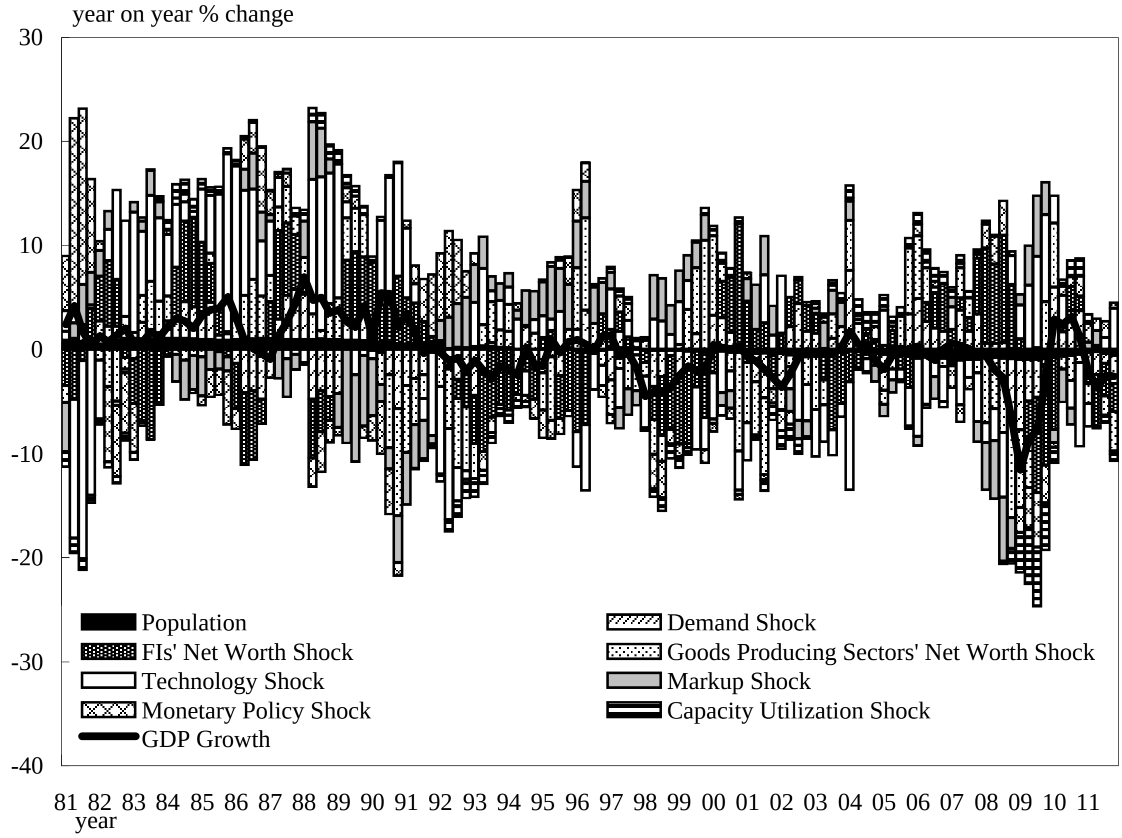
Figure 12: Decomposition of TFP Growth into channels (Capacility Utilization Unadjusted)



Notes: In computing "TFP series when no net worth shocks occur through monitoring cost channel," we calculated the size of monitoring cost generated by net worth shocks and added them to actual GDP series, then we obtained hypothetical TFP serires without the effect of net worth shocks through monitoring cost.

Figure 13: Decomposition of GDP Growth

(1) Decomposition (Quarterly)



Notes: Contributions of other shocks and initial values are not shown in the Figure.

(2) Decomposition (Average of 10 years)

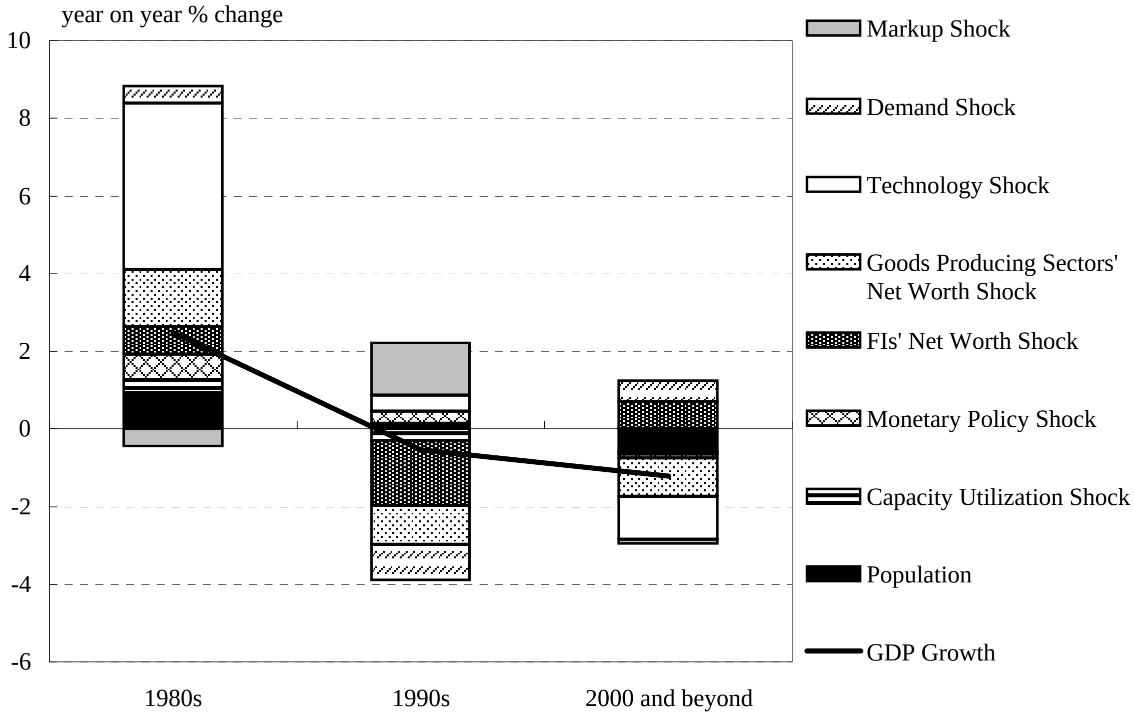
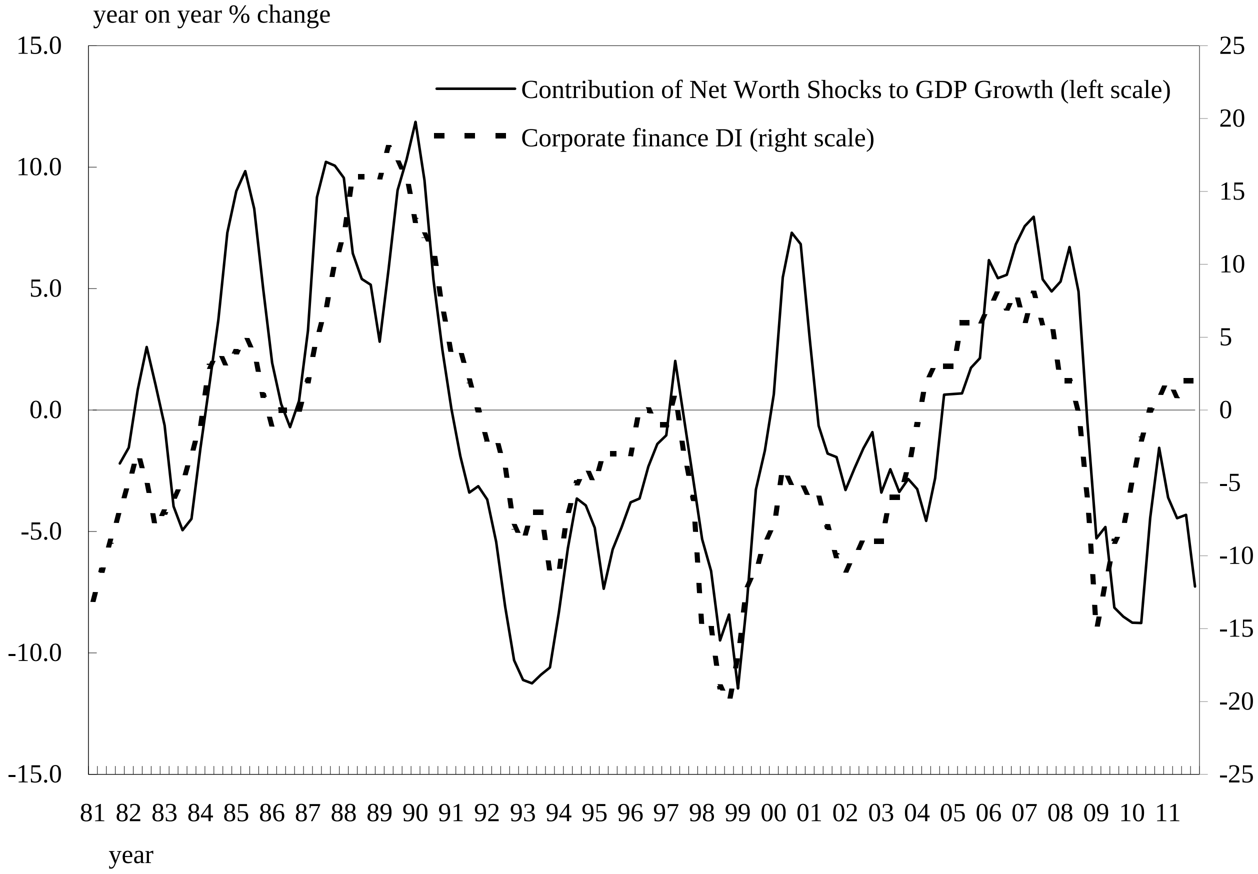


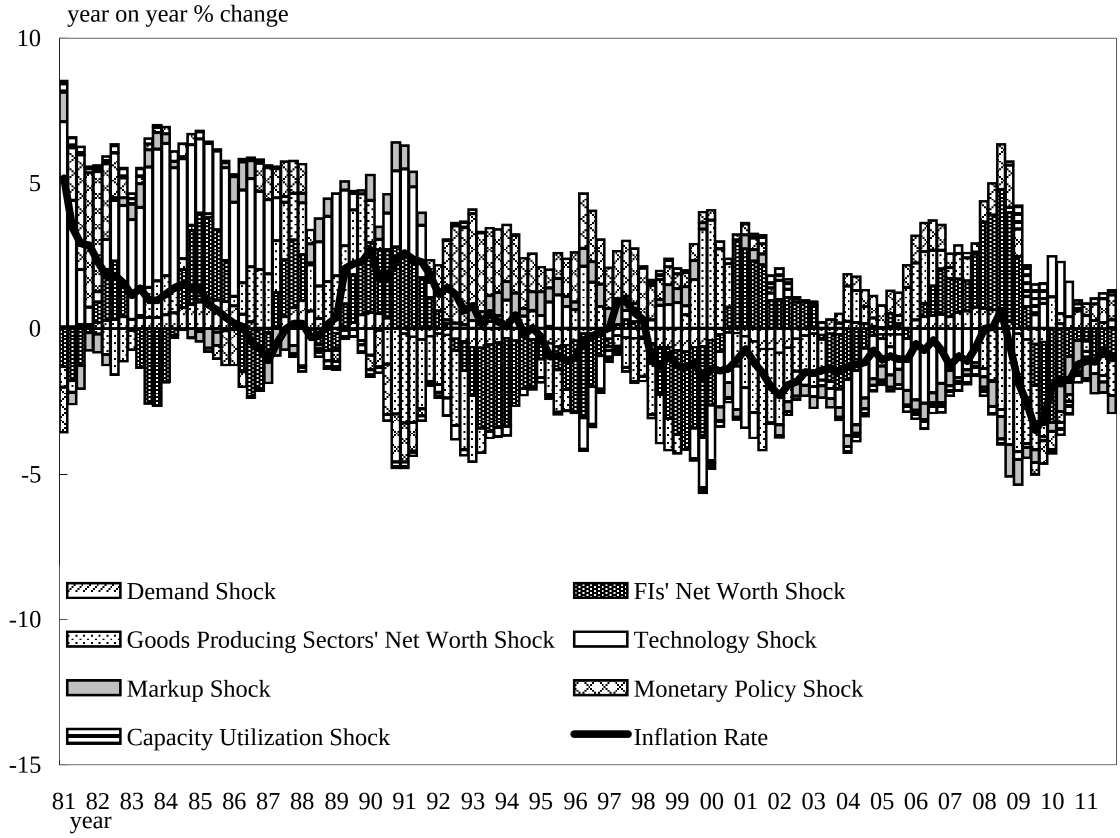
Figure 14 : Corporate Finance D.I. and Contribution of Net Worth Shocks to GDP Growth



Notes: Contributions of Net Worth Shocks to GDP Growth are smoothed by two-year moving average.
Source: Bank of Japan, "Tankan, Short-term Economic Survey of Enterprises in Japan."

Figure 15: Decomposition of Inflation Rate

(1) Decomposition (Quarterly)



Notes: 1.Inflation rate is weighted average of inflation of non-durable and that of durable.
Notes: 2.Contributions of other shocks and initial values are not shown in the Figure.

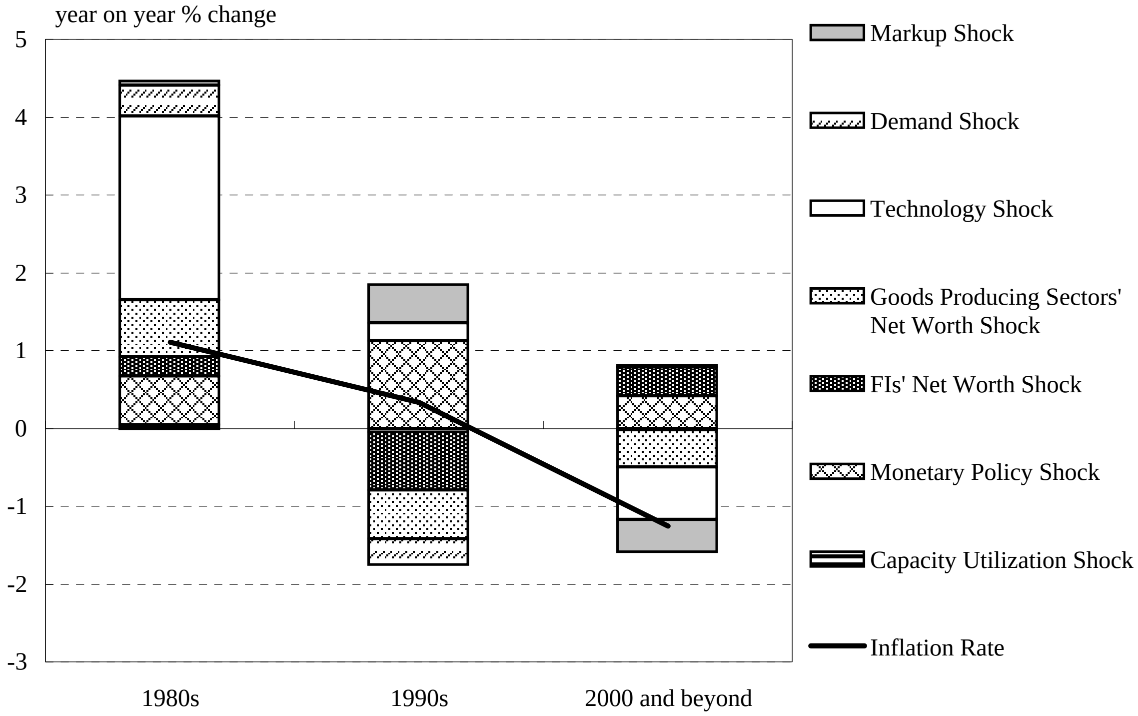


Table: Estimated Parameters

(1) Values of Estimated Parameters (Prior and Posterior Distributions)

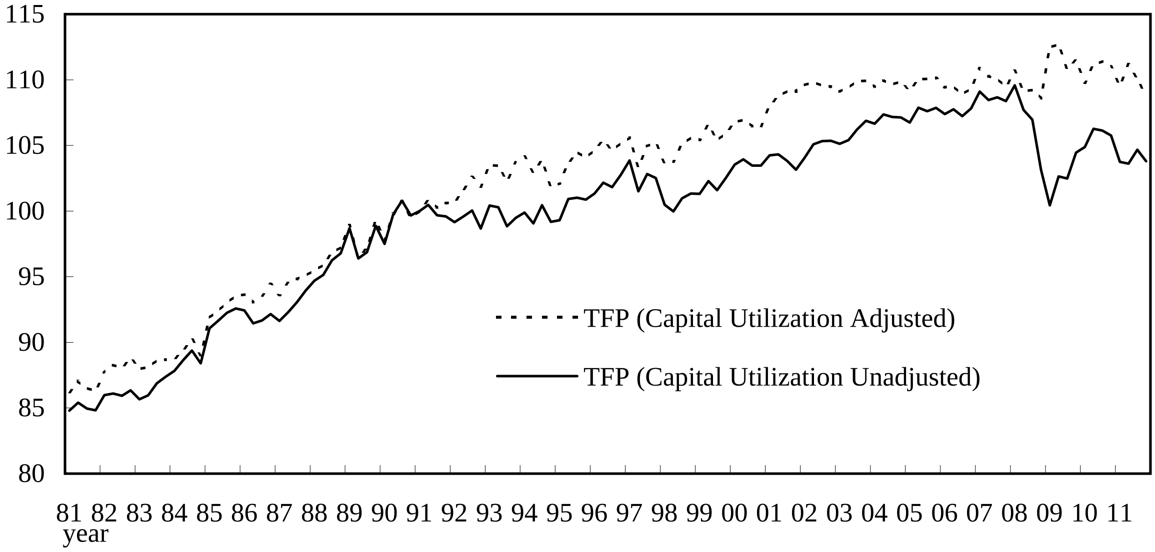
	Prior Distribution			Posterior Distribution		
	Distribution	Mean	S.D.	Mean	5th Percentiles	95th Percentiles
Capital Stock Adjustment Cost (Non-durable)	norm	1	0.05	1.06	0.99	1.14
Capital Stock Adjustment Cost (Durable)	norm	1	0.05	1.06	0.99	1.13
Durable Stock Adjustment Cost	norm	8	3	0.05	0.03	0.07
Price Adjustment Cost (Non-durable)	norm	16	6	29.72	23.94	35.22
Price Adjustment Cost (Durable)	norm	16	6	39.08	32.14	45.78
Nominal Wage Adjustment Cost (Non-durable)	norm	16	6	25.59	18.26	32.93
Nominal Wage Adjustment Cost (Durable)	norm	16	6	19.52	10.59	28.20
Policy Weight on Inflation in Taylor Rule	norm	1.8	0.05	1.93	1.85	2.01
Parameter for Capital Utilization Rate	norm	5	1	6.18	5.12	7.22
Permanent Technology Shock (Durable) AR	norm	0.5	0.15	0.23	0.19	0.27
Permanent Technology Shock (Common) AR	norm	0.5	0.15	0.14	-0.02	0.26
Net Worth Shock (FI) AR	beta	0.85	0.1	0.25	0.22	0.28
Net Worth Shock (Non-durable) AR	beta	0.85	0.1	0.34	0.20	0.46
Net Worth Shock (Durable) AR	beta	0.85	0.1	0.36	0.32	0.43
Demand Shock (Non-durable) AR	beta	0.5	0.15	0.80	0.70	0.91
Demand Shock (Durable) AR	beta	0.5	0.15	0.76	0.57	0.90
Investment Adjustment Shock (Non-durable) AR	beta	0.7	0.15	0.92	0.88	0.96
Investment Adjustment Shock (Durable) AR	beta	0.7	0.15	0.89	0.86	0.92
Price Markup Shock (Non-durable) AR	beta	0.5	0.15	0.47	0.39	0.56
Price Markup Shock (Durable) AR	beta	0.5	0.15	0.54	0.43	0.64
Nominal Wage Markup Shock (Non-durable) AR	beta	0.5	0.15	0.43	0.36	0.51
Nominal Wage Markup Shock (Durable) AR	beta	0.5	0.15	0.40	0.34	0.44
Capacity Utilization Rate Shock AR	beta	0.5	0.15	0.03	0.03	0.03
Permanent Technology Shock (Durable) SD	invg	0.4	2	0.06	0.05	0.07
Permanent Technology Shock (Common) SD	invg	0.4	2	0.05	0.05	0.05
Temporary Technology Shock (Common) SD	invg	5	5	0.79	0.78	0.80
Temporary Technology Shock (Non-durable) SD	invg	2	5	0.27	0.25	0.29
Monetary Policy Shock SD	invg	0.1	2	0.01	0.01	0.01
Net Worth Shock (FI) SD	invg	0.5	1	0.07	0.06	0.07
Net Worth Shock (Non-durable) SD	invg	0.5	1	0.07	0.06	0.07
Net Worth Shock (Durable) SD	invg	0.5	1	0.07	0.06	0.08
Demand Shock (Non-durable) SD	invg	1	2	0.14	0.13	0.15
Demand Shock (Durable) SD	invg	1	5	0.48	0.37	0.60
Investment Adjustment Shock (Non-durable) SD	invg	1	5	0.54	0.30	0.79
Investment Adjustment Shock (Durable) SD	invg	1	5	1.16	0.96	1.38
Price Markup Shock (Non-durable) SD	invg	0.5	5	0.11	0.09	0.13
Price Markup Shock (Durable) SD	invg	1.5	5	0.26	0.22	0.31
Nominal Wage Markup Shock (Non-durable) SD	invg	0.5	5	0.39	0.35	0.45
Nominal Wage Markup Shock (Durable) SD	invg	0.5	5	0.47	0.34	0.62
Capacity Utilization Rate Shock SD	invg	0.1	0.1	0.10	0.09	0.10

(2) Values of Calibrated Parameters

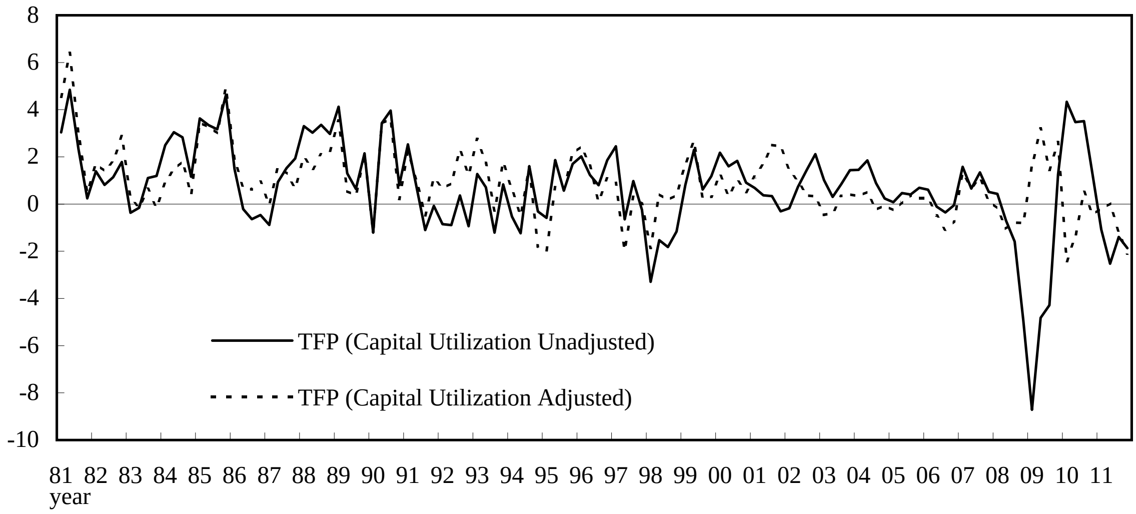
Elasticity of Labor Supply	1
Capital Share	0.36
Households' Discount Factor	0.99
Capital Depreciation Rate	0.028
Durable Stock Depreciation Rate	0.0375
Price Markup at Steady State (Non-durable)	5
Price Markup at Steady State (Durable)	5
Wage Markup at Steady State (Non-durable)	21
Wage Markup at Steady State (Durable)	21
FIs' Net Worth Ratio	0.1
Goods Production Sectors' Net Worth Ratio	0.6

Appendix: Figure 1: Total Factor Productivity

(1) Level (1991Q1=100)



(2) Growth Rate (year on year % change)



(3) Growth Rate (average of 10 years)

year on year % change

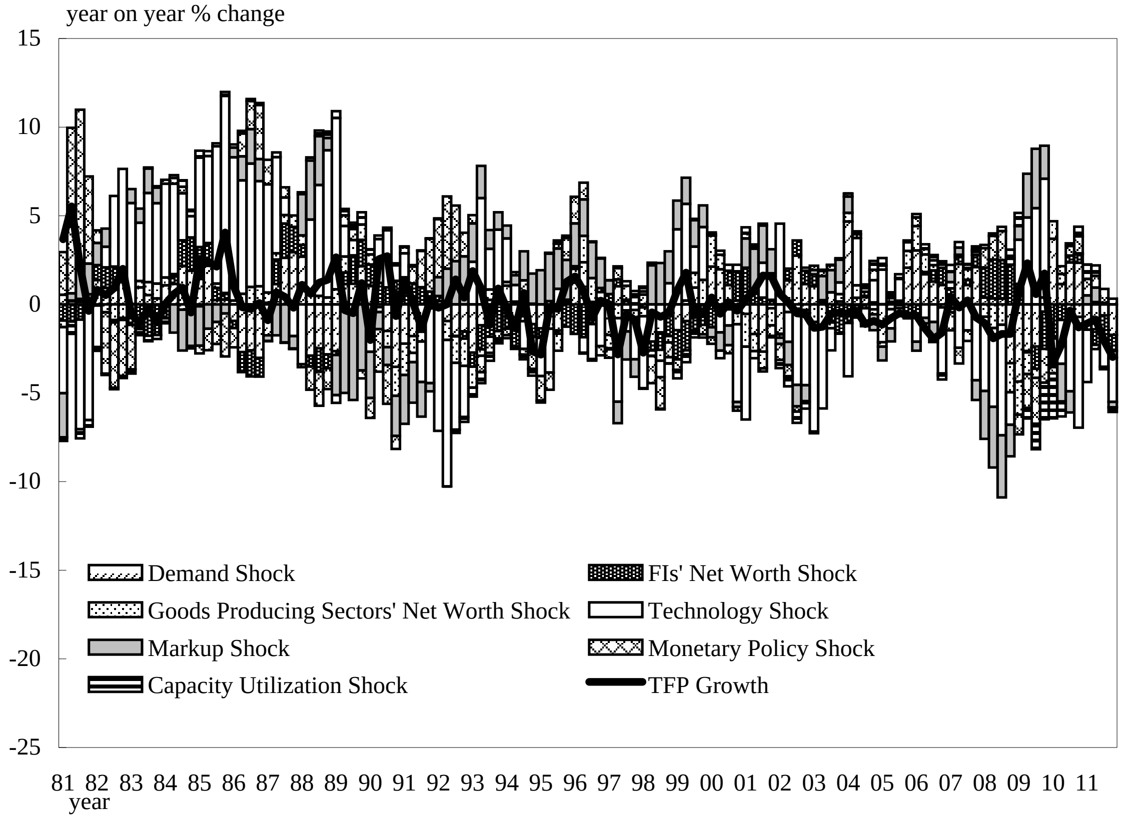
	1980s	1990s	2000 and beyond
TFP (Capital Utilization Unadjusted)	1.84 *N/A*	0.42 *-1.42*	0.16 *-0.26*
TFP (Capital Utilization Adjusted)	1.78 *N/A*	0.77 *-1.01*	0.31 *-0.46*

Notes: Numbers reported below growth rates are changes in growth rates.

Sources: Cabinet Office, "National Accounts," Ministry of Health, Labour and Welfare, "Monthly Labour Survey";
Ministry of Internal Affairs and Communications, "Labour Force Survey";
Ministry of Economy, Trade and Industry, "Indices of Industrial Production"

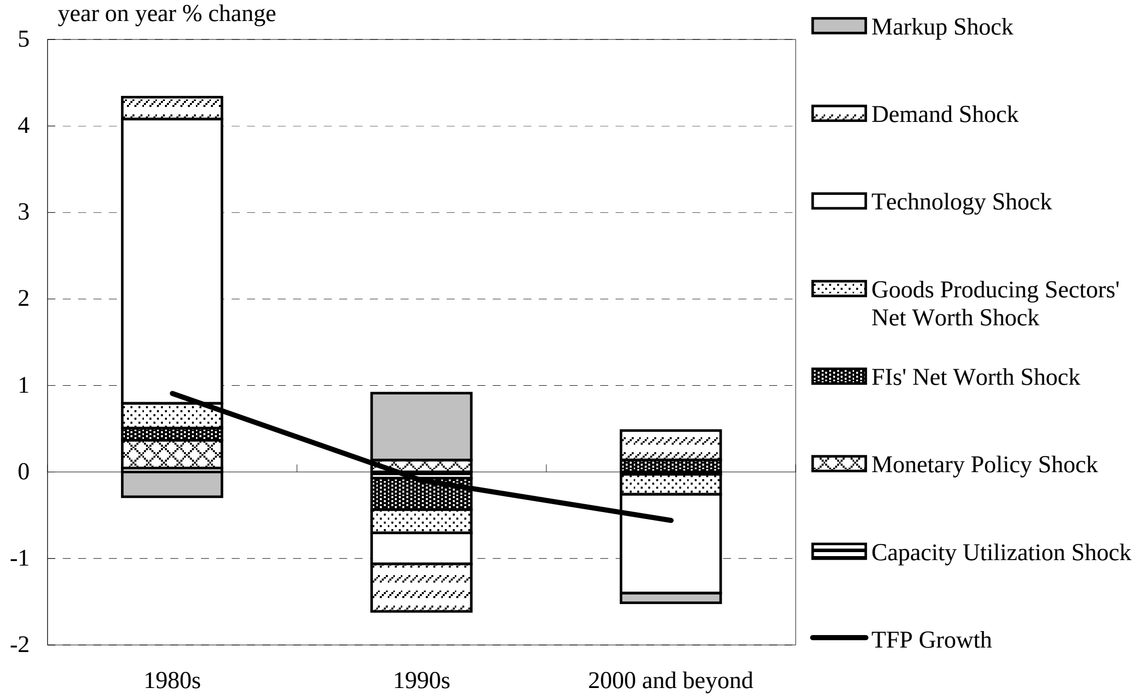
Appendix: Figure 2: Decomposition of TFP Growth (Capacility Utilization Adjusted)

(1) Decomposition (Quarterly)



Notes: Contributions of other shocks and initial values are not shown in the Figure.

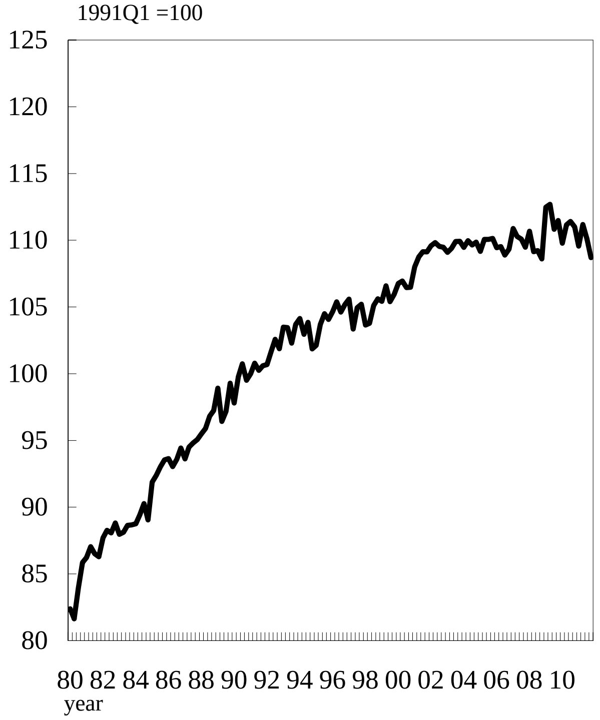
(2) Decomposition (Average of 10 years)



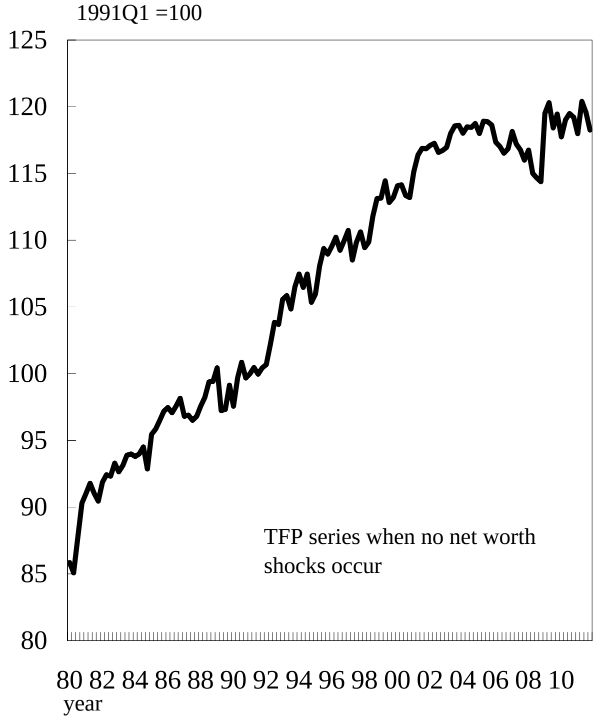
Appendix: Figure 3: Counterfactual Simulation for TFP (Utilization Adjusted)

(1) Level

Actual TFP



Model-generated TFP



(2) Growth Rate (year on year % change)

year on year % change

	1980s	1990s	2000 and beyond
Actual TFP	1.78	0.77	0.31
	N/A	*-1.01*	*-0.46*
Model-generated TFP when net worth shocks are absent	1.36	1.41	0.40
	N/A	*0.05*	*-1.01*

Notes: Numbers reported below growth rates are changes in growth rates.