The Multi-Sector Business Cycle Model and Aggregate Shocks - An Empirical Analysis -*†

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Abstract

This paper discusses the applicability of a multi-sector business cycle model to the Japanese economy. Through dynamic factor analysis, output fluctuations are decomposed into aggregate and sectoral shocks. It is shown that independent sectoral shocks are more significant than common shocks, which conclusion is consistent with the model proposed by Long and Plosser (1983). In addition, the paper reveals that the importance of aggregate shocks increased during the so-called "bubble" period of the late 1980's.

1. INTRODUCTION

Following the seminal works of Slutsky (1937) and Frish (1938), business cycle research has focused on identifying impulses and propagation mechanisms and on evaluating the adherence of the business cycle model to existing data or, occasionally, to "stylized" facts. In the process, an enormous number of business cycle models with different sources of shocks and different propagation mechanisms have been introduced. Compared to the developments in modeling, however, there have been relatively few studies on the so-called stylized facts, particularly outside the U.S.

In their textbook, Cooley and Prescott (1995) list ten stylized facts about the U.S. economy. The first relates to the co-movement of employment and GDP; i.e., employment is strongly pro-cyclical in the U.S. economy. Based on this "fact", most business cycle models adopt the intertemporal substitution of leisure as one of the main amplifying mechanisms. But if we turn to an examination of other countries, such as Japan, it is no longer clear whether these frequently cited stylized facts apply. For example, Figure 1 shows movements of employments and output in Japan from 1960-1979 in Japan.[1] Obviously there is no clear co-movement among GDP, employments, and the unemployment rate. This implies that the standard real business cycle models that rely heavily on intertemporal substitution of leisure, such as the models of Kydland and Prescott (1982) or Hansen (1985), might not be good starting points to investigate business cycles in Japan.

While most business cycle models, including the models of Lucas (1972) or Hansen (1985), rely on the labor-leisure choice as their propagation mechanism, there is one famous exception. The model described in Long and Plosser (1983) is different from other business cycle models in many respects. First, their model contains multiple

[1]GDP and employment are detrended using an hp-filter. All the data are seasonally adjusted. Details of the data are provided in the following section.

production sectors. A sector whose outputs are mainly used as production inputs in other sectors can be regarded as the leading sector in the economy; that is to say, the sector is understood to be more influential in business cycle than the others. Second, Long and Plosser assume no serial correlation in technological shocks. The shocks are independent across sectors and over time. The i.i.d. impulses create prolonged fluctuation in the aggregate output through the input-output relation among sectors. Third, although their model contains labor-leisure choice, labor inputs become constant over time. This property is a by-product of their specification of technology and preferences. It is worth noting, however, that the Long and Plosser model does not rely on the intertemporal substitution of leisure as its propagation mechanism. Several empirical analyses have been mane according to this model using U.S. economic data. While few investigations have been made using Japanese data, this type of business cycle model might actually more applicable to the Japanese economy might actually be more appropriate for this type of business cycle model, since the Japanese economy due to the fact that the Japanese economy shows little correlation between employment and output, while the U.S. economy shows strong pro-cyclicality for employment . Accordingly, this paper analyzes business cycles in Japan using a model based on that of Long and Plosser (1983).

Although Long and Plosser (1983) model is regarded as one of the most important real business cycle approaches, so far, compared to other real business cycle models, very few empirical researches have been conducted based on the model.[2] In this paper, several empirical aspects of business cycles in the Japanese economy will be examined using the Long and Plosser model. The first is the magnitude of aggregate shocks in the Japanese economy. If aggregate shock can explain most sectoral fluctuations, we do not need to consider multi-sector models. On the other hand, if independent

[2]Exceptions are Long and Plosser (1987), Norrbin and Schlagenhauf (1988), (1990), Yoshikawa (1992), Dupor (1999), and Horvath (1998). Each of these will be discussed in subsequent sections.

sectoral shocks are important factors, a single sector model might not be appropriate for business cycle research. Since neither aggregate nor sectoral shocks are observable, it is necessary to decompose output fluctuations in each sector into common and sectoral shocks, which can be achieved by means of the dynamic factor analyses developed by Stock and Watson (1987). The empirical results suggest that aggregate shocks are too small to support single sector models; that is to say, aggregate shocks in Japan have only limited power to explain output fluctuations.

Second, changes in economic structures over time are investigated. The Japanese economy experienced rapid economic growth during the 1960s. Since then, the Japanese economy went through several major business cycles such as the oil shocks of the '70s and the "bubble" economy of the '80s. Rolling regressions reveal the structural changes of the economy during the sample period. The results suggest that the common factor increased in importance during the business cycles of the 1980s; i.e., during the "bubble" economy.

The remainder of the paper is organized as follows. The next section gives a brief description of the macroeconomy in Japan and the third section discusses the Long and Plosser model along with its empirical implications. Section four describes the empirical results of dynamic factor analyses. The final section gives concluding remarks and discusses implications for the future.

2. AN OVERVIEW OF THE JAPANESE MACROECONOMY

This section describes some characteristics of the Japanese macroeconomy. Table 1 shows cross-correlations between GDP and several macroeconomic variables. All data except for the unemployment rates are detrended using an hp-filter with $\lambda = 1600$. The data are seasonally adjusted and cover the 40 years from the first quarter in 1960 to the fourth quarter in 1999.

The standard deviation of private consumption is about 80% of the standard deviation of GDP. Non-residential investment is 4 times more volatile than GDP. Both consumption and non-residential investment are highly procyclical, much as in the U.S. On the other hand, the weak correlation between employment and GDP, which is highly characteristic of the Japanese economy, is not seen in the U.S. The minimal correlation between employment and GDP is well known in Japan.[3] In fact, it is only very recently that the unemployment rate has begun to vary significantly.

Figure 2 shows movement of the total manufacturing index. The data is monthly and seasonally adjusted, and detrended by an hp-filter. The shaded areas indicate the official contraction periods of the Japanese economy as defined officially by the Cabinet Office. The decline in the production index up until the second oil shock of the late 1970s is sharp and corresponds to the shaded areas quite well. After the second oil shock, the movements of the production index seem to be less volatile than before and the correspondence between the index and the contraction periods is vague, suggesting that structural changes have occurred in the Japanese economy during the sample periods.

Taking these results together, we can safely say that in Japan, 1) private consumption, investment, imports, and real wage are pro-cyclical; 2) private consumption is smoother than GDP; and 3) investment is more volatile than GDP. All of these findings are consistent with standard real business cycle (RBC) models such as by Hansen's (1985). The lack of pro-cyclicality in employment is inconsistent with many RBC models but is consistent with the Long and Plosser model.

[3] Hamori and Kitasaka (1997) also pointed out that in Japan, unlike in the US, labor input does not vary substantially over time.

3. THE MODEL

As mentioned above, Long and Plosser's model does not rely on the intertemporal substitution of leisure as the propagation mechanism.[4] In this paper, apart from the specifications of the stochastic environments, the model employed resembles Long and Plosser (1983)'s model.

A representatitve agent with infinite life span maximizes her expected discounted utility from the consumption of n different goods and leisure. The utility function is given as

$$U = E_0 \left[\sum_{t=0}^{\infty} \beta^t \left(\theta_0 \ln Z_t + \sum_{i=1}^{n} \theta_i \ln C_{it} \right) \right], \tag{1}$$

where $0 < \beta < 1$ and $\theta_i \geq 0$ for $i = 1, 2, ..., n$. Z_t and C_{it} are leisure and consumption of the commodity i at period t, respectively.

There are n production sectors that have linear homogenous technology as follows,

$$Y_{i,t+1} = \lambda_{i,t+1} L_{it}^{b_i} \prod_{j=1}^{n} M_{ijt}^{a_{ij}}, \qquad i = 1, 2, .., n. \tag{2}$$

where $Y_{i,t+1}$ is the total stock of commodity i available at time t+1. L_{it} is the amount of labor inputs used in the production of commodity i. M_{ijt} is the quantity of commodity j allocated at time t to the production of commodity i. $\lambda_{i,t+1}$ is a random variable whose value is realized at time t+1. The parameters b_i and a_{ij} are nonnegative constant that satisfy

$$b_i + \sum_{j=1}^{n} a_{ij} = 1, \quad i = 1, 2, ..., n. \tag{3}$$

The representative agent has H time available at each period, which gives us the

[4]See Long and Plosser (1983) for detailed discussion of the model. Horvath (1998) built a slightly extended model that incorporates sector specific capitals.

labor resource condition as

$$Z_t + \sum_{i=1}^{n} L_{it} = H, \quad t = 0, 1, 2, ... \tag{4}$$

Commodity resource allocation can be written as[5]

$$C_{jt} + \sum_{i=1}^{n} M_{ijt} = Y_{jt}, \quad j = 1, 2, ..., N; \ t = 0, 1, 2, ... \tag{5}$$

The stochastic process of $\lambda_t = (\lambda_{1,t}, \lambda_{2,t}, ...\lambda_{n,t})'$ is specified as follows,

$$\ln \lambda_t = Bx_t + \varepsilon_t, \tag{6}$$

$$x_t = g_1 x_{t-1} + g_2 x_{t-2} + \omega_t, \tag{7}$$

where $B : 1 \times n$ matrix, $g_i :$ a scaler for i = 1, 2, $\varepsilon_t = (\varepsilon_{1,t}, \varepsilon_{2,t}, ...\varepsilon_{n,t})'$ is a stationary stochastic vector that is independent across sectors and over time, and their first differences follow normal distribution,[6]

$$\Delta\varepsilon_t \sim N(0, R), \tag{8}$$

$$R = \begin{pmatrix} \sigma_{\varepsilon 1}^2 & 0 & 0 & 0 & 0 \\ 0 & \sigma_{\varepsilon 2}^2 & 0 & 0 & 0 \\ . & . & . & . & . \\ . & . & . & . & . \\ 0 & 0 & 0 & 0 & \sigma_{\varepsilon n}^2 \end{pmatrix}. \tag{9}$$

[5]The depreciation rate is assumed to be 100%. This assumption is necessary for derivations of the value function.

[6]The first differences are used for the sake of consistency with the subsequent empirical sections of this paper.

x_t represents the unobservable state variable that represents the common shocks across sectors and follows AR2 with error term ω_t,

$$\Delta\omega_t \sim N\left(0, \left(\sigma_\omega^2\right)\right). \tag{10}$$

Vector B can be interpreted as indicating the sensitivities of each sector to the macroeconomic common shock, x_t. If B is a zero vector, the economy has pure sectoral shocks only, which corresponds to the case in Long and Plosser. On the other hand, if $\sigma_{\varepsilon i}^2 = 0$ for all i and all the elements in B are identical, the macroeconomic shocks alone can account for all the fluctuations of the outputs.

The representative agent maximizes (1) subject to $(2) - (10)$. Following Long and Plosser, it is easy to derive the following optimal consumption and input quantities at time t,

$$C_{it}^* = \left(\frac{\theta_i}{\gamma_i}\right) Y_{it}, \qquad i = 1, 2, .., n, \tag{11}$$

$$Z_t^* = \theta_0 \left(\theta_0 + \beta \sum_{i=1}^{n} \gamma_i b_i\right)^{-1} H, \tag{12}$$

$$M_{ijt}^* = \left(\frac{\beta\gamma_i a_{ij}}{\gamma_j}\right) Y_{jt}, \quad i, j = 1, 2, ..., n, \tag{13}$$

$$L_{it}^* = \beta\gamma_i b_i \left(\theta_0 + \beta \sum_{i=1}^{n} \gamma_i b_i\right)^{-1} H, \qquad i = 1, 2, .., n, \tag{14}$$

and

$$\gamma_j = \theta_j + \beta \sum_{i=1}^{n} \gamma_i b_i, \quad i, j = 1, 2, ..., n. \tag{15}$$

(12) and (14) imply that employment and leisure are constant over time in this economy. The agent does not change her leisure consumption even if the economy

is hit by a large technological shock. This feature derives from the lag that appears in the production function, (2). Suppose the economy consists of a single production sector, that is, n=1. An increase in λ_{t+1} raises the marginal productivity of labor at time t. The marginal value of labor, however, also depends on the value of the commodity in terms of the utility. Because of an increase in λ_{t+1}, the amounts of the commodity and consumption also increase, which decreases the marginal value of the commodity. The two opposing effects offset each other in the model.[7] The derived optimal consumption and the input demands are proportional to the output, which gives us the following equation,

$$y_{t+1} = const + Ay_t + \eta_{t+1}, \tag{16}$$

where $y_t = (\ln Y_{1t}, \ln Y_{2t}, .., \ln Y_{n,t})'$, $\eta_{t+1} = (\ln \lambda_{1t+1}, \ln \lambda_{2t+1}, .., \ln \lambda_{n,t+1})'$, and $A = (a_{ij})$: an $N \times N$ matrix which is equivalent to the input-output coefficient matrix. Long and Plosser claimed that even if η_t is independent across sectors and over time, the simulated outputs have strong co-movements and serial correlation over time, which is consistent with the U.S. data. The model in this paper has two mechanisms that cause co-movements among outputs in this economy. The first mechanism is the input-output relationship represented by the matrix, A. A shock in one sector is transmitted to other sectors because its product of the sector is used in other sectors as one of the inputs. The second mechanism is the direct effects of the common factor, x_t, which affects the outputs of each sector through the vector, B in equation (6). The relative importance of the two mechanisms depends on the parameters, which should be estimated through empirical analyses.

[7] Since the leisure-labor choice does not play a significant role in the model, Dupor (1999) and Horvath (1998) do not include this aspect in their model.

4. EMPIRICAL ANALYSES

As is discussed above, Long and Plosser model has several empirical implications that are different from most business cycle models using a single-sector framework. The first is that it is mainly sectoral shocks rather than macroeconomic shocks, that drive aggregate fluctuations. The second is that the main propagation and transmitted mechanism is the input-output relation. This section considers these implications by investigating Japanese data.

Using a single factor analysis, Long and Plosser (1987) showed that approximately 50% of the variances of the industrial production indices in the U.S. can be explained by the common factor. Norrbin and Schlagenhauf (1990)[8] applied a dynamic factor analysis and obtained similar results. They interpreted their results as evidence that the representative single sector model has only limited power to explain business cycles. In this section, following Norrbin and Schlagenhauf (1990), I investigate the significance of the aggregate shocks in the variances of sectoral movements in the Japanese manufacturing and mining industries.

One of the differences of this paper from previous studies lies in its consideration of structural change. If structural changes occurred during the sample period, disregarding the said change, might lead to an inappropriate estimation of the common factor.[9] Considering the long sample period, 40 years, it is unlikely that all the parameters in the model are constant over time. In this section, a rolling regression is conducted in order to determine the changes in economic structures and the relative

[8] Norrbin and Schlagenhauf wrote several papers with different specifications. Norrbin and Schlagenhauf (1988) used quarterly labor data. Norrbin and Schlagenhauf (1990) and (1991) used industrial production indices in the U.S. The latter includes monetary variables as one of the aggregate shocks. All the papers suggest that although both aggregate and sectoral shocks are important in the U.S., the common factor is more influential than sectoral shocks.

[9] The direction of bias depends on the type of structural change.

importance of the common factor over time.[10]

Compared to the rich literature on the relative importance of the common factor in explaining sectoral fluctuation in the U.S., there are very few papers that uses the Japanese data. Yoshikawa (1992) is a rare exception. He regressed detrended production indices for Japanese manufacturing on GDP and calculated the importance of GDP in explaining the variance of each production index. He found that the importance of GDP varies to a great extent across sectors and over time.[11]. For example, macro-shock can explain 80% of the variations in metal production during the 1960s, while it can account for only 1% in the '70s. As for the precision instrument sector, the common factor drove only 1% of its variation in the '60s, while it increased to 28% in the '70s. Because GDP is available for lower frequencies than the production index, and also because GDP might not be the only source of the common shocks, rather than specifying the common shocks themselves, this paper adopts the dynamic factor analysis that is discussed in detail in the next subsection.

4-1. Econometric Methodology

Since the common factor is not observable, we have to estimate the variable from the observed data. Because the production indices have trends, the first differenced series are used in the estimation, i.e., the system to be estimated is as follows:

$$\Delta y_{t+1} = A\Delta y_t + \Delta\eta_{t+1}, \tag{17}$$

[10] Recently, Kim and Nelson (1999) developed a method to incorporate Markov switching models and dynamic factor analyses. I did not adopt their approach because the number of variables in this paper makes the computation very costly.

[11] Yoshikawa (1992) used quarterly data. The sample covered the periods III:1959 to IV:1970 and I:1971 to IV:1983.

$$\Delta\eta_t = B\Delta x_t + \Delta\varepsilon_t, \tag{18}$$

$$\Delta x_t = g_1\Delta x_{t-1} + g_2\Delta x_{t-2} + \Delta\omega_t, \tag{19}$$

$$\Delta\varepsilon_t \sim N(0, R), \quad \omega_t \sim N\left(0, \sigma_\omega^2\right). \tag{20}$$

The above system can be written in a state space system such as,

$$\Delta\eta_t = \widehat{B}X_t + \Delta\varepsilon_t, \tag{21}$$

$$X_t = GX_{t-1} + W_t, \tag{22}$$

$$\widehat{B} = \begin{pmatrix} B, & 0 \end{pmatrix}, \tag{23}$$

$$X_t = \begin{pmatrix} \Delta x_t \\ \Delta x_{t-1} \end{pmatrix}, \tag{24}$$

$$G = \begin{pmatrix} g_1 & g_2 \\ 1 & 0 \end{pmatrix}, \tag{25}$$

$$W_t = \begin{pmatrix} \Delta\omega_t \\ 0 \end{pmatrix}. \tag{26}$$

Given Δy_t and the matrix A, $\Delta\eta_t$ can be obtained. Assuming that the system is stable, a time invariant Kalman smoother is used to obtain the estimates of X_t.[12]

[12] The point estimates of the coefficients are consistent with the stability assumptions. See Hansen and Sargent (2001) for details. Havery (1989), (1993), and Hamilton (1994) have excellent explanations of the Kalman filter and smoother with maximum likelihood estimation.

The model can be estimated by using maximum likelihood techniques along with the Kalman smoother algorithm. Given the guess of X_t up to period t, the Kalman filter gives the best guess of X_{t+1} which is denoted as $\widehat{X}_{t+1}$. Therefore, given X_0 and other parameters, the Kalman filter gives a sequence of $\left\{\widehat{X}_t\right\}_{t=1}^{T}$. Given the estimate of $\left\{\widehat{X}_t\right\}_{t=1}^{T}$, the Kalman smoother returns more efficient estimates, $\left\{\widehat{\widehat{X}}_t\right\}_{t=0}^{T}$.The log-likelihood function for η_t to be maximized can be represented as

$$-\frac{1}{2}\sum_{t=0}^{T}\left\{n\ln(2\pi)+\ln|\Omega_t|+a_t'\Omega_t a_t\right\},^{13} \tag{27}$$

where $\Omega_t = B\Sigma_t B' + R$ and Σ_t is the variance-covariance matrix of $(x_t, x_{t-1})'$ around $\left(\widehat{\widehat{x}}_t, \widehat{\widehat{x}}_{t-1}\right)'$, which is given by the Kalman smoother.[14] T is the sample period. a_t is the residual defined by

$$a_t = \eta_t - \widehat{B}\widehat{\widehat{X}}_t. \tag{28}$$

The parameters and variables to be estimated are

$$\left(B, \sigma_{\varepsilon 1}^2, \sigma_{\varepsilon 2}^2, ...\sigma_{\varepsilon n}^2, G_1, G_2, \left\{\widehat{\widehat{X}}_t\right\}_{t=0}^{T}\right).^{15} \tag{29}$$

The share of the common factor, x_t, in the variance of the ith sector is defined as follows:

$$share_i = \frac{B_i^2\Sigma_{11}}{B_i^2\Sigma_{11}+\sigma_{\varepsilon i}^2}, \tag{30}$$

[13]In order to avoid obtaining local maximums, I check the results by 1) starting from various initial points, and 2) adopting very strict convergence criteria.

[14]In practice, Σ_t converges quickly. Therefore, in empirical parts, I calculate the stationary value of $\Sigma_t(=\Sigma)$, and use the variacnce, Σ in the maximization. See Hansen and Sargent (2001) for details.

[15]σ_ω^2 is fixed at unity since we need to fix one parameter to conduct estimations.

where the denominator is the variance of η_{ti}, and Σ_{11} is the (1,1) element of the variance-covariance matrix of Σ.

4-2. The Data and Results

I use the production index of Japanese manufacturing and mining. The sample covers the period January 1958 to April 2001.[16] The data is monthly and seasonally adjusted with 17 sectors. The results of unit root tests are reported in Table 2.[17] Tables 3 and 4 show the descriptive statistics and the correlation matrix of the first difference of the indices. The correlation matrix conveys important information regarding the co-movements among variables. First, the off-diagonal elements are positive, which implies the existence of co-movements among the variables to the same direction. Second, although they are all positive, the correlations are small: the maximum of the off-diagonal elements is smaller than 1/2, which implies a limited role for co-movements in their variations.

Table 5 reports the result of a single factor analysis without specific stochastic specification. The average uniqueness of the variables is bigger than 70%, which automatically means that aggregate shocks can account for less than 30% of the variations. This figure is smaller than that estimated by Long and Plosser (1987) for the U.S. It is also smaller than Yoshikawa's estimated value of 38%.

[16]Because new products appear every year, production indices are adjusted to cover the new products. Therefore, the production index of , for example, electrical machinery in 1960 contains different items from that in 1990. Whether this inconsistency creates serious biases is a question for future consideration.

[17]Except for the mining sector, unit root tests do not reject the null, and Johansen's cointegration test does not reject no cointegrating vectors. As the first differenced series can reject the unit root, apart from in the plastic sector, I use the first differenced series for further analyses. The critical values for cointegrating tests are obtained through the Monte-Carlo Simulation. The details of the cointegrating tests are available from the author upon request.

Parameter matrix, A, in Equation (16) cannot be estimated because it contains too many parameters. In order to estimate the system, it is necessary to impose some restrictions so that the number of parameters to be estimated is reduced. Following Long and Plosser (1983) and Norrbin and Schlagenhauf (1991), the cost share matrices from the input-output tables for Japan are used as the coefficient matrix, A in (16).[18] The input-output tables are rearranged so as to be consistent with the output data.

Table 6 reports the share of the common factor in the variance of each sector, defined by (30). The data covers the periods between January 1960 and December 1999. For (1) in Table 6, I used the 1980 input-output table as the coefficient matrix, A. For other columns, the first year input-output table is used. For example, in (3), 1965 input-output table is used. The last row reports the value of the likelihood function. The four rows above this are the estimated coefficients of (22) and their standard deviations. For example, for the whole sample, the estimated movement of the common factor, x_t, can be written as

$$x_t = \underset{(0.0188)}{-0.6531}\, x_{t-1} \underset{(0.0604)}{-0.0901}\, x_{t-2}.^{19} \tag{31}$$

The contributions of the common factor in Table 6 do not significantly diverge from those in Table 5. The Foods and Tobacco industry is not sensitive to the aggregate shocks, while Non-Ferrous Metals co-moves with the aggregate shocks to a great extent. The average contributions of the common factor in the variation of each index lie between 12% and 30%,[20] which is much smaller than those in the previous

[18] Among the many input-output tables created every five years, I use the tables compiled by the Ministry of International Trade and Industry because the definitions of sectors in these tables are close to those in the production indices.

[19] The coefficient of x_{t-1} is negative significant, which is difficult to interpret because most business cycle models assume that shocks have positive autocorrelation. Norrbin and Schlagenhauf (1988) also obtained a negative coefficient for the U.S. data.

[20] Weighted average in Table 6 is obtained with the value-added base production share of each

studies with U.S. data. This result shows the significance of the idiosyncratic shocks in business cycles in Japan.

In contrast to Yoshikawa's analysis, Table 6 does not reveal strong instability, although the average importance of the common factor is not constant over time. In order to investigate changes in parameters over time, I conduct a rolling regression with a five-year interval and one-month increment. Figure 3 plots the weighted average contributions of the common factor and the movements of the total production index over time. The average contributions of the common factor are obtained from iterations of the Kalman smoother estimation over the sample period.[21] The figure shows that until the mid of the 1980s, the importance of the common factor has no correlation with the production index. During the expansion periods in the mid-'80s, the so-called "bubble" era, the common factor increased its correlation with the production index, an increase that continues until the mid-'90s.

5. CONCLUSION

This paper has investigated whether or not the Long and Plosser (1983) style business cycle model is consistent with the Japanese experience. The dynamic factor analysis conducted here found aggregate shocks to be limited in their ability to explain sectoral movements, which suggests that the standard single sector model captures less than 30% of variances of sectoral movements. I also found that the "bubble cycle" during the 1980's was affected by aggregate shocks more than other

sector in each month.

[21]The input-output matrix at each step is obtained by linear interpolations. The starting period of the rolling regression is January 1960-December 1964. The next period is February 1960-January 1965. I have obtained 420 estimates of the contributions of the common factor defined by (30) for each production sector.

business cycles in Japan. The model employed here is simplified and does not extend to analysis of many pertinent factors. Monetary factors, imperfect competition, and the relative weights of the foreign and public sectors, for example, also merit considerations. In addition, this paper does not consider the economic mechanisms behind the structural changes detected by the rolling regressions. These are tasks for continuing research.

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Table 1

Period: 1960:01-1999:04

Variable	Std.	Cross-Correlation of Output with:										
		x(-5)	x(-4)	x(-3)	x(-2)	x(-1)	x	x(+1)	x(+2)	x(+3)	x(+4)	x(+5)
GDP	0.0155446	0.0241	0.2304**	0.4531**	0.6356**	0.8142**	1	0.8142**	0.6356**	0.4531**	0.2304**	0.0241
PCON	0.0128850	0.0251	0.1973**	0.4137**	0.5150**	0.6163**	0.7781**	0.5534**	0.3890**	0.2281**	0.0289	-0.1212
NREINV	0.0635827	-0.0416	0.102	0.2691**	0.4631**	0.6506**	0.7886**	0.7918**	0.7606**	0.6266**	0.4314**	0.2103**
RINV	0.0639469	0.1610*	0.2712**	0.3453**	0.3603**	0.3632**	0.4241**	0.3123**	0.1013	-0.0594	-0.2117**	-0.3620**
GCON	0.0123745	0.1218	0.1620*	0.1437	0.1341	0.1183	0.066	-0.075	-0.1387	-0.2147**	-0.2745**	-0.2291**
GINV	0.0563015	0.2095**	0.2435**	0.2657**	0.2225**	0.2245**	0.1933*	-0.0226	-0.1478	-0.1838*	-0.1719*	-0.1146
EXP	0.0439018	-0.046	-0.0715	-0.1117	-0.1019	-0.0806	-0.0039	0.0766	0.1973*	0.2738**	0.3106**	0.2716**
IMP	0.0595898	0.0882	0.1859*	0.3077**	0.4619**	0.5457**	0.5675**	0.5093**	0.4273**	0.2870**	0.12	-0.0643
WAGE	0.0084925	0.0137	0.1638*	0.2665**	0.3353**	0.4289**	0.5315**	0.4292**	0.3367**	0.2036*	0.0376	-0.0898
UNEMP	0.0067642	-0.0334	-0.0577	-0.0853	-0.1113	-0.1355	-0.1554*	-0.1642*	-0.1655*	-0.1563*	-0.1373	-0.1041
EMP	0.0140316	-0.3198**	-0.3189**	-0.2662**	-0.0822	0.0694	0.1899*	0.2492**	0.3458**	0.3606**	0.3665**	0.2764**

GDP: Real Gross Domestic Product
PCON: Real Private Consumption Expenditure
NREINV: Real Private Nonresidential Investment
RINV: Real Private Residential Investment
GCON: Real Governmental Consumption Expenditure
GINV: Real Governmental Investment
EXP: Exports
IMP: Imports
WAGE: Real Wage in Manufactures for 30 or larger firms (Monthly Labour Survey)
UNEMP: Unemployment Rate
EMP: Employment (koyousha)

**: significant at 5% level
*: significant at 10% level

Table 2

Summary of Unit Root Tests

Logarithms

	A1	A2	A3	A4	A5
Test Statistics	-1.61896	1.28685	1.06367	0.52179	-0.20109
p-value	0.8521	0.99997	0.99994	0.99971	0.9975
Lags	27	14	27	27	17
	A6	A7	A8	A9	A10
Test Statistics	2.02835	-0.22756	0.87515	1.08751	0.79949
p-value	1	0.99729	0.9999	0.99995	0.99987
Lags	27	27	26	15	19
	A11	A12	A13	A14	A15
Test Statistics	0.022136	1.69083	-0.02014	0.13495	-0.14145
p-value	0.99872	0.99999	0.99854	0.99908	0.99791
Lags	26	14	27	27	25
	A16	A17			
Test Statistics	0.66983	1.98135			
p-value	0.99981	1			
Lags	27	27			

First Differences

	A1	A2	A3	A4	A5
Test Statist	-7.25491	-4.29959	-5.09159	-4.46649	-5.20708
p-value	0.00000	0.00191	0.00018	0.00116	0.00013
Lags	13	26	26	30	26
	A6	A7	A8	A9	A10
Test Statist	-3.69533	-3.41520	-5.06868	-5.93401	-5.78888
p-value	0.01149	0.02615	0.00019	0.00001	0.00002
Lags	27	43	25	16	16
	A11	A12	A13	A14	A15
Test Statist	-3.04785	-6.43363	-4.81386	-4.48406	-7.67764
p-value	0.07450	0.00000	0.00041	0.00110	0.00000
Lags	25	13	27	27	14
	A16	A17			
Test Statist	-4.52861	-2.76469			
p-value	0.00096	0.15799			
Lags	37	37			

Methods: Weighted Symmetric Methods
Sample: 1958:2 to 2001:4

A1	Mining
A2	Iron and Steel
A3	Non-Ferrous Metals
A4	Fabricated Metals
A5	General Machinery
A6	Electrical Machinery
A7	Transport Equipment
A8	Precision Instruments
A9	Ceramics, Stone, and Clay Products
A10	Chemicals
A11	Petroreum and Coal Products
A12	Pulp, Paper, and Paper Products
A13	Textiles
A14	Wood and Wood Products
A15	Foods and Tobacco
A16	Rubber Products
A17	Plastic

Table 3
Descriptive Statistics of the Production Indices

Variable	Mean	Std.Dev.	Min	Max	Variable Index
Mining	-0.0012648	0.0337370	-0.1944884	0.1589817	a1
Iron and Steel	0.0044383	0.0180173	-0.0476949	0.0919014	a2
Non-Ferrous Metals	0.0049668	0.0209645	-0.0942356	0.0837699	a3
Fabricated Metals	0.0042374	0.0273281	-0.1157755	0.1600632	a4
General Machinery	0.0053428	0.0342840	-0.1275393	0.1412926	a5
Electrical Machinery	0.0096634	0.0239250	-0.1168248	0.1008607	a6
Transport Equipment	0.0052867	0.0356476	-0.1206969	0.1245729	a7
Precision Instruments	0.0062771	0.0360155	-0.1522543	0.1727204	a8
Ceramics, Stone, and Clay Products	0.0030455	0.0156564	-0.0646027	0.0618299	a9
Chemicals	0.0056124	0.0197267	-0.0652406	0.0741080	a10
Petroreum and Coal Products	0.0046221	0.0250703	-0.0731677	0.1053606	a11
Pulp, Paper, and Paper Products	0.0045737	0.0143929	-0.0552409	0.0610359	a12
Textiles	0.0007366	0.0119711	-0.0499658	0.0595510	a13
Wood and Wood Products	-0.0006216	0.0166539	-0.0791229	0.0597550	a14
Foods and Tobacco	0.0026469	0.0329279	-0.1462166	0.2079404	a15
Rubber Products	0.0041554	0.0210660	-0.0738237	0.0764961	a16
Plastic	0.0068331	0.0224978	-0.0765740	0.0914594	a17

Number of Observations 519

Sample Periods Feb:1958-April:2001

Monthly Seasonally Adjusted

Sources : *`Long Term Data Book of Indices of Industrial Production'*

1960, 1965, 1970, 1980, 1985, 1990, 1995 Research and Statistics Department, Minister's Secretariat,
Ministry of International Trade and Industry

All the data are first differences of the logarithms of the original index.

Table 4
Correlation Matrix

	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11	a12	a13	a14	a15	a16	a17
a1	1																
a2	0.1818	1															
a3	0.2797	0.4639	1														
a4	0.1168	0.3081	0.367	1													
a5	0.1688	0.2451	0.2448	0.227	1												
a6	0.1555	0.3962	0.4023	0.3211	0.3611	1											
a7	0.281	0.2754	0.4619	0.2596	0.3156	0.2799	1										
a8	0.1814	0.1602	0.2826	0.1796	0.2075	0.1946	0.314	1									
a9	0.2068	0.3722	0.3528	0.3257	0.2839	0.4011	0.2379	0.2235	1								
a10	0.2449	0.2913	0.4723	0.2708	0.1305	0.2793	0.3495	0.2344	0.273	1							
a11	0.1807	0.2068	0.2114	0.1883	0.0894	0.1231	0.1189	0.1021	0.2343	0.2214	1						
a12	0.2085	0.3821	0.4973	0.2896	0.2058	0.3288	0.187	0.2787	0.4275	0.3903	0.17	1					
a13	0.1019	0.3334	0.4033	0.3179	0.2122	0.311	0.2522	0.3023	0.4251	0.3281	0.194	0.4216	1				
a14	0.2473	0.3065	0.4062	0.3138	0.2022	0.23	0.3098	0.2752	0.3958	0.3407	0.1461	0.3384	0.4515	1			
a15	0.2064	0.1371	0.2543	0.1803	0.1558	0.0976	0.2725	0.1928	0.0919	0.2092	0.1377	0.1147	0.1496	0.2392	1		
a16	0.3279	0.3704	0.5151	0.3023	0.2844	0.3515	0.4544	0.3169	0.3432	0.3796	0.2494	0.3895	0.3056	0.359	0.232	1	
a17	0.1121	0.2994	0.498	0.2775	0.1759	0.3189	0.2432	0.1978	0.3114	0.3237	0.2598	0.4847	0.3884	0.2877	0.1529	0.4125	1

Sample: 1958:2 to 2001:4

A1	Mining
A2	Iron and Steel
A3	Non-Ferrous Metals
A4	Fabricated Metals
A5	General Machinery
A6	Electrical Machinery
A7	Transport Equipment
A8	Precision Instruments
A9	Ceramics, Stone, and Clay Products
A10	Chemicals
A11	Petroreum and Coal Products
A12	Pulp, Paper, and Paper Products
A13	Textiles
A14	Wood and Wood Products
A15	Foods and Tobacco
A16	Rubber Products
A17	Plastic

Table 5
Factor Analysis

Sectors	**Uniquness**	**Common Factor**
Mining	0.86352	0.13648
Iron and Steel	0.67583	0.32417
Non-Ferrous Metals	0.44579	0.55421
Fabricated Metals	0.74958	0.25042
General Machinery	0.83206	0.16794
Electrical Machinery	0.69852	0.30148
Transport Equipment	0.70158	0.29842
Precision Instruments	0.81908	0.18092
Ceramics, Stone, and Clay Products	0.65393	0.34607
Chemicals	0.68032	0.31968
Petroreum and Coal Products	0.89209	0.10791
Pulp, Paper, and Paper Products	0.60328	0.39672
Textiles	0.64833	0.35167
Wood and Wood Products	0.667	0.333
Foods and Tobacco	0.89714	0.10286
Rubber Products	0.55877	0.44123
Plastic	0.66105	0.33895
Average	0.708698235	0.291301765

The result of factor analysis with one factor

Sample: 1960:01-1999:12

Table 6
The Ratios of the Common Factor in Variances

	(1) Whole Periods	(2) 1960-64	(3) 1965-69	(4) 1970-74	(5) 1975-79	(6) 1980-84	(7) 1985-89	(8) 1990-94	(9) 1995-99
Mining	0.06584	0.07077	0.10762	0.15122	0.08765	0.13181	0.02119	0.04147	0.05731
Iron and Steel	0.19833	0.20960	0.14219	0.05771	0.21752	0.24254	0.26392	0.25955	0.12308
Non-Ferrous Metals	0.40158	0.41791	0.33502	0.25774	0.37194	0.60815	0.38348	0.33869	0.40158
Fabricated Metals	0.12447	0.03066	0.00568	0.06448	0.08920	0.38455	0.22758	0.33348	0.11912
General Machinery	0.11333	0.07829	0.15851	0.07733	0.05615	0.08525	0.29420	0.29189	0.12637
Electrical Machinery	0.16902	0.19382	0.24377	0.09486	0.16313	0.12244	0.17897	0.28758	0.24057
Transport Equipment	0.17123	0.11865	0.15287	0.15686	0.09853	0.26487	0.21380	0.20919	0.16482
Precision Instruments	0.06480	0.08051	0.02762	0.11591	0.02027	0.05219	0.16473	0.07547	0.04670
Ceramics, Stone, and Clay Products	0.20703	0.13744	0.12468	0.29328	0.23039	0.33581	0.15865	0.24675	0.11083
Chemicals	0.29006	0.24160	0.28821	0.50824	0.26364	0.30843	0.25825	0.28987	0.29189
Petroreum and Coal Products	0.07775	0.05487	0.01591	0.11358	0.04435	0.11795	0.09110	0.06842	0.03804
Pulp, Paper, and Paper Products	0.23740	0.36906	0.17793	0.35538	0.16318	0.19101	0.29775	0.24286	0.17261
Textiles	0.25450	0.02542	0.17928	0.25442	0.19607	0.42288	0.54581	0.62806	0.34712
Wood and Wood Products	0.16933	0.16718	0.06200	0.13794	0.07085	0.29743	0.28222	0.33350	0.22407
Foods and Tobacco	0.04388	0.00146	0.16740	0.06769	0.04649	0.06380	0.13915	0.05713	0.03559
Rubber Products	0.22740	0.23889	0.28391	0.22311	0.16972	0.26505	0.14480	0.31147	0.25419
Plastic	0.25279	0.24085	0.10466	0.22354	0.19035	0.36001	0.30596	0.70493	0.45946
Simple Average	0.1805	0.1575	0.1516	0.1855	0.1458	0.2502	0.2336	0.2777	0.1890
Weighted Average	0.1789	0.1148	0.1532	0.1793	0.1431	0.2440	0.2499	0.2937	0.1987
g1	-0.65308	-0.65488	-0.64877	-0.63525	-0.69334	-0.64550	-0.63187	-0.64711	-0.69733
Standard Error	0.01876	0.06016	0.05771	0.06125	0.04909	0.04263	0.04621	0.04260	0.06860
g2	-0.09011	-0.23812	-0.18043	-0.29906	0.12149	-0.03170	-0.24643	0.03094	-0.09187
Standard Error	0.06036	0.22389	0.19435	0.21023	0.08955	0.11757	0.16767	0.12642	0.21145
Likelihood	20795	2410	2581	2661	2665	2781	2790	2511	2762

The estimates by Kalman smoother.
See Section 4 for details.

Figure 1

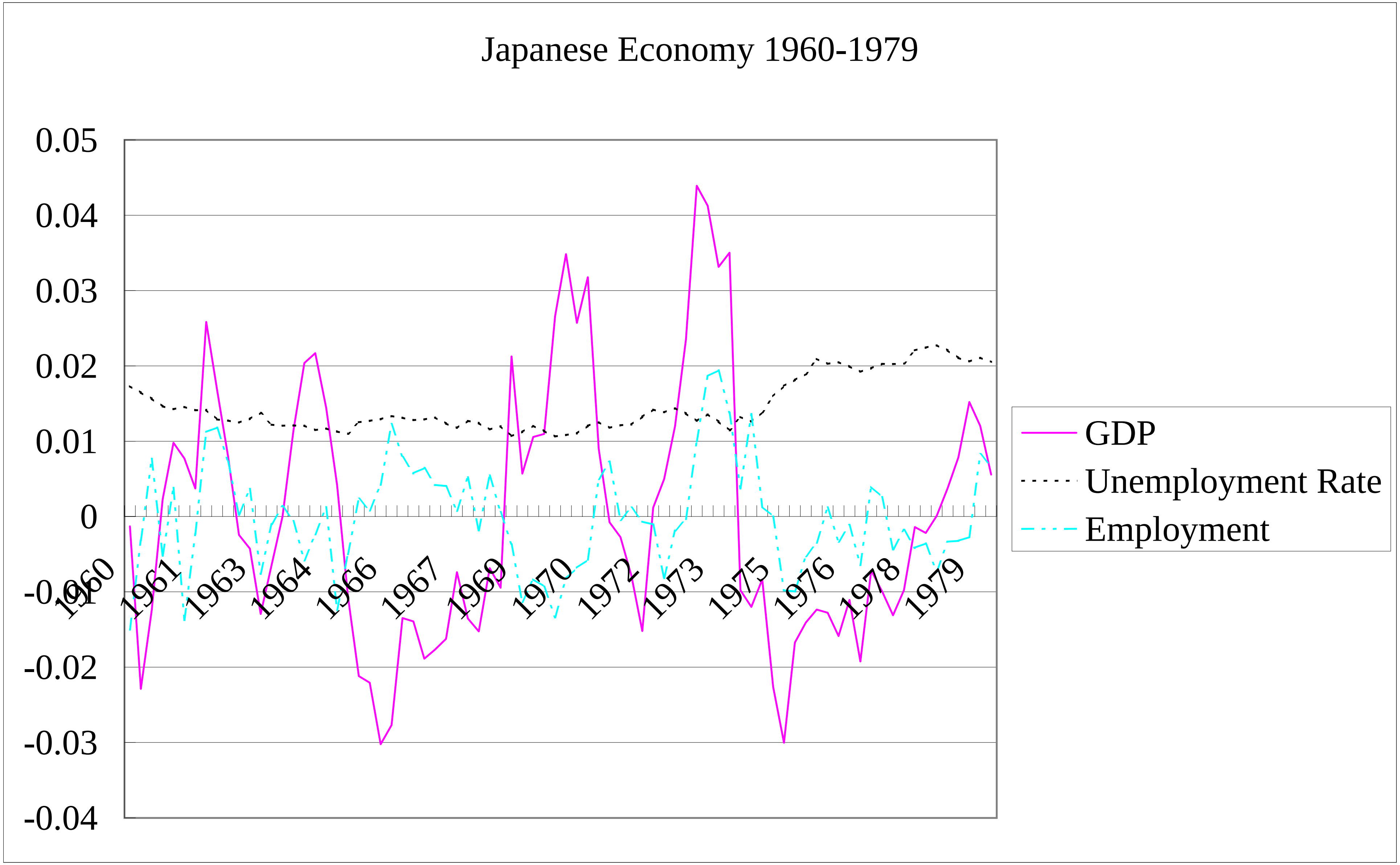
Japanese Economy 1960-1979
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
1960
1961
1963
1964
1966
1967
1969
1970
1972
1973
1975
1976
1978
1979
GDP
Unemployment Rate
Employment

Figure 2
Total Production Index and Contraction Periods

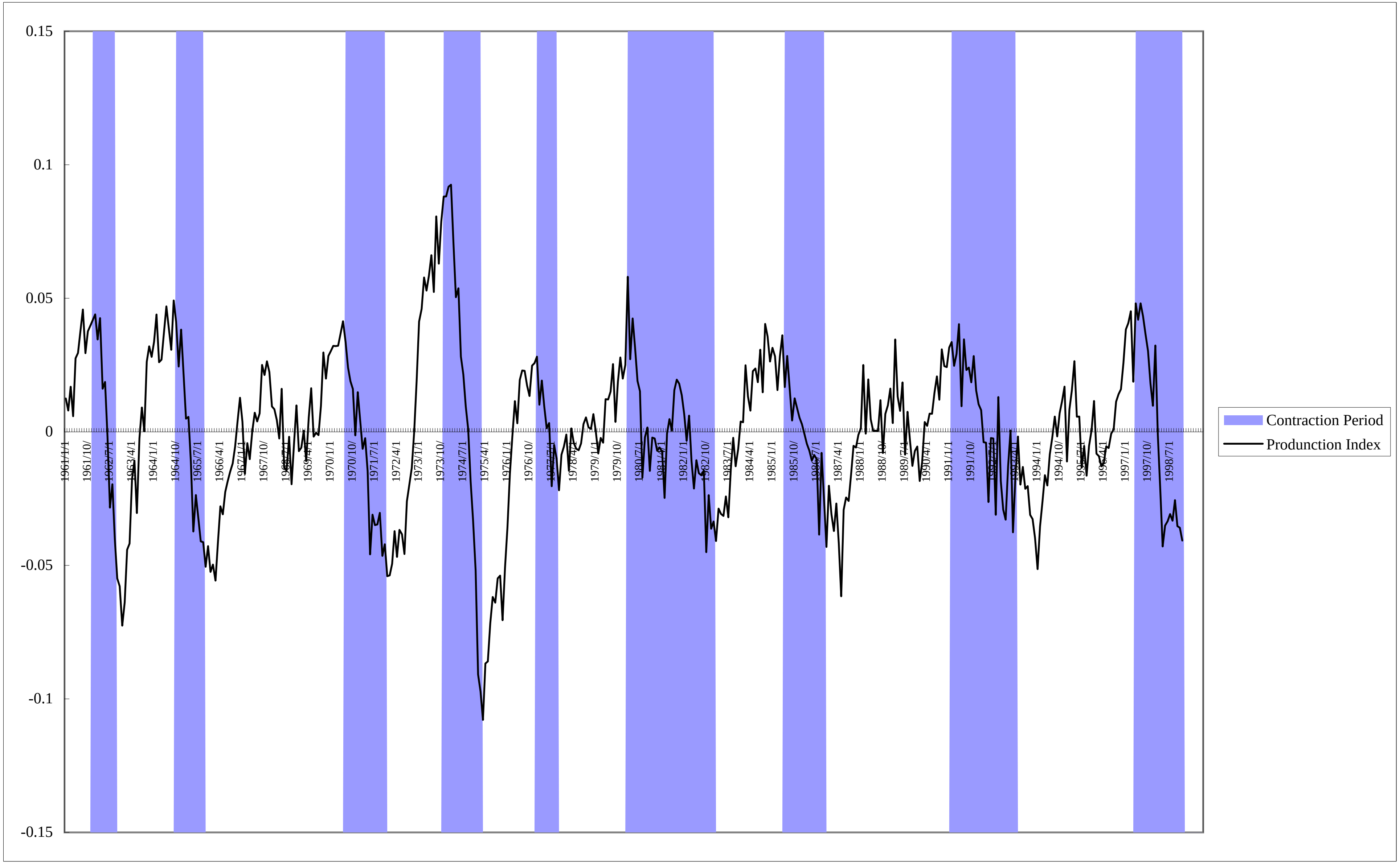

Figure 3

Total Production Index and Contributions of Common Factor