Working Paper Series

IMPORT PENETRATION AND CONSUMER PRICES

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Working Paper 02-1

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February, 2002

We would like to thank Yoichi Matsubayashi (Wakayama University), Hiroshi Fujiki, Shigenori Shiratsuka (the Institute for Monetary and Economic Studies, Bank of Japan), and the many staff of the Research and Statistics Department at the Bank of Japan for their helpful comments. Any remaining errors belong to the authors. The opinions expressed here are those of the authors, and should be ascribed neither to the Bank of Japan nor to the Research and Statistics Department. We can be reached at kouichirou.kamada@boj.or.jp and naohisa.hirakata@boj.or.jp .

ABSTRACT

This paper shows that changes in international competitiveness played a significant role in creating the deflationary pressure in Japan from 1980 to 2001. Applying Blanchard and Quah's (1989) *SVAR* technique to Dornbusch, Fischer, and Samuelson's (1977) classical comparative advantage model, we break down Japan's inflation rate of the consumer prices into three kinds of structural shocks: comparative advantage shocks, global productivity shocks, and cyclical demand shocks. The breakdown results tell us that the Japanese economy had been exposed to severe international competition since 1994, especially from the Asian economies. Japan's loss of international competitiveness had exerted continuous downward pressure on the consumer prices and deflationary pressure strengthened significantly at the very end of the 20th century.

(*JEL classification: C51, E31, F11;* comparative advantage, consumer prices, import penetration)

I. INTRODUCTION

At the very end of the 20th century, the Japanese economy entered a deflationary phase, with the consumer price index (excluding fresh food, CPI hereafter) decreasing by 0.5 percent in fiscal 2000, compared to the 0.1 percent decrease in 1999. Various economic conditions combined to produce this situation. First, since the asset bubble burst at the beginning of the 1990s, the Japanese economy had long remained in recession, and weak demand had exerted downward pressure on consumer prices. Second, technological progress continued inside and outside of the economy, which saved production costs and steadily lowered consumer prices. Third, an influx of inexpensive imports from the Asian economies entered Japan.[1]

Increases in imports from China were especially remarkable during the last decade. China's share of Japan's imports (on a yen basis) rose from 3.8 percent during the early 1980s to 14.5 percent in 2000. Manufacturers of industrialized countries that sought low production costs strengthened this trend through vigorous direct investments into China. Japanese corporations were no exception; they incorporated themselves aggressively into the Asian international production network by shifting, either wholly or in part, their production lines from Japan to China. Typically, they exported capital goods and parts as well as intermediate goods, and imported inexpensive final products. Cheap imports were directly responsible for the decline in consumer prices. In addition, they added downward pressure on prices of import-competing producers operating domestically. This competitive pressure from abroad forced Japan's distribution sector to lower selling prices by establishing an efficient distribution system and by squeezing their margins. The main purpose of this paper is to identify how important the changes in Japan's international competitiveness were in creating the deflationary phase of the period from 1980 to 2001.

The above discussion suggests that we should consider at least three kinds of structural shocks when talking about the recent developments regarding consumer prices in Japan: shocks that affect comparative advantage, those that promote global productivity, and those that create a business cycle. The problem is that statisticians cannot directly observe these shocks. The basic idea of this paper is that these structural

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[1] See Bank of Japan (2001) for a detailed description of the Japanese CPI during the 1990s.

shocks have specific effects on economic variables like the import penetration ratio (or the fraction of income spent for import), the output growth rate, and movements in consumer prices. First, a rise in comparative advantage results in a decline in the import penetration ratio. Second, suppose that a technological innovation spreads globally. The import penetration ratio is untouched, since it does not change an international structure of competitiveness. However, real output grows because of it. Third, a temporary shock that causes a business cycle is usually considered to have no long-run effects on the growth rate of the economy and on the import penetration ratio. These differences in affecting the economic variables are key factors in identifying the structural shocks that occur behind the movements of these variables.

The remainder of this paper is constructed as follows. In Section II, we present the basic model that forms the theoretical background of this paper. The classical model by Dornbusch, Fischer, and Samuelson (1977, DFS hereafter) gives the background. We describe the DFS model and concisely present its implications relevant to this paper. In Section III, we introduce the linear version of the DFS model and create a bridge between the non-linear DFS model and the linear *VAR* system estimated in the later section. There we show how unobservable structural shocks affect observable economic variables. In Section IV, we explain how the two-factor models by Blanchard and Quah (1989, BQ hereafter) and Quah and Vahey (1995) are extended to a three-factor model (see also Gartner and Wehinger [1998] for instance). In Section V, we implement the BQ decomposition, making use of Japanese data. We examine the impulse response functions and forecast error variance decomposition, and see how the three kinds of structural shocks affect the import penetration ratio, the real growth rate, and the inflation rate of the consumer price index. In Section VI, we break down the economic forecasts of several research institutions by the same technique as developed in the earlier sections, and see what shocks the forecasters expected to occur in the future. We also devise a forecasting technique as an application of the BQ decomposition. Section VII extends the DFS model to describe the Japanese reality and interprets the estimated *VAR* system through simulations by the extended model. Section VIII concludes our discussion.

II. THEORETICAL BACKGROUND

A. Dornbusch-Fischer-Samuelson Model

In this section, we present a basic model to see what information is contained in the movements of the import penetration ratio (i.e., real imports per real output) and the growth of the real output. Our theoretical basis is the classical model developed by Dornbusch, Fischer, and Samuelson (1977). We extend the model in line with Obstfeld and Rogoff (1996). The DFS model tells us that the world structure of specialization and trade patterns depend on deep parameters, such as production technology, consumers' tastes, and relative size of economies in the long run. To put it differently, we can infer from the movements of the import penetration ratio and other economic variables what exogenous shocks occur on the deep parameters. Below, we present the basics of the DFS model selectively, but do not aim at being comprehensive. Readers who are unfamiliar with the DFS model are recommended to see their original paper.

There is a continuum of goods in the world. Goods are labeled by $z \in [0,1]$. The ultimate production factor is only labor as in the Ricardian trade model. The factor requirement to produce one unit of good z is $a(z)$ in the home country and $a^*(z)$ in a foreign country. Let W and W^* be the nominal wage rates in the home country and in the foreign country, respectively. Then the assumption of free entry and exit guarantees that the price of good z is given by $a(z)W$ when produced in the home country and $a^*(z)W^*$ when produced in the foreign country. Good z is produced in the home country, but not in the foreign country, if and only if

$$a(z)W \le a^*(z)W^* \iff W/W^* \le a^*(z)/a(z).$$

Define a comparative advantage index of the home country against the foreign country in the production of good z by

$$A(z) \equiv a^*(z)/a(z).$$

Goods are so ordered that as z increases, the home country's comparative advantage declines: $A'(z) < 0$. Define a "border" good implicitly by

$$W/W^* \equiv A(Z). \qquad (2\text{-}1)$$

Note that we use the capital letter Z for the border good. Then the goods for $z \le Z$ are produced in the home country and the rest of the goods are in the foreign country.

Denote the amount of labor employed in the home country by L and that in the foreign country by L^*. Then the nominal income in the home country is given by WL and that in the foreign country is by W^*L^*. Now, let us assume that the utility function of a consumer is given by $U \equiv \int_0^1 \ln c(z)dz$, where $c(z)$ denotes the amount of good z consumed. Then, we can show that nominal expenditures are the same for all the goods in each country. This implies that the fraction Z of the world income is paid out for the goods produced in the home country. Since there are no profits left for producers under the assumption of perfect competition, we have

$$WL = Z(WL + W^*L^*) .$$

By solving this for Japan's relative wage, we obtain

$$W / W^* = \frac{Z}{1-Z}\frac{L^*}{L} \equiv B(Z; L^* / L) . \quad (2\text{-}2)$$

Combining this with equation (2-1), we can find the border good and the equilibrium relative wage rate. Remember that the fraction Z of the home country's income is spent for the goods produced domestically. To put it differently, the import penetration ratio or the fraction of income spent for imported goods is given by

$$M \equiv 1 - Z . \quad (2\text{-}3)$$

B. Comparative Statics

Here we investigate how various structural shocks move the key economic variables. In other words, we determine what shocks are inferred from the movements of the key variables. A simple diagram is sufficient for this purpose. Below, we focus on two important comparative statics: productivity shocks and labor shocks.

Productivity Shocks

Suppose that the foreign country's productivity enhances. That is, there occurs an equi-proportionate decline in the foreign country's unit labor requirement, $a^*(z)$, for every

$z \in [0,1]$. This shifts down $A(\cdot)$ (shown as a downward shift from the solid curve to the broken one in Chart 1(1)). As a result, the import penetration ratio rises in the home country. Because productivity shocks are usually considered to be permanent, once the import penetration ratio changes, it stays away from the initial equilibrium value.

Suppose alternatively that the home country's productivity improves simultaneously. That is, $a(\cdot)$ declines in the same proportion as $a^*(\cdot)$ does. In this case, $A(\cdot)$ remains at the original position. Hence, the import penetration ratio is unchanged. Note, however, that the output increases in each country.

<u>*Labor Shocks*</u>

Suppose that the labor amount increases in the foreign country. Then, L^*/L increases. This shifts up $B(\cdot)$ (shown as an upward shift from the solid curve to the broken one in Chart 1(2)). Consequently, the import penetration ratio rises in the home country. Note that the relative size of the foreign country to the home country is sufficient information to determine the equilibrium import penetration. Therefore, when population grows both in the foreign country and in the home country at the same speed, it has no influence on the equilibrium import penetration. Notice, however, that the population growth induces the output growth in this case.

We should distinguish two kinds of labor shock: a permanent one and a cyclical one. Let us define the employed labor amount precisely.

Employed Labor = (Adult Population)×(Participation Rate)
×(1-Unemployment Rate)×(Working Hours).

The first two components may be called labor-supply factors; shocks on them have permanent effects on the amount of labor. Since a shock on the factors is permanent, the import penetration ratio and the output level remain at the new positions after the shock occurs. Obviously, labor supply is growing much faster in the world, and especially in the Asian economies, than in Japan. Hence, the ratio L^*/L increases steadily for Japan. This implies that the equilibrium import penetration and the output level may have virtually deterministic time-trends in their behavior. On the other hand, the last two components may be called labor-demand factors. They capture temporary labor shocks. The labor demand shows cyclical behavior around the normal level in a business cycle. The import penetration ratio and the output level both return to their normal levels over time. (This is an important distinction in conducting empirical analysis. We will return to this issue in a later section.)

The above arguments are summed up as follows. First, if productivity enhances in only one country, the import penetration ratio changes. Second, if productivity enhances worldwide, the import penetration ratio is unchanged, but the output increases in each country. Third, a labor-demand shock has no effects on either import penetration ratio nor on real output in the long run. Fourth, a labor-supply shock creates trend behavior in the import penetration ratio and in real output. These consequences are used to identify what structural shocks hit an economy.

C. Consumer Price Index

To construct a CPI formula, we assume the following specific forms of unit-labor-requirement functions.

$$a(z) = \exp(Y + z) \text{ and } a^*(z) = \exp(Y^* + 1 - z).^2 \qquad (2\text{-}4)$$

Note that Y and Y^* represent productivity levels in the home and in the foreign country, respectively. In this case, the border good Z is defined implicitly by

$$W / W^* \equiv \exp(Y^* - Y + 1 - 2Z). \qquad (2\text{-}5)$$

This paper defines a CPI as a current period's expenditure relative to the benchmark period's expenditure that is required to keep the same utility level. Appendix A shows that the CPI is the geometric mean of current prices relative to the benchmark period's prices. That is,

$$P = \exp\{\int_0^1 \ln(p(z) / p_0(z))dz\},$$

where P is the CPI and $p(z)$ is the price of good z. The suffix 0 means the benchmark period.

If good z is produced in the home country, we have $p(z) = a(z)W$. Otherwise, we have $p(z) = a^*(z)W^*$. For simplicity, we start from a symmetric equilibrium:

[2] Obstfeld and Rogoff (1996) used a similar parameterization.

$$W_0 = W_0^* = 1;\ L_0 = L_0^* = 1;\ Y_0 = Y_0^* = 0;\ \text{and}\ Z_0 = 1/2. \tag{2-6}$$

Under these assumptions, Appendix A shows that the CPI is given by

$$P = \exp\{ZY + (1-Z)Y^* + Z\ln W + (1-Z)\ln W^* + (Z-1/2)^2\}. \tag{2-7}$$

It is intuitive that P depends on W and W^* as well as on Z. Especially, P is homogeneous of degree one with respect to W and W^*. As shown in Chart 1, the DFS model tells us the relative wage W/W^* in equilibrium, but their individual levels are undetermined. Thus, to determine nominal wages, we have to know either the home country's nominal wage or the foreign country's. This suggests that an additional assumption is necessary to determine the price index.

Once P is determined, we can define real expenditure in terms of the benchmark period's prices by

$$Y \equiv WL/P. \tag{2-8}$$

Trivially, in the benchmark period, we have $P_0 = 1$. Thus, under the assumption of the symmetric equilibrium in the benchmark period (i.e., equations (2-6)), the benchmark real output or GDP is given by $Y_0 = 1$.

III. STRUCTURAL SHOCKS IN A LINEAR SYSTEM

This section builds a bridge between the DFS model developed in the previous section and the *VAR* model estimated in a later section. As seen, the DFS model is highly non-linear. On the other hand, we will use a linear *VAR* model for the later empirical study. Therefore, it is desirable to show how the DFS model is translated into a linear system. In doing so, we will also find the necessary data transformation to construct the system.

Another purpose of this section is to derive implications of the DFS model for consumer prices. As discussed in the previous section, we have no information about nominal prices, since the DFS model tells little about the nominal wage in each country. Here, to determine the nominal wages, we make an assumption for the nominal wage rate in the foreign country and then derive the nominal wage rate in the home country in conjunction with the relative wage commanded by the DFS model.

A. Log Linearization

The technique to convert the non-linear DFS model into the corresponding linear *VAR* system is log-linearization. We demonstrate the technique by working on equation (2-2). First, take logarithms of both the sides of the equation. We get

$$\ln W_t - \ln W_t^* = \ln Z_t - \ln(1 - Z_t) + \ln L_t^* - \ln L_t ,$$

where we attach the time suffixes on the variables. The linear Taylor expansion of the above equation gives us

$$\{\ln W_0 + (W_t - W_0)/W_0\} - \{\ln W_0^* + (W_t^* - W_0^*)/W_0^*\} = \{\ln Z_0 + (Z_t - Z_0)/Z_0\} -$$
$$\{\ln(1 - Z_0) + (1 - Z_t - (1 - Z_0))/(1 - Z_0)\} + \{\ln L_0^* + (L_t^* - L_0^*)/L_0^*\} - \{\ln L_0 + (L_t - L_0)/L_0\} .$$

We can log-linearize equations (2-5), (2-7), and (2-8) in a similar fashion.

Start from a symmetric equilibrium (2-6). Let $\hat{X}$ be the rate of deviation of variable X from its symmetric equilibrium X_0 (i.e., $\hat{X}_t = (X_t - X_0)/X_0$) except for $\hat{Z}$, which denotes the points of deviation of Z from its symmetric equilibrium Z_0 (i.e., $\hat{Z}_t = Z_t - Z_0$). Then we have

$$\hat{W}_t - \hat{W}_t^* = 4\hat{Z}_t + \hat{L}_t^* - \hat{L}_t ;$$
$$\hat{W}_t - \hat{W}_t^* = Y_t^* - Y_t - 2\hat{Z}_t ;$$
$$\hat{P}_t = (Y_t + Y_t^* + \hat{W}_t + \hat{W}_t^*)/2 ; \text{ and}$$
$$\hat{Y}_t = \hat{W}_t + \hat{L}_t - \hat{P}_t . \qquad (3\text{-}1)$$

Note that $\hat{M} = -\hat{Z}$. Then, given Y, Y^*, $\hat{L}$, $\hat{L}^*$, and $\hat{W}^*$ as exogenous, we can solve for $\hat{M}$, $\hat{Y}$, and $\hat{P}$.[3] Taking the differences of the results, we obtain

$$D\hat{M}_t = \tfrac{1}{6}DY_t - \tfrac{1}{6}DY_t^* + \tfrac{1}{6}D\hat{L}_t^* - \tfrac{1}{6}D\hat{L}_t ;$$

[3] We can also solve for $\hat{W}$. We, however, ignore this below, since it is redundant for the following identification procedure.

$$D\hat{Y}_t = -\tfrac{5}{6} DY_t - \tfrac{1}{6} DY_t^* + \tfrac{1}{6} D\hat{L}_t^* + \tfrac{5}{6} D\hat{L}_t \text{; and}$$

$$D\hat{P}_t = \tfrac{1}{6} DY_t + \tfrac{5}{6} DY_t^* + \tfrac{1}{6} D\hat{L}_t^* - \tfrac{1}{6} D\hat{L}_t + D\hat{W}_t^* . \quad (3\text{-}2)$$

Notice that $D\hat{X}$ can be an approximated growth rate of variable X except for $D\hat{M}$, which denotes the points of change in M.[4]

B. *Structural Shocks*

Next, we assume the behavior of exogenous variables, Y, Y^*, $\hat{L}$, $\hat{L}^*$, and $\hat{W}^*$. The evolution of productivity in the home country and in the foreign country is assumed as follows.

$$DY_t = e_t / 2 - n_t \text{ and } DY_t^* = -e_t / 2 - n_t . \quad (3\text{-}3)$$

Here, the e and n represent two kinds of structural shocks on the productivity in the home country and the foreign country. We call the n a global productivity shock. It moves the productivity in both the countries in the same direction. For instance, when $n > 0$, productivity improves in both the countries. On the other hand, we call the e a comparative advantage shock. It moves productivity in the home country and the foreign country in opposite directions. For example, when $e > 0$, the home country loses comparative advantage to the foreign country. Note that both e and n have permanent effects on productivity levels in both the countries.

Our assumptions on the labor markets in the home country and in the foreign country are as follows:

$$\hat{L}_t^* = h_t \Rightarrow D\hat{L}_t^* = Dh_t \text{ and } \hat{L}_t = h_t \Rightarrow D\hat{L}_t = Dh_t . \quad (3\text{-}4)$$[5]

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[4] By definition, we have $D\hat{X}_t = (X_t - X_0)/X_0 - (X_{t-1} - X_0)/X_0 = (X_t - X_{t-1})/X_0$. By approximation, we have $D\hat{X}_t \cong (X_t - X_{t-1})/X_{t-1}$ in the neighborhood of X_0. This is the growth rate of variable X.

[5] In Section II, we discussed population growth as a labor supply shock. When population grows at a constant speed, we can rewrite equation (3-4) as follows:

$$\hat{L}_t^* = k^* \cdot t + h_t \Rightarrow D\hat{L}_t^* = k^* + Dh_t \text{ and } \hat{L}_t = k \cdot t + h_t \Rightarrow D\hat{L}_t = k + Dh_t .$$

By substituting these assumptions into system (3-2), we can easily see that these modifications do not

Literally, the h is a worldwide shock on the labor market. In the broader sense, however, the shock can be interpreted to capture an increase in demand for products made in the home country as well as in the foreign country. The reason is, as assumed in Section II, that an increase in the amount of employed workers leads to an increase in aggregate demand. Furthermore, here we take the h as a worldwide shock and assume that it has direct effects on the labor market in every country. Alternatively, as in Appendix C, we can take the h as a shock on the foreign labor market and show that a foreign labor shock is transmitted to a home labor market through the staggered wage setting at the home labor market. Either way, we can treat the h as a worldwide shock, though the shock may become effective in a different pace from country to country, as discussed in Section VII.

Finally, we assume a Phillips-curve relationship between the labor demand and the nominal wage rate in the foreign labor market.

$$D\hat{W}_t^* = b \cdot \hat{L}_{t-1}^* . \tag{3-5}$$

As mentioned near the beginning of this section, we assume that the nominal wage in the foreign country is determined first and then the nominal wage in the home country is derived endogenously in conjunction with the relative wage obtained in the DFS model.[6]

By substituting these assumptions into system (3-2), we can see how long the effects of each shock continue. The three economic variables are expressed as linear combinations of the shocks as follows:

$$D\hat{M}_t = \tfrac{1}{6} e_t ;$$
$$D\hat{Y}_t = -\tfrac{1}{3} e_t + n_t + Dh_t \text{; and}$$
$$D\hat{P}_t = -\tfrac{1}{3} e_t - n_t + b \cdot h_{t-1} . \tag{3-6}$$

A shock without a D in its front has a permanent effect, while a shock with a D has only a transitory effect. For a later use, we itemize the relevant effects of the e, n, and

substantially change our discussion.

[6] Explicitly, given the foreign wage rate, the wage in the home country becomes

$$D\hat{W}_t = D\hat{W}_t^* + \tfrac{2}{3}(DY_t^* - DY_t) + \tfrac{1}{3}(D\hat{L}_t^* - D\hat{L}_t) .$$

η on $D\hat{M}$, $D\hat{Y}$, and $D\hat{P}$ as follows:

(i) The ε has permanent effects on $D\hat{M}$, $D\hat{Y}$, and $D\hat{P}$;
(ii) the ν has no permanent effects on $D\hat{M}$, but has permanent effects on $D\hat{Y}$ and $D\hat{P}$; and
(iii) the η has no permanent effects on $D\hat{M}$ and $D\hat{Y}$, but has permanent effects on $D\hat{P}$.

We impose these restrictions to identify the structural shocks in the later sections.[7]

Some remarks are in order here. The first remark concerns the role of the Phillips curve in the system. The labor shock has temporary effects on the output of the home country, while it has permanent effects on the CPI. The latter becomes possible through the Phillips-curve relationship, which converts a cyclical shock on labor demand into a permanent shock on the price level.

The second remark is with regard to the timing of observing shocks and making decisions by economic agents. In the above argument, we implicitly assume that people can make decisions after observing the shocks. It may seem to be a strong assumption. In Appendix C, we assume the opposite, so as to describe reality more appropriately. That is, people have to make some decisions before observing the shocks. In particular, we assume that the wage rates in the home country and the foreign countries are determined before people observe the shocks.

IV. STATISTICAL METHOD

Our primary interest in this paper is in when the three kinds of structural shocks (i.e., ε, ν, and η) occurred and how they affected the Japanese economy, especially with regard to developments in consumer prices. Statisticians, however, cannot observe these shocks directly.[8] In the previous section, we showed that these shocks affected the three economic variables (i.e., $D\hat{M}$, $D\hat{Y}$, and $D\hat{P}$) in different ways. Below, we exploit

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[7] If we ignore the ε, the current model has a similar structure to Quah and Vahey (1995) and Mio (2001), where the movements of real output and prices are broken down into demand shocks and supply shocks.

[8] In the previous section, we mentioned the ability of economic agents in the model to observe the structural shocks. Here we talk about statisticians' ability to observe them. These should be strictly distinguished from each other.

these differences to identify the unobservable structural shocks. Particularly, we make use of the long-run properties of the structural shocks that were itemized from (i) to (iii) near the end of the previous section.

Blanchard and Quah (1989) developed the structural *VAR* model to break down economic variables into the sums of structural shocks. The basic idea of the BQ breakdown is to make use of restrictions on the long-run effects of the structural shocks on the economic variables. In this section, we extend their bivariate model into a trivariate case and explain its mathematical background in detail. Although some parts assume a trivariate case in their expressions, the same procedure is applicable to any multivariate model.

VAR and VMA Representations

Since it is impossible to directly observe the three kinds of structural shocks, we first estimate the associated *VAR* system and then identify these shocks from the regression errors. That is, we start with estimating the following *VAR* system:

$$DX_t = A_1 \cdot DX_{t-1} + A_2 \cdot DX_{t-2} + \cdots + A_h \cdot DX_{t-h} + u_t = A(L) \cdot DX_{t-1} + u_t \,. \qquad \text{(4-1)}$$

Here $DX = (D\hat{M}, D\hat{Y}, D\hat{P})'$ is a column vector of the three economic variables and $u = (u_M, u_Y, u_P)'$ is that of the regression errors. The regression errors may be cross-correlated with one another. Denote its variance-covariance matrix by

$$E(u \cdot u') = W \,. \qquad \text{(4-2)}$$

The W is estimable from the regression errors of equation (4-1).

By iterative substitution, the *VAR* system (4-1) is rewritten as a *VMA* system.

$$DX_t = u_t + C_1 \cdot u_{t-1} + C_2 \cdot u_{t-2} + \cdots = C(L) \cdot u_t \,, \qquad \text{(4-3)}$$

where $C(L) \equiv S_{i=0}^{\infty} C_i \cdot L^i$ and $C_0 = I$. Note also that equation (4-1) is written as

$$DX_t = (I - A(L) \cdot L)^{-1} \cdot u_t \,. \qquad \text{(4-4)}$$

Since equations (4-3) and (4-4) have to coincide with each other, we have

$C(L) = (I - A(L) \cdot L)^{-1}$. In particular, with $L = 1$, we have

$$C(1) = (I - A(1))^{-1}. \quad (4\text{-}5)$$

As mentioned, the regression errors in the u of equation (4-1) may be cross-correlated with one another. The Wold decomposition theorem says, however, that DX is constructed by a vector of shocks, $w = (e, n, h)'$, whose elements are neither cross-correlated nor auto-correlated:[9]

$$DX_t = B_0 \cdot w_t + B_1 \cdot w_{t-1} + B_2 \cdot w_{t-2} + \cdots = B(L) \cdot w_t, \quad (4\text{-}6)$$

where $B(L) \equiv S_{i=0}^{\infty} B_i \cdot L^i$ and $E(w \cdot w') = I$. In each of equations (4-3) and (4-6), the first term on the right-hand side corresponds to the effects of current shocks on DX, while the others have already determined and are independent of the current shocks. This implies that

$$u_t = B_0 \cdot w_t. \quad (4\text{-}7)$$

Calculating the variance-covariance matrix from equation (4-7), we obtain

$$W = E(u_t \cdot u_t') = B_0 \cdot E(w_t \cdot w_t') \cdot B_0' = B_0 \cdot B_0'. \quad (4\text{-}8)$$

Long-Run Restrictions

If we know the 3×3 matrix B_0, we can find the structural shocks from the regression errors in the *VAR* estimation through equation (4-7). However, the W is a variance-covariance matrix and thus a symmetric matrix. Hence, equation (4-8) imposes only six restrictions on nine undetermined parameters. Three additional restrictions are given by the long-run restrictions that we discussed in the previous section (the assumptions on the existence of long-run effects of the three kinds of structural shocks on the three economic variables).

Suppose that shock $w^{\#}$ occurs. A vector of the cumulative effects on the economic variables ($DX^{\#}$) is calculated from equation (4-6) as

[9] The w should be neither cross-correlated nor auto-correlated, but need not be independent.

$$DX^{\#} = B_0 \cdot w^{\#} + B_1 \cdot w^{\#} + B_2 \cdot w^{\#} + \cdots = B(1) \cdot w^{\#} . \qquad (4\text{-}9)$$

From this, we can calculate the variance-covariance matrix of $DX^{\#}$ as

$$E(DX^{\#} \cdot DX^{\#}{}') = B(1) \cdot E(w^{\#} \cdot w^{\#}{}') \cdot B(1)' = B(1) \cdot B(1)' . \qquad (4\text{-}10)$$

By equation (4-7), we know that $u^{\#} = B_0 \cdot w^{\#}$. Substitute this into equation (4-3). Then we have

$$DX^{\#} = B_0 \cdot w^{\#} + C_1 \cdot B_0 \cdot w^{\#} + C_2 \cdot B_0 \cdot w^{\#} + \cdots = C(1) \cdot B_0 \cdot w^{\#} .$$

From this, we can obtain the variance-covariance matrix of $DX^{\#}$ as

$$\begin{aligned} E(DX^{\#} \cdot DX^{\#}{}') &= C(1) \cdot B_0 \cdot E(w^{\#} \cdot w^{\#}{}') \cdot B_0{}' \cdot C(1)' \\ &= C(1) \cdot B_0 \cdot B_0{}' \cdot C(1)' = C(1) \cdot W \cdot C(1)' . \qquad (4\text{-}11) \end{aligned}$$

In the last equality, we used equation (4-8). Since equations (4-10) and (4-11) have to coincide with each other, we have

$$B(1) \cdot B(1)' = C(1) \cdot W \cdot C(1)' . \qquad (4\text{-}12)$$

Now remember that the $B(1)$ summarizes the cumulative effects of shocks. We impose the theoretical restriction on this matrix. Specifically, the requirements are given in equation (4-9) as

$$DX^{\#} = \begin{bmatrix} D\hat{M}^{\#} \\ D\hat{Y}^{\#} \\ D\hat{P}^{\#} \end{bmatrix} = \begin{bmatrix} B_{11}(1) & 0 & 0 \\ B_{21}(1) & B_{22}(1) & 0 \\ B_{31}(1) & B_{32}(1) & B_{33}(1) \end{bmatrix} \begin{bmatrix} e^{\#} \\ n^{\#} \\ h^{\#} \end{bmatrix} . \qquad (4\text{-}13)$$

To obtain $B(1)$ as a triangle matrix, as shown in equation (4-13), we implement the Cholesky decomposition on equation (4-12). That is,

$$B(1) = CholeskyDecomposition\{C(1) \cdot W \cdot C(1)'\} . \qquad (4\text{-}14)$$

Decomposition Procedure

Substituting equation (4-7) into equation (4-3) and comparing the result with equation (4-6) gives us $C(L)\cdot B_0 = B(L)$. In particular, with $L=1$, we have $C(1)\cdot B_0 = B(1)$. Now we have $C(1)$ from equation (4-5) and $B(1)$ from equation (4-14). By substituting these into $B_0 = C(1)^{-1}\cdot B(1)$, we obtain B_0. Using this result, we finally find the structural shocks from equation (4-7) as $w_t = B_0^{-1}\cdot u_t$.

Once we identify the structural shocks, we can consider the pure effects of each structural shock on the three economic variables. To do so, we first construct the following series of pure structural shocks.

$$\overline{w_e} = (e,0,0)'\text{; } \overline{w_n} = (0,n,0)'\text{; and } \overline{w_h} = (0,0,h)'.$$

Convert these vectors by the matrix B_0 into the vectors of regression errors in the system (4-1). That is,

$$\overline{u_e} = B_0\cdot\overline{w_e}\text{; } \overline{u_n} = B_0\cdot\overline{w_n}\text{; and } \overline{u_h} = B_0\cdot\overline{w_h}.$$

If we give these errors to the estimated *VAR* system (4-1), we can find the contributions of each structural shock on the three economic variables.

Impulse Response Functions

If we give a one-time structural shock of $B_0\cdot(1,0,0)'$ on equation (4-1), we obtain the impulse response functions of the three economic variables to a comparative advantage shock.[10] Similarly, if we give a shock of $B_0\cdot(0,1,0)'$, we obtain the impulse response functions to a global productivity shock; if we give a shock of $B_0\cdot(0,0,1)'$, we obtain those to a cyclical demand shock.

[10] Remember that the variance-covariance matrix of w is an identity matrix. Thus, the $(1,0,0)'$ is a one-standard-error comparative advantage shock.

V. Empirical Results

In this section, we apply the statistical method developed in the previous section to Japanese data. Our sample includes the logarithms of the import penetration ratio (i.e., real import / real GDP),[11] real GDP, and the CPI (excluding fresh food and adjusted for consumption taxes) in Japan.[12] The frequency is one quarter. All the data are seasonally adjusted. The sample spans from the first quarter of 1980 to the first quarter of 2001. (Readers who are interested in the time-series properties of the data should refer to Appendix B.)

From an empirical point of view, we are interested in the following three points. First, we actually break down the three economic variables (i.e., the import penetration ratio, the real output growth, and the CPI inflation rate) into three kinds of structural shocks (i.e., comparative advantage shocks, global productivity shocks, and cyclical demand shocks). Second, we derive impulse response functions to examine more closely how each structural shock affects the three economic variables. Third, we implement forecast error variance decomposition to measure the importance of each structural shock in a statistically precise way.

A. Shock Identification

We described the procedure to implement the BQ decomposition in the previous section. This technique starts with the estimation of a *VAR* system of $D\hat{M}$, $D\hat{Y}$, and $D\hat{P}$ (normalized by subtracting the mean values).[13] Lag selection is one issue with which

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[11] Many nontraded goods exist in the real world, as opposed to our assumption that all goods are tradable. It may be better to exclude nontraded goods in the empirical analysis or to consider nontraded goods explicitly by incorporating transportation costs. Either way, however, we lose the simplicity of the DFS model in Section III. For this reason, we do not distinguish between tradables and nontradables in this paper.

[12] In Section III, we ignore exchange rates. This is a reasonable assumption in dealing with long-run equilibrium if the purchasing power parity holds in the long run. In the short run, however, the movements of exchange rates may have complex effects on the price levels. We should keep it in mind that the empirical results are subject to these exchange-rate effects.

[13] In Sections II and III, we talked about population growth as a labor-supply shock. Obviously, the Japanese population relative to the world population has decreased over time. We remove the effects of

practitioners are concerned. From the viewpoint of parsimony, we can rely on the Akaike information criterion, which suggests that the optimal length of lags is two quarters in the current case. This length seems so short that the model may be misspecified. However, a long lag length consumes the degree of freedom so quickly that we may fail to identify structural shocks correctly.

A practical approach for lag selection is to try several lag lengths and to choose the one that is the most appropriate under the various conditions assumed in the model. In particular, the Wold decomposition theorem says that the identified series of structural shocks should be neither cross-correlated nor auto-correlated. We estimated a *VAR* system with 6-quarter lags and identified the structural shock. We calculated the *Q* statistics for correlation up to eight lags to test the cross- and auto-correlation in the identified structural shocks. The results suggest no cross- and auto-correlation among the identified structural shocks. Therefore, we can safely use the six-quarter-lagged *VAR* system in the following analysis.[14,15]

B. Impulse Response Functions

Although our primary concern is with the historical decomposition of the CPI inflation into the three kinds of structural shocks, it is better to examine first the impulse response functions implied in the estimated *VAR* system. We present the cumulative impulse response functions in Chart 2. Chart 2(1) includes the impulse responses of the import penetration ratio to unit structural shocks of three kinds. To begin with, we see the effects of a comparative advantage shock (the thick line). As the theory predicts, when Japan loses comparative advantage, the import penetration ratio rises permanently. The effects of a global productivity shock (the thin line) and a cyclical demand shock

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differences in population growth rates on the economic variables by subtracting their average growth rates.

[14] It should be noted that lag selection affects quantitative results. To see the effects of lag selection, we estimated *VAR* systems with one to nine lags and conducted the same analysis. The results, which are not presented here, show that qualitative implications are almost untouched despite the difference in lag length up to eight quarters.

[15] Yamazawa (1998) implemented cross-section analysis (industry by industry) by regressing a change in the ratio of Japan's export to the US's on a change in the ratio of Japan's labor productivity to the US's. He suggested that the comparative advantage theory was likely to hold during 1970's and 1980's when taking capital productivity and technological progress into consideration.

(the broken line) die out due to the constraints imposed on their long run properties. A temporary rise in world demand raises the Japanese import penetration in the short run, but the effect vanishes away in three years. An interesting observation is that a global productivity shock raises the Japanese import penetration ratio for about nine years. This is too long persistence to be ignored when we are concerned with short-run projections. It is interesting from a theoretical point of view, since the naïve DFS model in Section III does not allow a global productivity shock to have effects on the import penetration ratio even in the short run. We return to this question in a later section.

Chart 2(2) includes the impulse responses of the real GDP to unit structural shocks of three kinds. As the theory tells us, when Japan loses comparative advantage, the real GDP is reduced permanently. To the contrary, a rise in global productivity raises Japanese real output permanently. The effects of a cyclical demand shock die away due to the constraint imposed on the long-run property.

Chart 2(3) includes the impulse responses of the CPI to unit structural shocks of three kinds. Remember that there are no constraints on the long-run properties of the three kinds of structural shocks concerning the CPI level. Every structural shock has permanent effects on the CPI level. When Japan loses comparative advantage, the CPI falls and remains low permanently. A temporary rise in the cyclical demand raises the CPI level and keeps it higher permanently. An interesting finding is that a global productivity shock lowers the CPI level slightly at most for two year. Thereafter, the CPI rises beyond its initial level and keeps the higher level permanently. This is an observation that we did not predict in the naïve version of the DFS model. We will return to this issue in a later section.[16]

We present the flow-based impulse responses in Chart 3. Here we focus on the CPI inflation rate for a later reference. Chart 3(3) includes the flow-based impulse responses of the CPI inflation rate to unit structural shocks of three kinds. As the theory implies, losing comparative advantage leads to a decline in the CPI inflation rate. The deflationary effects continue for seven years. A rise in the cyclical demand raises the CPI inflation rate. The inflationary effects last for seven years. When productivity rises

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[16] Similar empirical results were reported in Mio (2001), who broke down CPI inflation into demand shocks and supply shocks. He reported that by raising the long-run elasticity of demand shocks, the long-run elasticity of supply shocks took a negative value. The positive long-run elasticity of the CPI with respect to a supply shock is not necessarily illogical, however. The Bank of Japan (2001, Box 5) argued from the theoretical point of view that technological innovation created new demand and might raise the wage rate. Yet, there is no consensus among economists in how innovation drives wage inflation.

worldwide, deflation occurs for a half year, but afterwards, inflation continues for almost nine years.

C. Forecast Error Variance Decomposition

To see quantitatively how important the three kinds of structural shocks are, we implement forecast error variance decomposition. In the case of the trivariate BQ decomposition, forecast error variance decomposition shows us the proportions of movements in three economic variables due to three kinds of structural shocks. See the top figure in Chart 4 for explanation. The horizontal axis denotes forecast horizons, while the vertical one denotes the percentage contribution of each shock to the variation in the import penetration ratio. In the short run, cyclical demand shocks explain 80 percent of deviations in the import penetration ratio. Nonetheless, as a forecast horizon increases, comparative advantage shocks dominate the other shocks and explain 80 percent of deviations in the import penetration ratio eventually. This is quite natural, when remembering the constraint that we imposed on the three kinds of structural shocks.

The effects of global productivity shocks on real output are so overwhelming as to explain 90 percent of the output variations in the long run. Many studies have shown that supply or permanent shocks are more important than demand or temporary shocks. In our case, the effects of cyclical demand shocks are small even in the short run and diminish quickly due to the long-run restrictions imposed on the structural shocks. Although we adopt a break down method quite different from the existing literature, our results support the claim in the recent literature. A comparative advantage shock has little long-run effects on the output, although we impose no *a priori* restriction on the effects of the comparative advantage shock, as shown above. The middle figure in Chart 4 shows that the contributions of a comparative advantage shock to the real output start from 25 percent in the short run and diminish rapidly toward zero.

Finally, we will see that cyclical demand shocks explain 30 percent of the CPI variations in the long run. Half of the effects come from comparative advantage. If we sum up comparative advantage shocks and global productivity shocks and call the sum supply-side shocks, we can say that supply-side shocks explain 70 percent of the CPI inflation variations. This is an important result, since it suggests the importance of supply-side information as well as that of demand-side information, such as the output gap, in estimating the Japanese Phillips curve.[17]

D. Decomposition of CPI Inflation Rates

Now we are ready to break down the Japanese CPI inflation rate into the three kinds of structural shocks and to analyze what factors affected the historical behavior of the CPI from the latter half of 1980s to the end of the century. The result is presented in Chart 5(1). Here we focus on discussing the CPI inflation rates, although we can break down the changes in the import penetration ratio and the growth rates of real output.

The effects of various shocks were overlapped with each other and combined to produce the historical developments in the CPI inflation. Below, we pick up the major impacts and consider their coincidence with historical episodes.

The Yen Appreciation Recession

Usually, the Japanese recession from 1985 to 1986 was explained by the rapid appreciation of the yen after the Plaza Accord and the subsequent disinflation was a result from the recession. The break down, however, tells us that Japan's loss of international competitiveness was another cause of the rapid disinflation during this period.

The Asset Bubble Period

The period from 1987 to 1990 corresponds to the "asset bubble period" in Japan. The decomposition says that the rise in the CPI inflation was the consequence of the rapid productivity growth that occurred worldwide before and during this period.[18] (Remember that global productivity growth creates downward pressure on the CPI in the short run, but upward pressure in the long run.) It is interesting that the inflation during this period was triggered by productivity growth rather than by positive demand shocks.

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[17] Kamada and Masuda (2001) and Hirose and Kamada (2001) discuss the difficulties of estimating the Japanese Phillips curve and demonstrate techniques to overcome them.

[18] Interestingly, the "Asian miracle" started in 1987.

The Post Asset Bubble Period

The Japanese economy shrank rapidly with the burst of the bubble economy during the period from 1991 to 1993. Although Japan entered a disinflation phase gradually, the CPI inflation rate showed a very sticky behavior for a few years. As suggested by the impulse response function examined above, the inflationary pressure triggered by the preceding productivity growth had a long duration into this period.

The Short-lived Boom During 1994-1996

Japan experienced a short-lived boom for a few years after the burst of the bubble economy. Two forces worked in opposite directions to one another and formed a subtle balance to keep the inflation rate around zero percent. One force is the inflationary pressure caused by the short-lived boom. The other is the deflationary pressure caused by Japan's loss of international competitiveness. During this period, chain stores emerged along major roads, and many discount stores appeared in urban areas. These stores began to sell —quite aggressively— inexpensive electronics imported from the Asian economies.

The Period of Financial System Instability

From 1997 to 1999, we were forced to acknowledge the fragility of both the domestic and international financial systems. The sharp decline in the CPI inflation rate in 1997 was due to the decline in global productivity during the Asian Crisis that was triggered by the attack on the Thai baht. Subsequently, the failures of large financial institutions (Sanyo Securities, Hokkaido Takushoku Bank, and Yamaichi Securities) attacked the Japanese economy as negative demand shocks.

The End of the 20th Century

From the mid-1999 to 2000, the Japanese economy was recovering, although the pace was very slow. An influx of inexpensive imports from China, however, rushed into the Japanese apparel and food markets. Furthermore, import-competing producers operating domestically were forced to rearrange their distribution system to be more efficient. Or their margins were squeezed severely.

VI. INFLATION FORECASTS

In this section, we try two things, both of which are related to the forecasts of the CPI inflation rate. First, we examine the inflation forecasts of several research institutions and explore what structural shocks are implied in their forecasts of future CPI inflation rates. Second, we devise a way of forecasting inflation rates by making use of the BQ decomposition technique.

A. *Expected Shocks Implied in Inflation Forecasts*

There are many forecasts of the consumer prices published by research institutions. Forecasters may have their own sources of information. Even if they share the same information set, their judgements may be quite subjective and depend on what information they take most seriously. We can make use of the *SVAR* technique developed above to infer how forecasters make their predictions on future inflation rates.

Chart 5(2) shows the expected shock implied in seven institutions' economic outlook. The outlooks were released soon after the publication of the quarterly estimates of the National Accounts during the first quarter of 2001. (Note that the selection of the institution was arbitrary and that we had no intention to evaluate their forecast performance.) In the table, we show the total amount of structural shocks for each kind that the forecasters expect to occur during 2001 fiscal year.[19] That is, we present the following values.

$$e_{2001/II} + e_{2001/III} + e_{2001/IV} + e_{2002/I};$$

$$n_{2001/II} + n_{2001/III} + n_{2001/IV} + n_{2002/I}; \text{ and}$$

$$h_{2001/II} + h_{2001/III} + h_{2001/IV} + h_{2002/I}.$$

From the table, we see that these institutions have very pessimistic expectations on the future of the Japanese economy: (i) five out of seven institutions predict global productivity to decline; (ii) five institutions expect Japan to lose international competitiveness; and (iii) four institutions consider that demand shrinkage will occur.

[19] In breaking down the forecasts, we used the *VAR* system and the key matrices estimated in Section V.

The sample size of institutions is too small to derive statistically reliable results from this analysis. Nonetheless, the predictions tell us the following story on the whole: The growth of the world economy will slow. Moreover, the Japanese economy will lose international competitiveness. Furthermore, it cannot be denied that the economy will be exposed to additional negative demand shocks.

B. Making Inflation Forecasts

Here we introduce a way of making inflation forecasts. In theory, we can make inflation forecasts by giving our predictions about the three kinds of structural shocks in the future. We, however, have no quantitative intuition on the behavior of the three kinds of structural shocks, but have some quantitative intuition on the behavior of real GDP and the import penetration ratio. So the realistic approach is to make predictions on real GDP, on the import penetration ratio, and on one of the three kinds of shocks, and to find consistent predictions on the CPI. In this section, we assume that no more comparative-advantage shocks will occur in the future. Under this assumption, we calculate the inflation forecasts that are consistent with the reported expectations of a certain private institution on the import penetration ratio and the real GDP.

We can make use of the BQ decomposition in forecasting future CPI inflation rates with a small modification. For instance, suppose that we have forecasts of the growth rates of real output, $D\hat{Y}$, and the changes in the import penetration ratio, $D\hat{M}$. Further, we assume that no further comparative advantage shocks, e, will occur in the future. Then we can solve for the CPI inflation rates $D\hat{P}$ as well as for the global productivity shocks and the cyclical demand shocks that are consistent with these assumptions. Mathematically, we have

$$\begin{bmatrix}1\\0\\0\end{bmatrix} D\hat{M}_t + \begin{bmatrix}0\\1\\0\end{bmatrix} D\hat{Y}_t + \begin{bmatrix}0\\0\\1\end{bmatrix} D\hat{P}_t = A(L)DX_{t-1} + \begin{bmatrix}B_{0,11}\\B_{0,21}\\B_{0,31}\end{bmatrix} e_t + \begin{bmatrix}B_{0,12}\\B_{0,22}\\B_{0,32}\end{bmatrix} n_t + \begin{bmatrix}B_{0,13}\\B_{0,23}\\B_{0,33}\end{bmatrix} h_t .$$

Shift the undetermined variables to the left and the predetermined variables to the right. Rearranging the result, we obtain

$$\begin{bmatrix}D\hat{P}_t\\n_t\\h_t\end{bmatrix} = \begin{bmatrix}0 & -B_{0,12} & -B_{0,13}\\0 & -B_{0,22} & -B_{0,23}\\1 & -B_{0,32} & -B_{0,33}\end{bmatrix}^{-1} \left(A(L)\cdot DX_{t-1} + \begin{bmatrix}-1 & 0 & B_{0,11}\\0 & -1 & B_{0,21}\\0 & 0 & B_{0,31}\end{bmatrix} \begin{bmatrix}D\hat{M}_t\\D\hat{Y}_t\\e_t\end{bmatrix} \right).$$

Iterating this process gives us the forecasts on CPI inflation.

Chart 5(1) shows the CPI projection that is made from institution A's projections of real GDP, the import penetration ratio, and our assumption that no more comparative advantage shocks will occur. According to the projection, deflation will strengthen in Japan due to the shrinkage of demand, to the slowdown of global productivity growth, and to the loss of international competitiveness that occurred in the past.

VII. DISCUSSIONS

There are differences between the impulse response functions in Section V and predictions by the naïve theoretical model developed in Section III. Two reactions are remarkable when a global productivity shock hits the world: First, although the consumer price index falls for a while in response to a global productivity shock, it runs past the original level soon after. This may be against intuition, since the worldwide rises in productivity exert downward pressure on prices. Second, the import penetration ratio is above the original level temporarily. However, if a global shock raises productivity both in the home country and in the foreign country to the same extent, it must not change the import penetration ratio at all. In addition, a cyclical demand shock raises the import penetration ratio in the short run, which we did not predict from the naïve model developed in Section III. Below in this section, we focus on these remarkable phenomena and discuss possible explanations for them. The purpose of this section is to show that there exists economic theory to explain the impulse response functions obtained in Section V, but is not to claim that there are no other explanations for them.

A. Worldwide Productivity Growth and Wage Inflation

The impulse response function in Chart 2(3) tells us that a global productivity shock pushes up the CPI level eventually. To the contrary, the model in Section III predicted the opposite consequence: That is, the CPI declined due to a global productivity shock. This suggests that another important assumption is missing in the structural model for the determination of price levels. One remedy is to modify the Phillips curve that was introduced in Section III. The generalized Phillips curve is given by

$$D\hat{W}_t^* = f(\{e_{t-i}, n_{t-i}, h_{t-i}\}_{i=1}^{\infty}) .$$

Then we obtain the following CPI equation.

$$D\hat{P}_t = -\tfrac{1}{3}e_t - n_t + f(\{e_{t-i}, n_{t-i}, h_{t-i}\}_{i=1}^{\infty}) .$$

The CPI level rises eventually, if the effects of a global productivity shock accumulate over time and push up the foreign wage rate enough to set off the deflationary effect that occurred spontaneously with the productivity growth. That is, if

$$S_{i=1}^{\infty} \partial f / \partial n_{t-i} > 1 , \tag{7-1}$$

then the CPI level may decline first, but then rises over the initial level eventually, when a global productivity shock occurs.[20]

Below, for the purpose of simulation, we assume as follows:

$$D\hat{W}_t^* = 0.5 D\hat{W}_{t-1}^* + 0.5\hat{L}_{t-1}^* + 1.0 n_{t-1} . \tag{7-2}$$

This function is rewritten in the form of $f(\cdot)$ function:

$$D\hat{W}_t^* = 0.5 S_{i=1}^{\infty} 0.5^{i-1} h_{t-i} + 1.0 S_{i=1}^{\infty} 0.5^{i-1} n_{t-i} .$$

Therefore, we have $S_{i=1}^{\infty} \partial f / \partial n_{t-i} = 2 > 1$, satisfying condition (7-1). This new Phillips curve says that a 1 percent increase in global productivity raises the foreign wage by 2 percent. To put it differently, technological growth is reflected in wage increases rather than in price declines. Furthermore, the impact on wage is magnified and persistent due to the auto-regressive property of the above Phillips curve.

To see the effects of this assumption on the CPI explicitly, we simulate the impulse response functions to the three kinds of structural shocks. Chart 6(3) gives the results. After a global productivity shock occurs, the CPI declines immediately, but rises thereafter beyond its initial level. Although the simulation results show much simpler behavior than the estimated impulse-response functions, the directions of deviations are

[20] Note that the summation runs from $t-1$ to infinity, but does not run from t. If $\partial f / \partial v_t > 1$, the CPI does not decline, as opposed to the estimated impulse response. We eliminate this possibility by assuming that a shock that occurs in the current period has no effects on the current foreign wage rate.

consistent with the impulse response functions of the estimated *SVAR* model.

B. Differential Speed of Learning-by-Doing

In Section V, we showed that a global productivity shock kept the Japanese import penetration ratio high for a long time. This is an interesting result since, according to the naïve version of the DFS model in Section III, a global productivity shock would have no effects on the import penetration ratio even in the short run. We show below that a difference in the speed of adapting to new technology between Japan and foreign countries is a clue to solving this puzzle.

We assume that Y and Y^* evolve as follows:

$$DY_t = a \cdot DY_{t-1} + (1-a)(e_t / 2 - n_t) \text{ ; and}$$
$$DY_t^* = a^* \cdot DY_{t-1}^* + (1-a^*)(-e_t / 2 - n_t) \text{ .} \qquad (7\text{-}3)$$

Here we assume that the technological progress occurs sequentially. In particular, it follows an *AR*(1) process. Note that we discount structural shocks by $(1-a)$ and $(1-a^*)$. By doing so, a single percentage-point global productivity shock enhances productivity by one percent in both the countries eventually, and a single percentage-point competitiveness shock changes the comparative advantage between the home country and the foreign country by one percent in the long run. It is convenient to rewrite the above processes in *MA* representations as follows:

$$DY_t = S_{i=0}^{\infty}(1-a)a^i(e_{t-i} / 2 - n_{t-i}) \text{ ; and}$$
$$DY_t^* = S_{i=0}^{\infty}(1-a^*)a^{*i}(-e_{t-i} / 2 - n_{t-i}) \text{ .} \qquad (7\text{-}4)$$

One can interpret these equations as learning-by-doing processes. A small a implies that the home country's learning speed is very fast after a new technology is invented, but decelerates rapidly in a short time. To the contrary, a large a implies that learning proceeds slowly, but continues relatively steadily over time. The estimated impulse response function shows that an increase in global productivity raises Japan's import penetration ratio in the short run, though it disappears eventually by the imposed restriction. This happens because of a difference in the pattern of learning-by-doing between Japan and the rest of the world. Assume that the foreign countries learn a new technology very fast, while Japan does it very slowly and takes a long time to catch up.

This means that $a^* < a$. Under this assumption, the foreign country's productivity outruns Japan's productivity and Japan's import penetration rises due to the inferiority of technology in the short run. In the long run, however, Japan learns the new technology fully and the productivity gap disappears.

To see the effects of differential learning speeds, we simulate the impulse response functions to the three kinds of structural shocks. Chart 6(1) presents the results, where we let $a = 0.6$ and $a^* = 0.4$. When a global productivity shock occurs, Japan's import penetration ratio rises. Thereafter, the import penetration ratio returns to the original level over time.

C. Differential Fluctuations of Business Cycles

In Section V, we found that a worldwide labor shock raised the Japanese import penetration ratio high in the short term. According to the naïve model developed in Section III, however, the same amount of labor shock has no effect on the import penetration ratio. We show that differences in the extent and persistence of business cycles create this phenomenon.

We assume that a labor shock has sticky effects, although the effects are cyclical and die out eventually. We also assume a difference in the fluctuations of business cycles as follows. The Japanese business cycle is small but persistent, while those of foreign countries are large but short-lived. More concretely, the $\hat{L}$ and $\hat{L}^*$ evolve as follows:

$$\hat{L}_t = f \cdot \hat{L}_{t-1} + (1-f)h_t \text{; and}$$

$$\hat{L}_t^* = f^* \cdot \hat{L}_{t-1}^* + (1-f^*)h_t . \qquad (7\text{-}5)$$

where $f^* < f$. Equivalently, we have

$$D\hat{L}_t = S_{i=0}^{\infty}(1-f)f^i Dh_{t-i} \text{; and}$$

$$D\hat{L}_t^* = S_{i=0}^{\infty}(1-f^*)f^{*i} Dh_{t-i} . \qquad (7\text{-}6)$$

To see the effects of a difference in the patterns of business cycles, we make a simulation with $f = 0.6$ and $f^* = 0.4$. As predicted, the import penetration ratio rises with the worldwide demand shock and shrinks toward zero.

The above arguments can be expressed mathematically. A somewhat messy calculation gives us

$$D\hat{M}_t = \tfrac{1}{12} S_{i=0}^{\infty}\{(1-a^*)a^{*i} + (1-a)a^i\}e_{t-i} + \tfrac{1}{6} S_{i=0}^{\infty}\{(1-a^*)a^{*i} - (1-a)a^i\}n_{t-i}$$

$$+ \tfrac{1}{6} S_{i=0}^{\infty}\{(1-f^*)f^{*i} - (1-f)f^i\}Dh_{t-i};$$

$$D\hat{Y}_t = \tfrac{1}{12} S_{i=0}^{\infty}\{(1-a^*)a^{*i} - 5(1-a)a^i\}e_{t-i} + \tfrac{1}{6} S_{i=0}^{\infty}\{(1-a^*)a^{*i} + 5(1-a)a^i\}n_{t-i}$$

$$+ \tfrac{1}{6} S_{i=0}^{\infty}\{(1-f^*)f^{*i} + 5(1-f^*)f^{*i}\}Dh_{t-i}; \text{ and}$$

$$D\hat{P}_t = -\tfrac{1}{12} S_{i=0}^{\infty}\{5(1-a^*)a^{*i} - (1-a)a^i\}e_{t-i} - \tfrac{1}{6} S_{i=0}^{\infty}\{5(1-a^*)a^{*i} + (1-a)a^i\}n_{t-i}$$

$$+ \tfrac{1}{6} S_{i=0}^{\infty}\{(1-f^*)f^{*i} - (1-f)f^i\}Dh_{t-i} + DW_t^*. \qquad (7\text{-}7)$$

Even if $a \neq a^*$ and $f \neq f^*$, the effects of the second and third summations in the right-hand side of the $D\hat{M}$ equation disappear over time. Therefore, a global productivity shock and a worldwide labor shock have no long-run effect on the import penetration ratio.

With the modified Phillips curve (7-2), a shock on the labor market has permanent effects on the CPI level. In this sticky model, the effects are gradually accumulated over time, but the final levels of variables are the same as the non-sticky model developed in Section III.

In this section and in Section III, we assume that all the shocks are observable before any decision-making takes place. Most shocks, however, are unobservable and people have to make decisions before the shocks occur. In Appendix C, we assume that people cannot observe shocks in the current period. They make rational expectations of the relevant economic variables and determine the wage rate in the current model before they observe the shocks. We assume there that the labor shock originates only from the foreign labor market. Owing to the staggered wage setting, however, the shock is transmitted to the home labor market and develops to worldwide shocks. We discuss the solution procedure and examine the dynamic behavior of the relevant variables in the appendix, since the model shows interesting properties that are not observed in the model developed here.

VIII. CONCLUSION

We showed the importance of changes in international competitiveness in determining the developments of consumer prices in Japan. Our theoretical background was the classical comparative-advantage model by Dornbusch, Fischer, and Samuelson (1977). The theory tells us as follows:

(A-1) When a country's productivity enhances in comparison to the rest of the world, its import penetration ratio declines;

(A-2) when productivity enhances globally, output grows in every country, but the import penetration ratio is untouched, since the relative productivity is unchanged; and

(A-3) temporary shocks that cause business cycles have no effects on the import penetration ratio and the real output growth.

Our econometric method was based on an extension of Blanchard and Quah's (1989) *SVAR* technique. Taking the above long-run properties as restrictions and based on the Japanese data during the period of 1980 to 2001, we broke down Japan's CPI inflation rate into three kinds of structural shocks: comparative advantage shocks, global productivity shocks, and cyclical demand shocks. To begin with, we examined impulse response functions to see the effects of each shock on the economy. The main findings related to the CPI were as follows:

(B-1) When Japan loses comparative advantage, the CPI declines;

(B-2) when worldwide boom occurs, the CPI rises; and

(B-3) when productivity enhances globally, Japan's CPI declines temporarily, but rises up a half year after and outruns the original level in two years.

Next, we implemented the forecast variance decomposition to see the importance of each structural shock. The followings are the main results:

(C-1) Cyclical demand shocks explain 30 percent of variations in CPI;

(C-2) comparative advantage shocks explain 50 percent of variations in CPI; and

(C-3) supply-side shocks (or the sum of comparative advantage shocks and global productivity shocks) explain 70 percent of variations in CPI.

The last finding is important, since it claims that we should take into consideration supply-side information as well as demand-side information, such as output gap, in estimating the Phillips curve.

Furthermore, we examined chronologically what structural shocks happened in Japan:

(D-1) The disinflation during the period of the “yen appreciation recession” was caused partially by Japan’s loss of comparative advantage;

(D-2) the increases in CPI during the asset-bubble period was triggered by global productivity growth rather than by the boom; and

(D-3) the reorganization of the distribution system began under the pressure of inexpensive imports from China at the very end of the 20th century.

As for the outlook of the Japanese CPI in 2001 fiscal year, we analyzed the CPI projections published by several economic institutions after the publication of the quarterly estimates of the National Accounts during the first quarter of 2001. Breaking down the CPI forecasts, the forecasters reached a consensus that productivity growth would slow down globally; Japan’s international competitiveness would decline; and the world demand would weaken further.

APPENDIX A

DERIVATION OF THE CONSUMER PRICE INDEX

In this appendix, we derive the consumer price index or equation (2-7) by solving a consumer's utility maximization problem. Define a consumer's utility function by

$$U = \int_0^1 \ln c(z) dz \, .$$

To find a consumer price index, we first fix a utility level arbitrarily, say $\overline{U}$. The minimum expenditure to achieve this utility is obtained by solving the following problem.

$$\min_{\{c(z)\}_{z=0}^1} \quad \int_0^1 p(z)c(z)dz$$
$$\text{s.t.} \qquad \overline{U} = \int_0^1 \ln c(z) dz \, .$$

The Lagrangian L is given by

$$L = \int_0^1 p(z)c(z)dz + l\,(\overline{U} - \int_0^1 \ln c(z)dz) \, .$$

The first order condition for optimization is

$$p(z)c(z) = l \, .$$

Substituting back this result into the above constraint gives

$$\int_0^1 \ln p(z)dz + \overline{U} = \ln l \, .$$

Therefore, the minimum expenditures to achieve the utility level $\overline{U}$ is given as

$$S = \int_0^1 p(z)c(z)dz = \int_0^1 l\, dz = l = e^{\overline{U}} \exp\{\int_0^1 \ln p(z)dz\} \, .$$

Denote the price levels in the benchmark quarter by $p_0(z)$ for $z \in [0,1]$. Then the S in the benchmark quarter is given by

$$S_0 = e^{\overline{U}} \exp\{\int_0^1 \ln p_0(z)dz\} .$$

Since the CPI is defined as a current period's expenditure relative to the benchmark period's expenditure that is required to keep the same utility level:

$$P = \exp\{\int_0^1 \ln p(z)dz\} / \exp\{\int_0^1 \ln p_0(z)dz\} = \exp\{\int_0^1 \ln(p(z)/ p_0(z))dz\} .$$

Note that the CPI is given by the geometric mean of current prices relative to the benchmark period's prices.

When $z \le Z$, $p(z) = a(z)W$; otherwise, $p(z) = a^*(z)W^*$. The unit factor requirements are given by equation (2-4). Thus the total expenditure is given by

$$\begin{aligned} S &= e^{\overline{U}} \exp\{\int_0^Z \ln(a(z)W)dz + \int_Z^1 \ln(a^*(z)W^*)dz\} \\ &= e^{\overline{U}} \exp\{\int_0^Z (Y + z + \ln W)dz + \int_Z^1 (Y^* + 1 - z + \ln W^*)dz\} \\ &= e^{\overline{U}} \exp\{ZY + (1-Z)Y^* + Z\ln W + (1-Z)\ln W^* + Z^2 - Z + 1/2\} . \end{aligned}$$

We assume that the economy starts from a symmetric equilibrium, given by equation (2-6). Thus the total expenditure in the benchmark quarter is given by

$$S_0 = e^{\overline{U}} \exp(1/4) .$$

Therefore, the price index, which is defined as the minimum expenditure in the current period relative to that in the benchmark period (i.e., $P \equiv S / S_0$), is given by equation (2-7). Yet the individual price levels are undetermined before the nominal wage level in the home or foreign country.

Appendix B

Time Series Properties of the Data

Section III tells us theoretically how the key economic variables are broken down into the three kinds of structural shocks. In particular, equation (3-6) implies that $\hat{M}$, $\hat{Y}$, and $\hat{P}$ are $I(1)$ processes and not co-integrated with one another.[21] In this appendix, we examine whether our data have these time-series properties. According to the test results, the assumption is not unreasonable that our data have the desirable properties.

Chart 7(1) is the summary of the augmented Dickey-Fuller test and the Phillips-Perron test for unit roots, where the length of lags is so chosen as to minimize the Akaike information criterion. According to the augmented Dickey-Fuller test, it is ambiguous whether the real GDP and the CPI follows an $I(1)$ process, though the import penetration ratio is found to follow an $I(1)$ process. According to the Phillips-Perron test, however, we can safely say that each of the three variables follows an $I(1)$ process.

Chart 7(2) is the summary of the Engle-Granger test for co-integration, where the Akaike information criterion is used again for the selection of lags. The test results tell us that the null hypothesis of no co-integration among the three economic variables cannot be rejected even at the 10 percent significance level in the loosest model with an intercept and a time-trend.

[21] In the literature, researchers appear to have reached a consensus that the output level follows an $I(1)$ process, although the consensus has only weak foundations from a statistical point of view. In contrast, the treatments of prices depend on their standpoints. For instance, Quah and Vahey (1995) treat the price level (retail price index, monthly) as an $I(2)$ process, while Mio (2001) takes the price level (private demand deflator, quarterly) as an $I(1)$ process.

APPENDIX C

PREDETERMINED WAGE MODEL

In Section III, people can observe all shocks before making their decisions. The assumption may be too strong, however. Alternatively, we consider the predetermined-wage model where structural shocks are not observable *ex ante* and people in the home country have to determine the wage rate before observing the shocks. We also assume that the foreign wage depends only on the information in the past and thus people can predict it with no error.[22] Given the sure foreign wage rate, people determine the home wage rate under the uncertainty about structural shocks.

An additional assumption here is that cyclical demand shocks occur only in the foreign country. The assumption is opposed to the original assumption that the cyclical demand shocks occur everywhere in the world. We show that the staggered wage setting implied in the predetermined-wage model develops the foreign demand shock into the worldwide demand shock and thus creates a similar situation to what we treated in Section III.

Step 1: Before Shocks

People cannot foresee any structural shocks in the current period. They are assumed to form rational expectations under this uncertainty according to the two equations in system (7-3) and the second equation in system (7-5):

$$E_{t-1}DY_t = a \cdot DY_{t-1};$$

$$E_{t-1}DY_t^* = a^* \cdot DY_{t-1}^*; \text{ and}$$

$$E_{t-1}\hat{L}_t^* = f^* \cdot \hat{L}_{t-1}^*,$$

where the notation E_{t-1} is an expectation operator based on the past information.

The first equation in system (7-5) is irrelevant, since the labor amount in the home

[22] It may take a long time for trading patterns to change, and thus the DFS model should be taken as a long-run equilibrium model. In contrast, fluctuation in the labor market is a short-run phenomenon. Therefore, it should be noted that we make the very strong assumption that the trading and industrial structures in the world are as flexible as the world labor markets.

country is determined endogenously as follows.

$$\hat{W}_t = \hat{W} \mid \{E_{t-1}\hat{L}_t = 0\}.$$

Given the rational expectations about the movements of structural parameters and the foreign wage rate, people decide the home wage rate so that the home labor market is in equilibrium *ex ante*. Under these assumptions, the home wage rate has to satisfy the following conditions about the first and second equations in system (3-1).

$$\hat{W}_t - \hat{W}_t^* = 4E_{t-1}\hat{Z}_t + f^* \cdot \hat{L}_{t-1}^* \text{; and}$$
$$\hat{W}_t - \hat{W}_t^* = Y_{t-1}^* + a^* \cdot DY_{t-1}^* - Y_{t-1} - a \cdot DY_{t-1} - 2E_{t-1}\hat{Z}_t.$$

Combining these equations, we obtain

$$E_{t-1}\hat{Z}_t = \tfrac{1}{6}(Y_{t-1}^* + a^* \cdot DY_{t-1}^* - Y_{t-1} - a \cdot DY_{t-1} - f^* \cdot \hat{L}_{t-1}^*) \text{; and}$$
$$\hat{W}_t - \hat{W}_t^* = \tfrac{2}{3}(Y_{t-1}^* + a^* \cdot DY_{t-1}^* - Y_{t-1} - a \cdot DY_{t-1}) + \tfrac{1}{3} f^* \cdot \hat{L}_{t-1}^*. \tag{C-1}$$

Step 2: After Shocks

Next we consider short-run equilibrium after shocks hit the economy. Eliminating $\hat{Z}$ from the first and second equations in system (3-1), we have

$$3(\hat{W}_t - \hat{W}_t^*) = 2\{Y_{t-1}^* + a^* \cdot DY_{t-1}^* + (1-a^*)(-e_t/2 - n_t) - Y_{t-1} - a \cdot DY_{t-1} - (1-a)(e_t/2 - n_t)\} + f^* \cdot \hat{L}_{t-1}^* + (1-f^*)h_t - \hat{L}_t.$$

Substituting equation (C-1) in this equation, we obtain

$$\hat{L}_t = -2(a - a^*)n_t - (2 - a - a^*)e_t + (1 - f^*)h_t. \tag{C-2}$$

In this section, we treat h as a shock on foreign labor. Equation (C-2) shows, however, that if $f^* \neq 1$, the h can be interpreted as a shock on domestic labor as well. On the whole, it can be considered to be a worldwide demand shock.

Remember that this relationship is obtained from the two equations in system (3-1). Thus, if we give this value of $\hat{L}$ to the same system as an exogenous variable, we can reproduce the predetermined $\hat{W}$ as an endogenous solution to the system. Exploiting this property, we can obtain the solution for $D\hat{M}$, $D\hat{Y}$, and $D\hat{P}$ in the case of the predetermined-wage model by substituting the following $D\hat{L}$ as an exogenous variable into system (3-2). That is, substitute

$$D\hat{L}_t = -2(a - a^*)Dn_t - (2 - a - a^*)De_t + (1 - f^*)Dh_t$$

as well as systems (7-4) and the second equation of system (7-6) into system (3-2).

Then we obtain

$$\begin{aligned} D\hat{M}_t &= \tfrac{1}{12} S_{i=0}^{\infty}\{(1-a^*)a^{*i} + (1-a)a^i\}e_{t-i} + \tfrac{1}{6} S_{i=0}^{\infty}\{(1-a^*)a^{*i} - (1-a)a^i\}n_{t-i} \\ &\quad + \tfrac{1}{6}(2 - a - a^*)De_t + \tfrac{1}{3}(a - a^*)Dn_t + \tfrac{1}{6} S_{i=1}^{\infty}(1-f^*)f^{*i}Dh_{t-i}\,; \\ D\hat{Y}_t &= \tfrac{1}{12} S_{i=0}^{\infty}\{(1-a^*)a^{*i} - 5(1-a)a^i\}e_{t-i} + \tfrac{1}{6} S_{i=0}^{\infty}\{(1-a^*)a^{*i} + 5(1-a)a^i\}n_{t-i} \\ &\quad - \tfrac{5}{6}(2 - a - a^*)De_t - \tfrac{5}{3}(a - a^*)Dn_t + (1-f^*)Dh_t + \tfrac{1}{6} S_{i=1}^{\infty}(1-f^*)f^{*i}Dh_{t-i}\,; \\ D\hat{P}_t &= -\tfrac{1}{12} S_{i=0}^{\infty}\{5(1-a^*)a^{*i} - (1-a)a^i\}e_{t-i} - \tfrac{1}{6} S_{i=0}^{\infty}\{5(1-a^*)a^{*i} + (1-a)a^i\}n_{t-i} \\ &\quad + \tfrac{1}{6}(2 - a - a^*)De_t + \tfrac{1}{3}(a - a^*)Dn_t + \tfrac{1}{6} S_{i=1}^{\infty}(1-f^*)f^{*i}Dh_{t-i} + DW_t^*\,. \end{aligned} \qquad \text{(C-3)}$$

We also conducted the numerical simulation and present the results in Chart 8.

Some remarks are in order here. First, the system (C-3) shows that comparative advantage shocks and global productivity shocks have temporary effects on the import penetration ratio, the real output, and the CPI level. These additional temporary effects are seen in Chart 8 where, during the zero period, the import penetration ratio is higher, the real output is lower, and the CPI inflation rate is higher than they were in Chart 6.

Second, as shown in system (C-3) and in Chart 8, the temporary effects of cyclical demand shocks on the current CPI level disappear in the predetermined wage model, though they were very small in the current parameterization. The logic goes as follows: When cyclical shocks occur, the home wage rate is adjusted in the perfect foresight model so as to achieve the full employment in the domestic labor market. This movement of the wage rate is reflected in the price level. To the contrary, the labor demand in the home country is adjusted in the predetermined-wage model so as to keep the home wage rate at the predetermined level. The import penetration ratio is also unchanged, since the relative wage rate is at the predetermined level. As a result, the current price levels are untouched.

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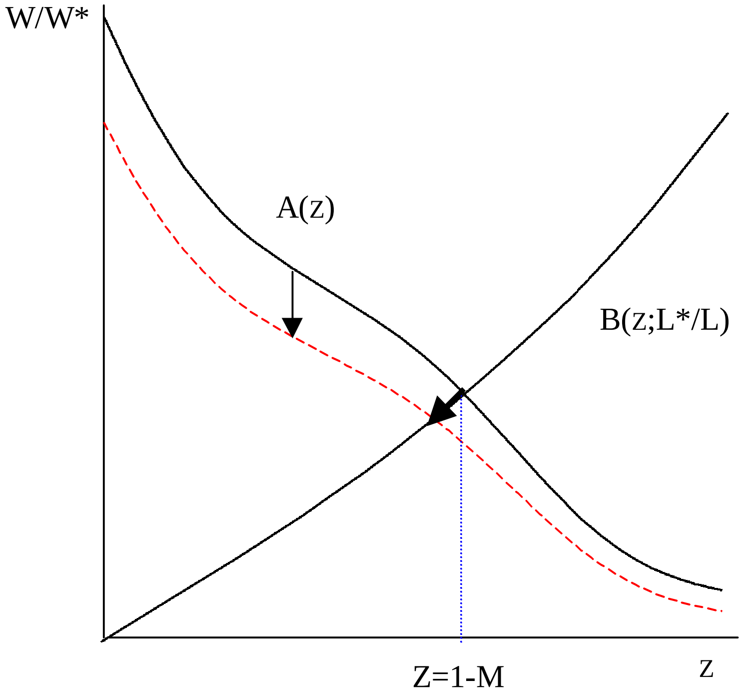
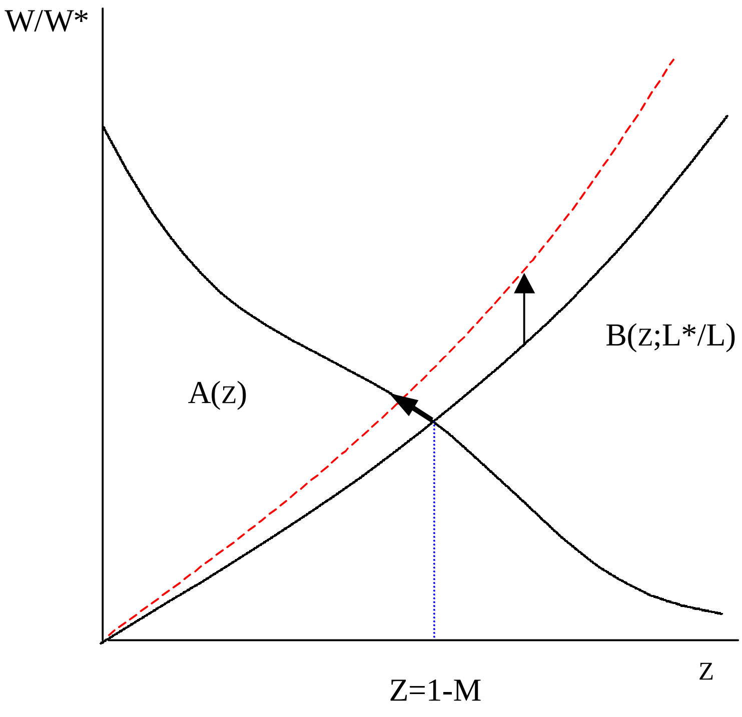
(Chart 1)

Dornbusch-Fischer-Samuelson Model

(1) Effects of Productivity Shocks



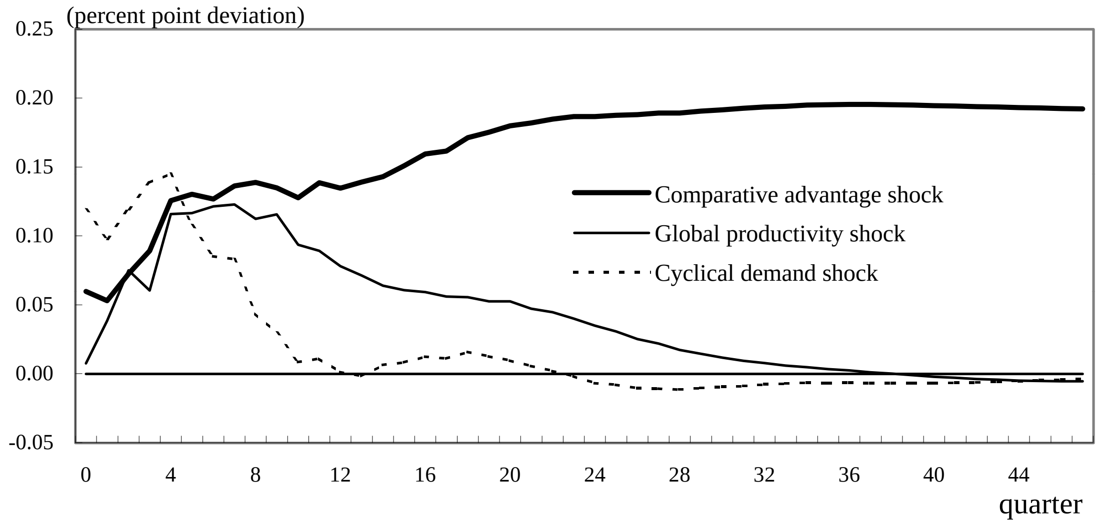
(2) Effects of Labor Shocks



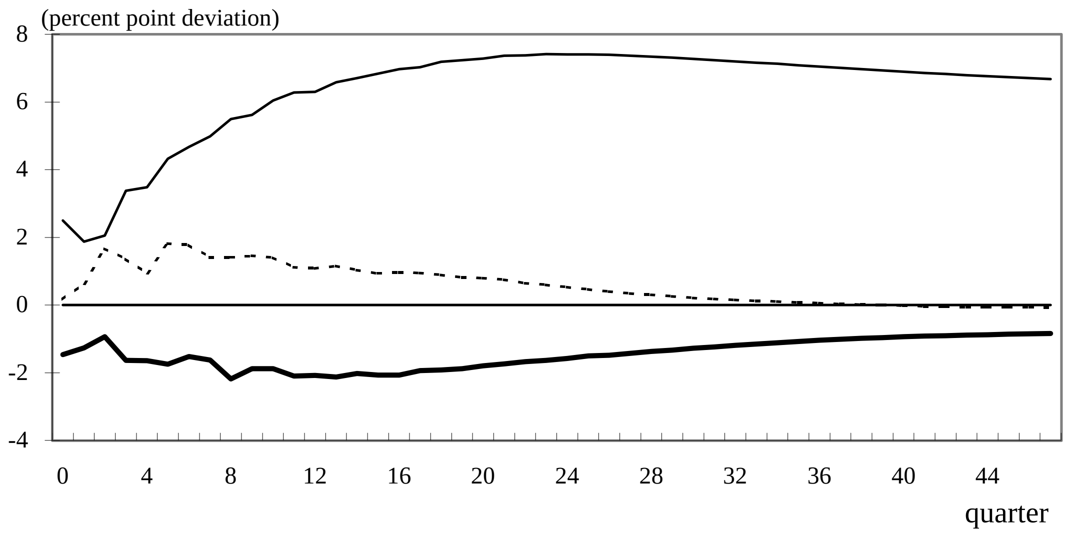
(Chart 2)

Cumulative Effects of Structural Shocks

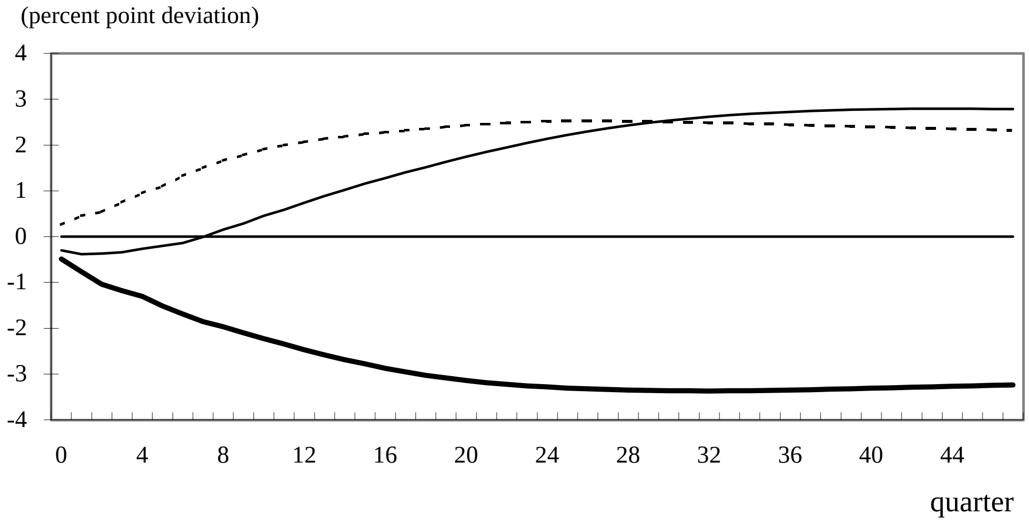
(1) Import Penetration Ratio



(2) Real GDP



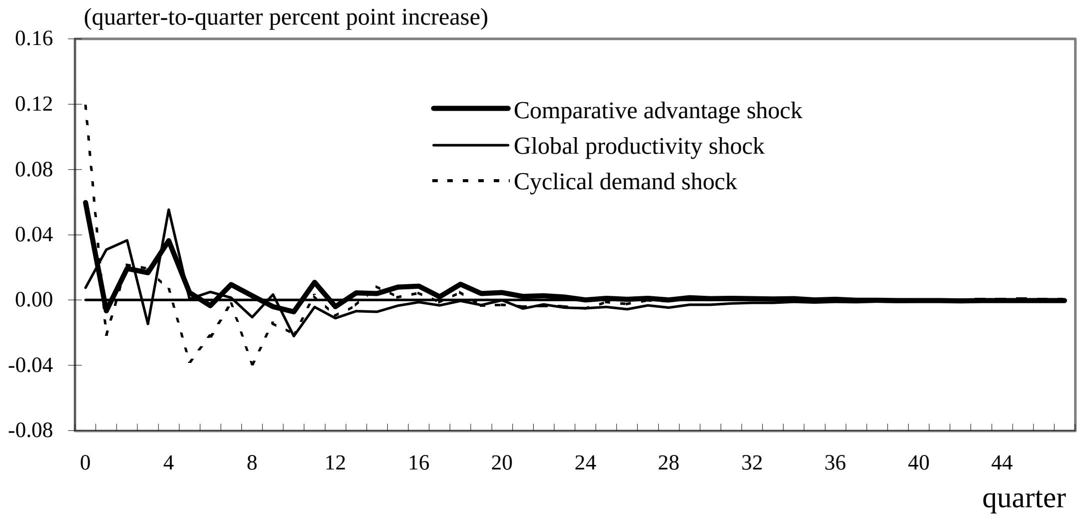
(3) Consumer Prices



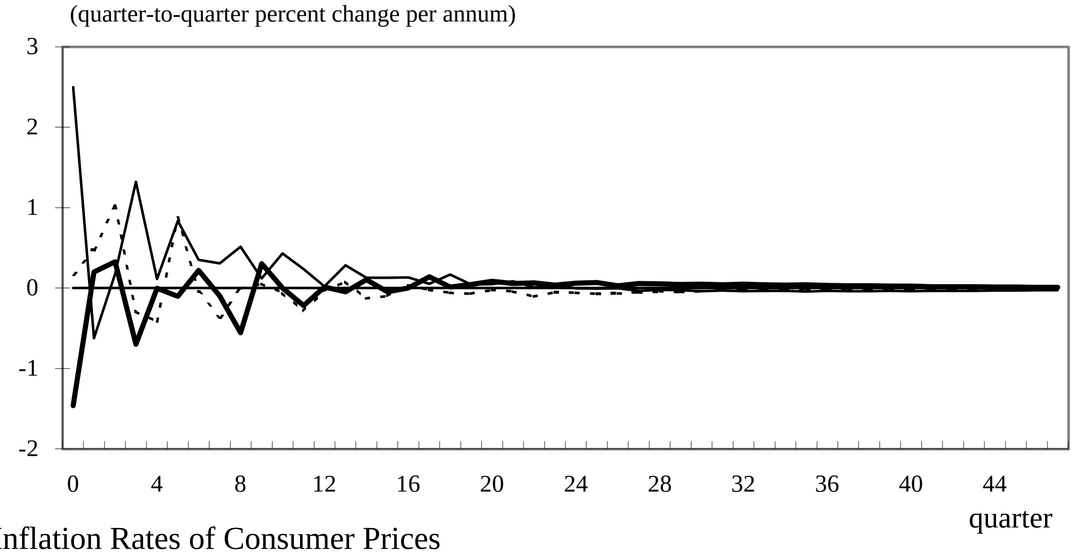
(Chart 3)

Flow-Based Effects of Structural Shocks

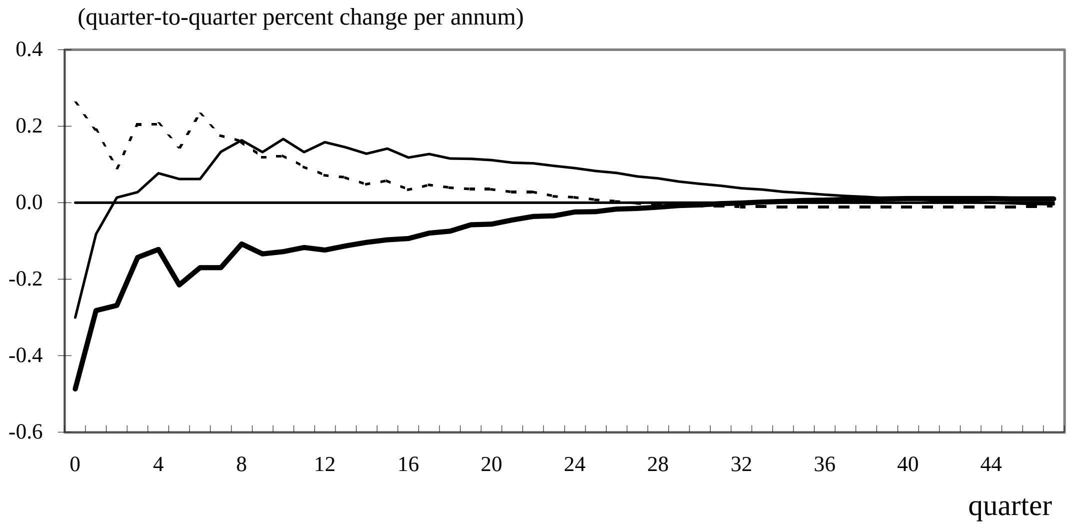
(1) Changes in Import Penetration Ratio



(2) Growth Rates of Real GDP



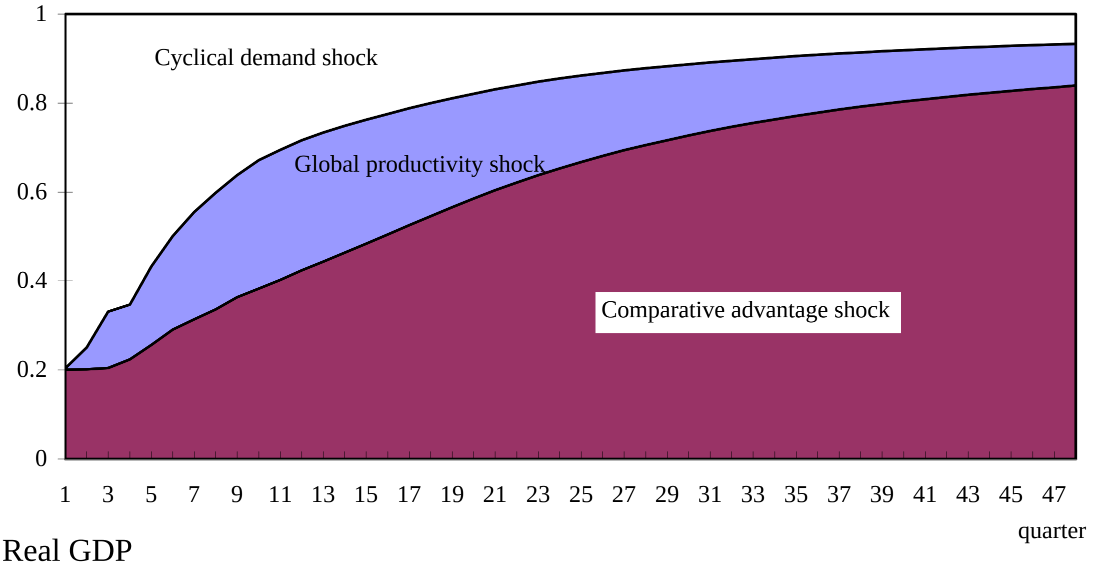
(3) Inflation Rates of Consumer Prices



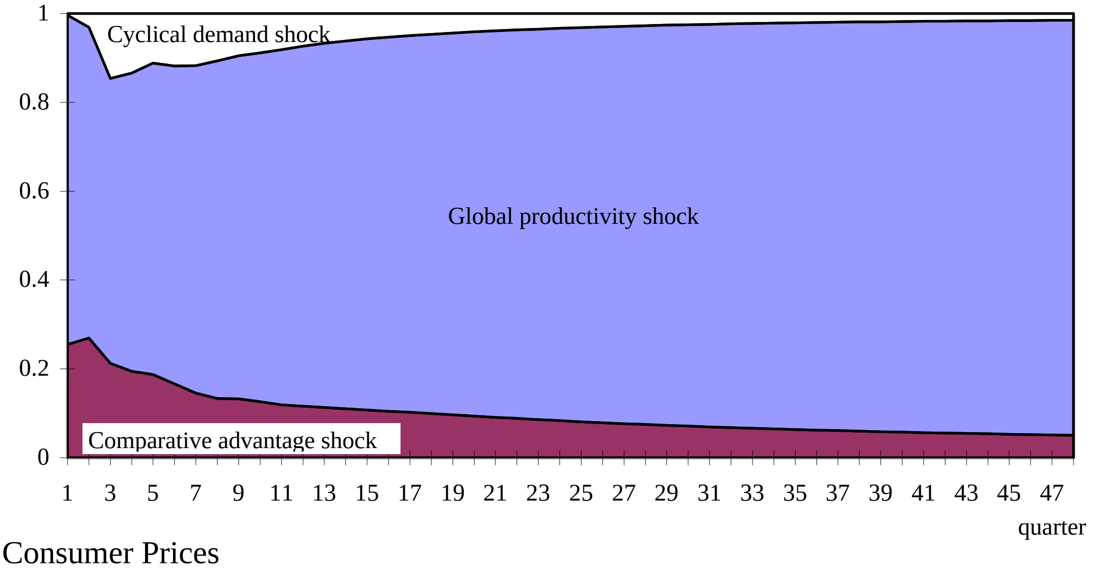
(Chart 4)

Forecast Error Variance Decomposition

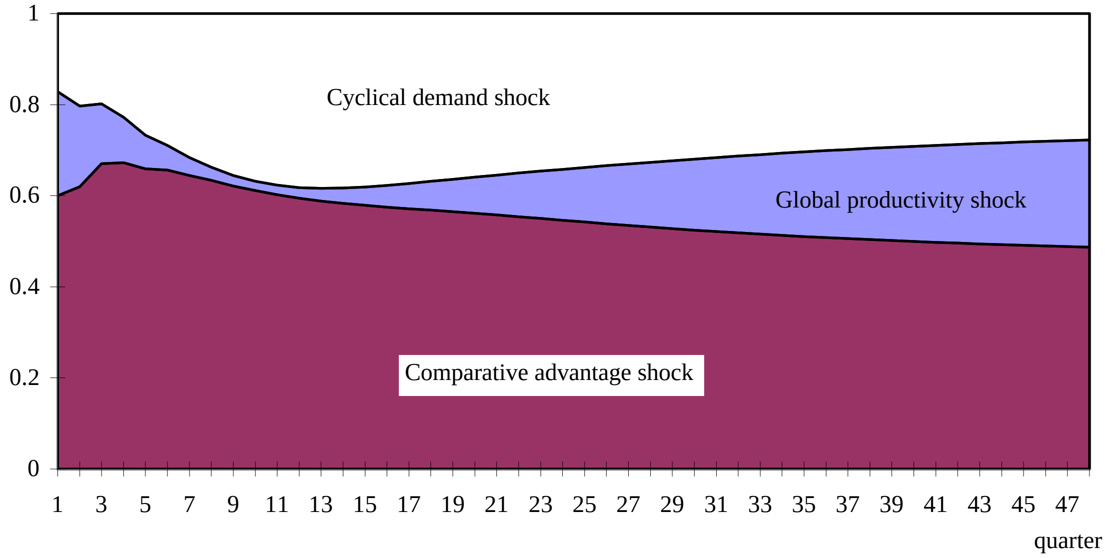
(1) Import Penetration Ratio



(2) Real GDP



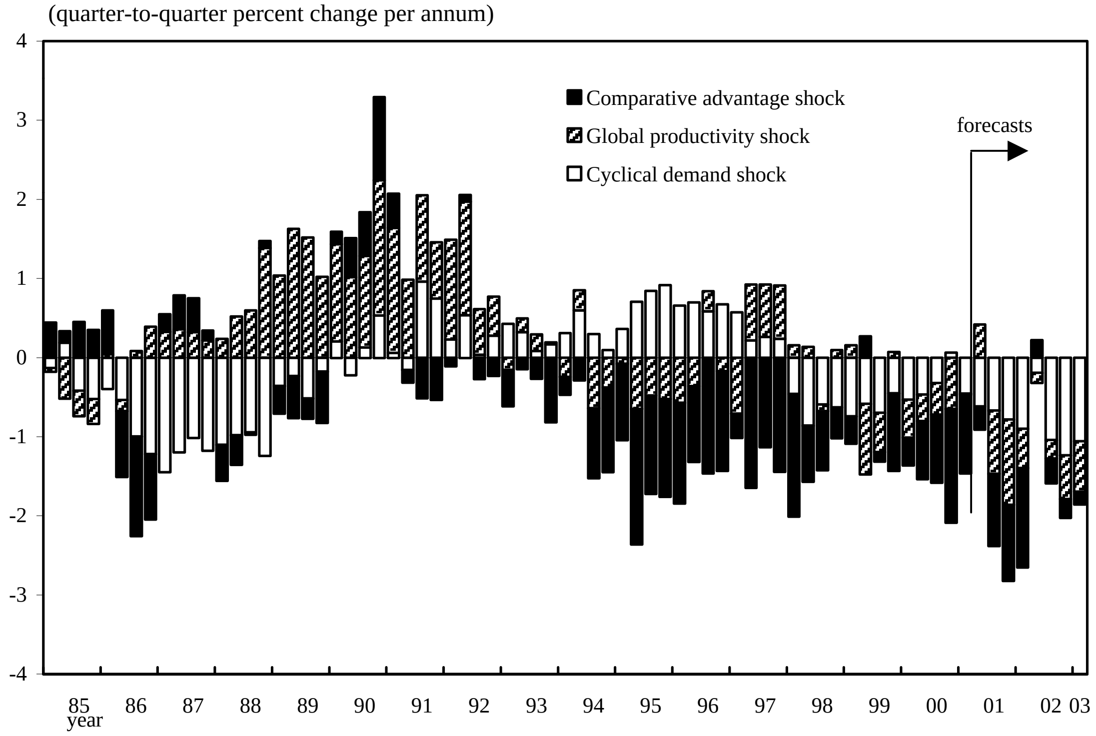
(3) Consumer Prices



(Chart 5)

Decomposing and Forecasting CPI Inflation

(1) Decomposing Inflation Forecasts



Notes :1. The sum of bars in each quarter is lower than the actural inflation rate by the sample mean (1.09 percent per annum)

2. Research institution A's expectations on the import penetration ratio and the real GDP growth rate are used. No more comparative advantage shocks are assumed. (See the table below)

(2) Expected Shocks Implied in Inflation Forecasts

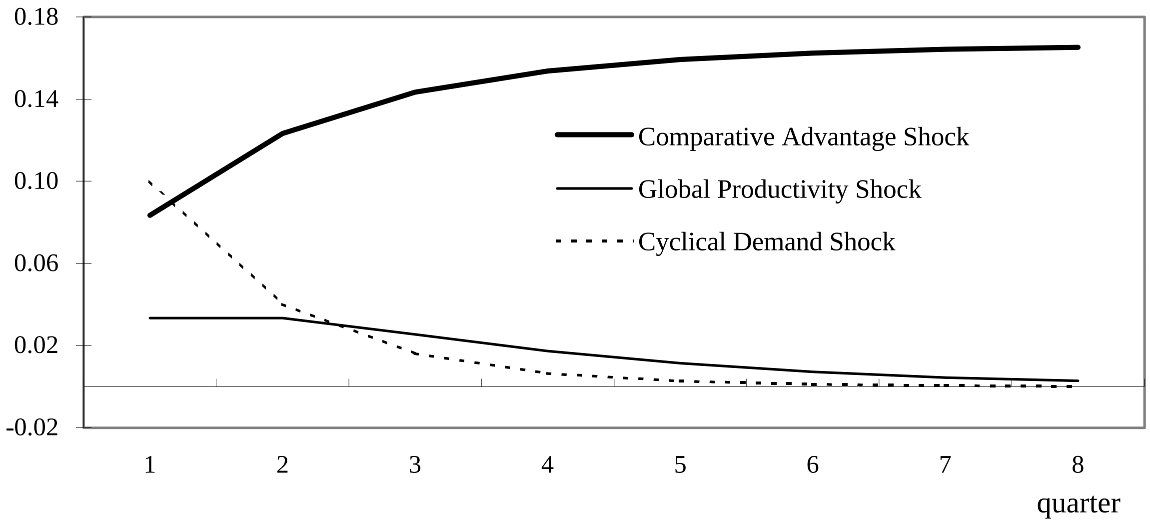
	Shocks		
Institution	Comparative advantage	Global productivity	Cyclical demand
A	1.16	-0.39	-2.22
B	3.77	2.02	0.58
C	-0.24	-0.40	0.36
D	0.99	1.32	-0.33
E	-1.21	-1.36	-2.07
F	2.43	-0.82	-0.84
G	8.26	-0.68	14.58

Note: Total shock during 2001 fiscal year expected in the second quarter of 2001

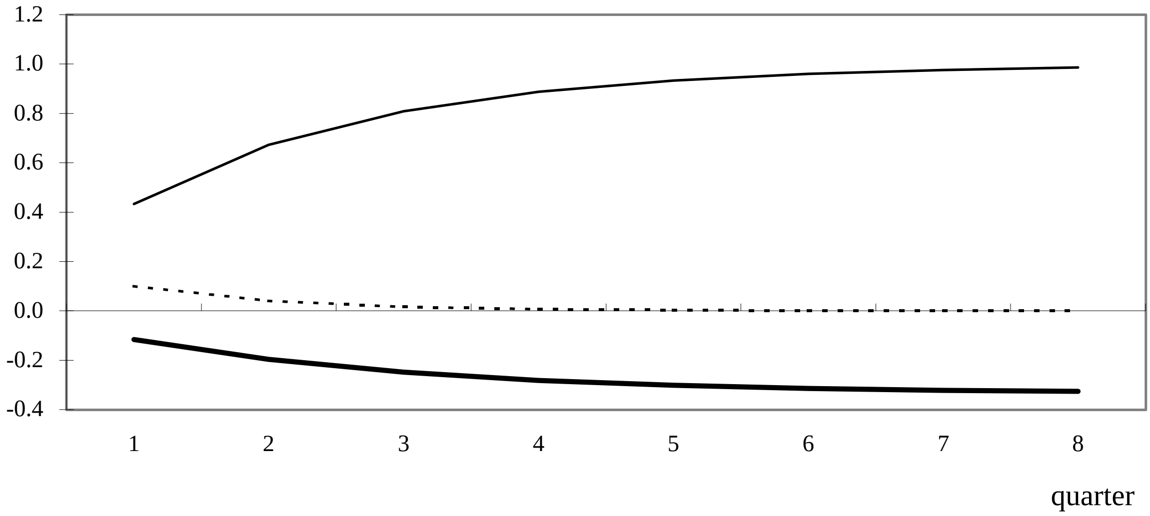
(Chart 6)

Simulation by Structural Model

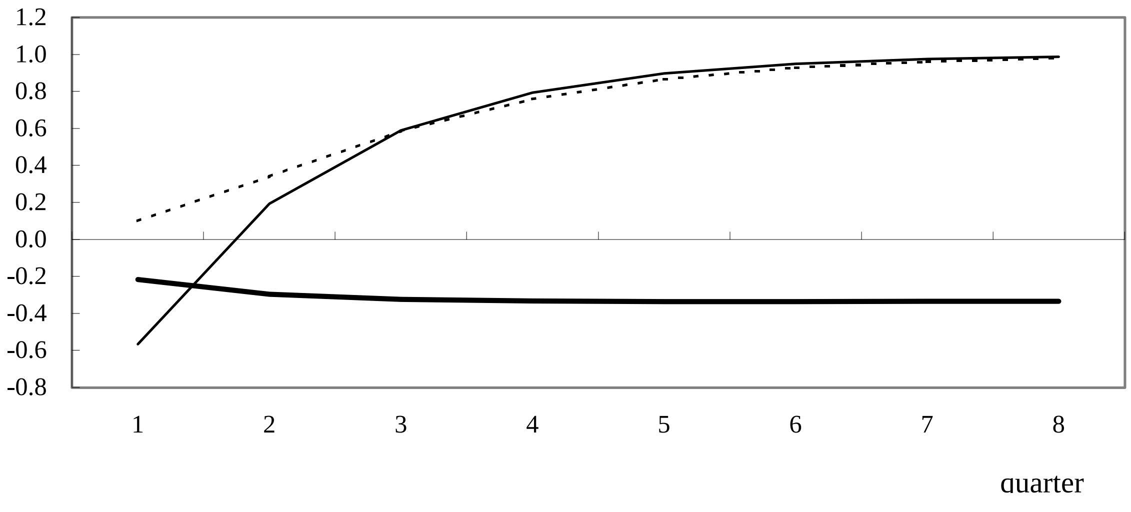
(1) Import Penetration Ratio



(2) Real Output



(3) Consumer Prices



(Chart 7)

Test for Unit Root and Cointegration

(1) Unit Root Test

$$D^{2}\,lnX_{t} = m + a\,t + dD\,lnX_{t-1} + \mathring{a}d_{i}\,D^{2}\,lnX_{t-i} + v_{t}$$

Augmented Dickey-Fuller (τ) test	μ=0 and α=0	μ≠0 and α=0	μ≠0 and α≠0
X		δ	
GDP	-1.18	-1.69	-2.22
CPI	-2.65 ***	-2.48	-2.78
IPR	-2.50 ***	-3.30 ***	-3.35 *

Pillips-Perron (z) test	μ=0 and α=0	μ≠0 and α=0	μ≠0 and α≠0
X		δ	
GDP	-88.66 ***	-115.32 ***	-115.28 ***
CPI	-28.79 ***	-39.68 ***	-54.69 ***
IPR	-106.70 ***	-104.62 ***	-103.76 ***

Notes: 1. GDP = real GDP; CPI = consumer price index, excluding fresh food, seasonally adjusted and adjusted for the consumption taxes; IPR = import penetration ratio.
2. * = 1 percent significant; ** = 5 percent significant; *** = 10 percent significant.

(2) Cointegration Test

$$lnY_{t} = m + a\,t + \mathring{a}b_{k}\,lnX_{k,t} + u_{t}\ ;\ \ D\,u_{t} = d\,u_{t-1} + \mathring{a}d_{i}\,D\,u_{t-i} + v_{t}$$

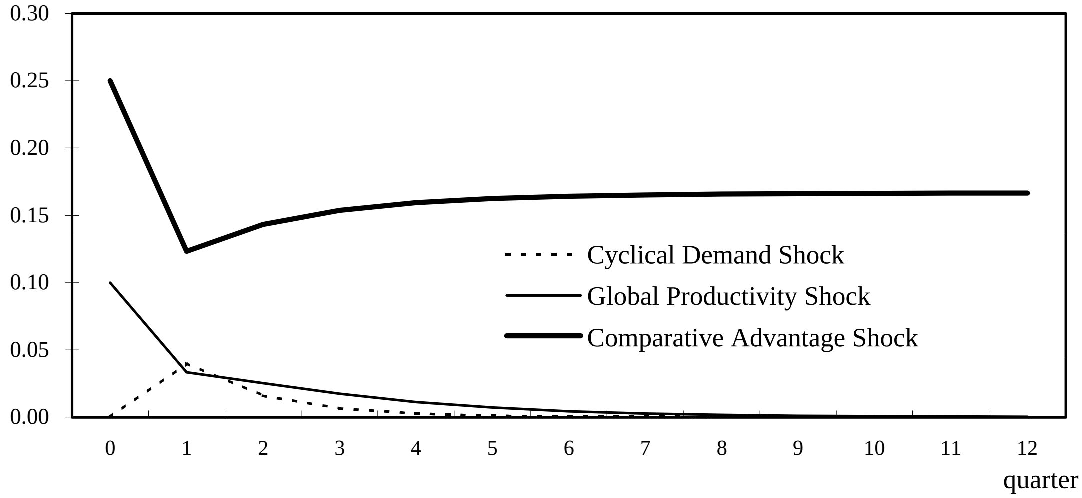
Engle-Granger test		μ=0 and α=0	μ≠0 and α=0	μ≠0 and α≠0
Y	*X*		δ	
GDP	CPI, IPR	-3.18 *	-2.25	-2.33
CPI	GDP, IPR	-3.22 *	-2.78	-2.13
IPR	GDP, CPI	-0.66 **	-0.98	-2.65
CPI	IPR	-0.64	-2.14	-1.61
IPR	CPI	-0.43	-1.44	-2.94
GDP	IPR	-0.61	-2.26	-1.82
IPR	GDP	-0.39	-1.46	-3.02
GDP	CPI	-2.47 *	-3.40 **	-3.04
CPI	GDP	-2.47 *	-3.53 **	-3.13

Notes: the same as above.

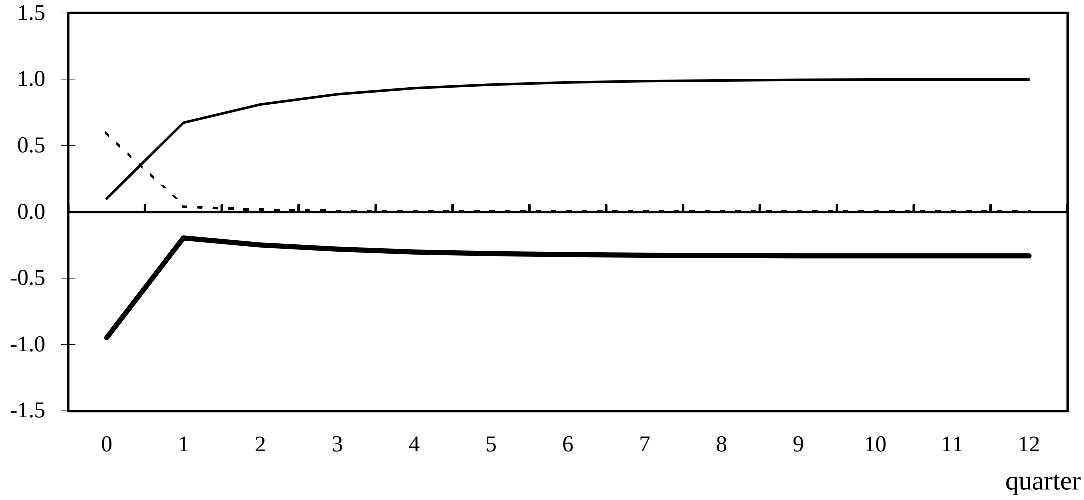
(Chart 8)

Simulation by Predetermined Wage Model

(1) Import Penetration



(2) Real Output



(3) Consumer Price Index