What explains the recent fluctuations in Japan's output? A structural factor analysis of Japan's industrial production

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Abstract

Since the mid-2000s, Japan's industrial production (IP) has been characterized by increasing volatility. To examine the background to this, we apply the structural factor analysis developed by Foerster, Sarte, and Watson (2011) and decompose variations in Japan's IP into aggregate and sectoral shocks taking input-output relationships between sectors into account. We find that aggregate shocks explain most of the fluctuations in Japan's IP and are highly correlated with variations in overseas economic growth, especially since the early 2000s. However, we find a large increase in the relative importance of sectoral shocks when focusing on the more recent increase in the volatility of IP. Specifically, our analysis suggests that the intersectoral spillovers brought about by the disruptions of supply chain network in the wake of Great East Japan Earthquake and the declines of domestic production (or production capacity) in some sectors as a result of a deterioration in global competitiveness or the shift to overseas production have contributed to the recent fluctuations of Japan's IP.

JEL Classification: E23, E32, C32

Keywords: Industrial Production; Structural Factor Analysis; Lehman Shock; Great East Japan Earthquake; Supply Chain Network; Input-output Matrix

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1 Introduction

Japan's industrial production (IP) was relatively stable until the mid-2000s, but since then has become increasingly volatile.[1] During the global financial crisis, the growth rate of IP dropped more severely in Japan than that in the United States, where the financial crisis originated. IP in Japan also registered sharp declines in the immediate aftermath of the Great East Japan Earthquake in March 2011 and in the subsequent period (Figure 1). Breaking down changes in IP by sector shows that the large swings in IP are largely due to the simultaneous movement of output in different sectors rather than by developments in, say, one or two particular sectors (Figure 2).

Thus, in recent years, Japan's economy has been subject to a variety of shocks, and these appear to have substantially affected IP. However, the nature of the shocks and the way they have propagated through the economy are not entirely clear, and there are a variety of possible explanations for the observed patterns. One possible explanation is that the recent fluctuations in Japan's IP have been driven by aggregate shocks which affected all (or a large number of) sectors. Another possible explanation is that they have been driven by sectoral shocks which, however, affected other sectors through production linkages, thus causing output in various sectors to move in a synchronized fashion. Yet another potential explanation is that by coincidence numerous sectors were affected by sectoral shocks in the same direction at the same time.

Against this background, the aim of this study is to investigate the sources of the recent fluctuations in Japan's IP by examining the sectoral comovement observed in the data. For this purpose, we apply the structural factor analysis developed by Foerster, Sarte, and Watson (2011, FSW henceforth) to Japan's IP. In the FSW framework, a time series model is presented as a reduced form of a multi-sector dynamic stochastic general equilibrium (DSGE) model into which intersectoral production linkages are explicitly incorporated. Employing this framework makes it possible to decompose variations in sectoral and aggregate IP into aggregate shocks and sectoral shocks by taking into account the input-output relationships between sectors. In other words, the FSW framework is superior to other factor models in that it correctly estimates the importance of aggregate shocks by disentangling spillover effects through production linkages from purely aggregate shocks.[2]

Using the structural factor analysis they develop, FSW investigate the reasons for the reduction

[1] In this study, we use the adjusted-base index of Japan's IP (2005 base year), which is calculated by detecting large fluctuations after the Lehman shock as outliers (estimation by the Research and Statistics Department, Bank of Japan). Since Japan's IP fell sharply for about six months since fall 2008 as a result of the Lehman shock, quarterly changes of the released-base seasonally adjusted figures, which regard this fall as a seasonal factor, tend to be somewhat stronger in the fourth and first quarters than the adjusted-base seasonally adjusted figures, which treat this factor as an outlier. The series of the adjusted-base index of Japan's IP is released in the Bank of Japan's "Monthly Report of Recent Economic and Financial Developments".

[2] If it is the case that the movements in some large industries have dominant impact on the variations of aggregate IP (as is discussed by Gabaix (2011)), the advantage of using structural factor analysis is relatively small. In this respect, FSW confirm that this hypothesis can be rejected by a statistical decomposition of the variations of IP in the U.S. economy. Our study also rejects the hypothesis using the same methodology of FSW in Appendix 1. We also confirm that it is quite important to take into account the cross-correlations of sectoral IP to investigate the background for the variations of Japan's aggregate IP.

in the variations in IP in the U.S. economy during the "Great Moderation" since the mid-1980s. Their analysis indicates that the volatility of IP in the U.S. has decreased mainly due to a decline in the importance of aggregate shocks and the consequent increase in the relative importance of sectoral shocks. They argue that since sectoral shocks occur independently across different sectors, they may cancel each other out, so that variations in aggregate IP may decline if the relative importance of sectoral shocks increases. FSW's empirical analysis suggests that this has indeed been the case in the U.S. economy since the mid-1980s. However, their data sample does not include the large variations in IP following the Lehman shock.[3] In addition, it appears that the U.S. economy did not experience any large shocks causing negative intersectoral spillover effects the way that Japan did as a result of disruptions to supply chain networks due to the Great East Japan Earthquake. Therefore, applying structural factor analysis to recent variations in Japan's IP is likely to yield new insights into the nature of shocks and their propagation mechanisms through the rest of the economy in a context other than the U.S. economy.

To the best of our knowledge, this study is the first to apply structural factor analysis to Japan's IP. However, it is closely related to a number of studies, such as those by Iyetomi et al. (2011) and Kimura and Shiotani (2009), which have attempted to determine the sources of variations in Japan's IP using different time series methodologies. In contrast to FSW and our study, these studies aim to determine whether the major sources of the fluctuations in Japan's IP are demand shocks or supply shocks by using inventory as well as production data, rather than paying attention to intersectoral production linkages. These studies also differ from ours in that their analysis does not include data for the period after the Great East Japan Earthquake. Another closely related study is that by Shioji and Uchino (2012), who investigate the mechanisms underlying the large decline in Japan's IP after the Lehman shock, focusing especially on the automobile industry. They carry out a panel analysis using production, shipment, and inventory data of Japanese automobile companies located in Japan and the United States. However, their study also does not investigate intersectoral production linkages, and they do not examine data for the period after the Great East Japan Earthquake. Therefore, our analysis can be considered to be the first to investigate these aspects.

The rest of this paper is organized as follows. Section 2 explains the structural factor analysis framework employed in this study. Section 3 then apply this framework to Japan's IP from the late 1970s onward to evaluate the relative importance of aggregate shocks and sectoral shocks. Section 4 then examines the recent increase in fluctuations in Japan's IP in greater detail. Finally, Section 5 concludes.

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[3] Stock and Watson (2012) investigate the macroeconomic dynamics in the recession and the subsequent slow recovery after the financial crisis, based on a dynamic factor model. However, their analysis is not based on the structural factor analysis taking account of intersectoral production linkages.

2 Structural factor analysis

2.1 Model

In the structural factor analysis developed by FSW, the model is presented as a multisector DSGE model, which takes the following form:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \sum_{j=1}^{N} \left(\frac{C_{jt}^{1-\sigma} - 1}{1-\sigma} - \psi L_{jt} \right), \tag{1}$$

subject to

$$C_{jt} + \sum_{i=1}^{N} M_{jit} + \sum_{i=1}^{N} Q_{jit} = Y_{jt}, \tag{2}$$

$$Y_{jt} = A_{jt} K_{jt}^{\alpha_j} \left(\Pi_{i=1}^{N} M_{ijt}^{\gamma_{ij}} \right) L_{jt}^{1-\alpha_j - \sum_{i=1}^{N} \gamma_{ij}}, \tag{3}$$

$$\ln A_t = \ln A_{t-1} + \varepsilon_t. \tag{4}$$

$$K_{jt+1} = Z_{jt} + (1-\delta) K_{jt}, \tag{5}$$

$$Z_{jt} = \Pi_{i=1}^{N} Q_{ijt}^{\theta_{ij}}, \quad \sum_{i=1}^{N} \theta_{ij} = 1, \tag{6}$$

In this economy, there are N distinct sectors indexed by $j = 1, \ldots, N$. t is a time subscript. (1) is a standard utility function maximized by a representative household, with C_{jt} representing a consumption of good j and L_{jt} representing a labor supply in sector j. (2) represents the resource constraints in sector j. Output Y_{jt} are not only directly consumed as C_{jt}, but also used as intermediate input for producing consumption goods in sector i (M_{jit}) and as intermediate goods for producing investment goods in sector i (Q_{jit}).

(3) is the production function in sector j (Y_{jt}). Y_{jt} is produced using capital (K_{jt}), labor (L_{jt}), and intermediate goods produced in various sectors. (4) indicates that the vector of shift parameters for sectoral production functions ($A_t = (A_{1t}, \ldots, A_{Nt})'$) follows a random walk process, where $\varepsilon_t = (\varepsilon_{1t}, \ldots, \varepsilon_{Nt})'$ is a vector of structural shocks to sectoral production functions.[4] (5) is the law of motion for capital stock in sector j, where Z_{jt} denotes sector investment in sector j. (6) is the production function for investment goods in sector j. Z_{jt} is produced using amount Q_{ijt} of good i with the constant returns to scale technology. The values of α_j, γ_{ij}, and θ_{ij} are taken from the input-output matrix.

FSW derive the first order conditions (FOCs) of the above model. They then show that a linear approximation of the FOCs and resource constraints around the deterministic steady state

[4] The simplest interpretation of this specification is to regard ε_t as a vector of productivity shocks. However, as we show in Appendix 2, it is possible to incorporate exogenous demand shocks into the resource constraint (2), so that the estimates of ε_t include demand shocks. Therefore, in the analysis below, we assume that our estimates of structural shock ε_t include not only productivity shocks.

of the model yields the following vector ARMA(1,1) model for sectoral output growth $X_t = (\Delta \ln Y_{1t}, \ldots, \Delta \ln Y_{Nt})'$ and structural shocks ε_t:

$$(I - \Phi L)X_t = (\Pi_0 + \Pi_1 L)\varepsilon_t, \tag{7}$$

where L is the lag operator and Φ, Π_0, Π_1 are $N \times N$ matrices which depend on structural parameters α_j, γ_{ij}, θ_{ij}, β, σ, ψ, and δ.[5]

2.2 Shock decomposition

In the structural factor analysis, we decompose the series of structural shocks ε_t, obtained from (7), into aggregate and sectoral shocks as follows:

$$\varepsilon_t = \Lambda_s S_t + \nu_t, \tag{8}$$

where S_t is a $k \times 1$ vector of aggregate shocks, which is estimated as the principal components of ε_t, where k is the number of factors.[6] ν_t is an $N \times 1$ vector of sectoral shocks. Λ_s is an $N \times k$ matrix of coefficients determining the impact of aggregate shocks on productivity in individual sectors. FSW assume that (S_t, ν_t) is serially uncorrelated, S_t and ν_t are mutually uncorrelated, and the matrix $E\nu_t\nu_t'$ is diagonal, which means that sectoral shocks are mutually independent across different sectors.

The approach here differs from typical dynamic factor analyses in the sense that it takes account of intersectoral production linkages. This can be understood by rewriting the model described by (7) and (8) as the following dynamic factor model:

$$X_t = \Lambda(L)F_t + u_t, \tag{9}$$

where $\Lambda(L) = (I - \Phi L)^{-1}(\Pi_0 + \Pi_1 L)\Lambda_s$, $F_t = S_t$, and $u_t = (I - \Phi L)^{-1}(\Pi_0 + \Pi_1 L)\nu_t$. F_t is a vector of common factors and u_t is a vector of reduced-form idiosyncratic factors. Note that, because of the presence of the coefficient matrix $(I - \Phi L)^{-1}(\Pi_0 + \Pi_1 L)$, the covariance matrix of u_t does not generally become a diagonal matrix, even if the elements of ν_t are uncorrelated. This means that sectoral shocks can yield cross-sectional correlations in output growth through input-output production linkages. In this situation, typical dynamic factor analyses assuming that the elements of u_t are mutually uncorrelated across sectors results in incorrect estimates of the importance of

[5] For the definitions of Φ, Π_0, and Π_1, see Appendix B of FSW (available online only; http://public.econ.duke.edu/~atf5/FSW%20Technical%20Appendix.pdf).

[6] In our main analysis, we choose $k = 1$ to facilitate the economic interpretation of aggregate shocks. However, in the sensitivity analysis in Appendix 3, which examines the sensitivity of our results to various alternative model specifications, we also set $k = 2$ and find that main results in our analysis remain largely unchanged.

aggregate shocks.

2.3 Data and parameters

Next, let us explain Japan's IP data used for our analysis. The data of Japan's IP is published as a monthly series by the Ministry of Economy, Trade and Industry (METI). However, following FSW, to eliminate excessive volatility, we convert monthly data into quarterly data. The observation period is 1978:Q1 to 2012:Q4. Regarding the sectoral breakdown, we avoid excessive disaggregation in order to provide intuitive explanations about the sources of fluctuations in IP in each period. Specifically, we distinguish between the following 19 industries:[7] iron and steel; non-ferrous metals; fabricated metals; general machinery; electrical machinery; information and communication electronics equipment; electronic parts and devices; transport equipment (excl. motor vehicle parts); motor vehicle parts; precision instruments; ceramics, stone and clay products; chemicals; petroleum and coal products; plastic products; pulp, paper and paper products; textiles; foods and tobacco; other manufacturing; and mining. To calculate IP of "transport equipment (excl. motor vehicle parts)," we use IP data for transport equipment and motor vehicle parts as well as the shares of these industries in total IP.

Next, let us explain the values for the model parameters. The parameters for sectoral production linkages, γ_{ij} and θ_{ij} are calculated from the 2005 input-output and fixed capital matrices provided by Japan's Cabinet Office. Since we use data for 19 sectors, we construct an input-output matrix consisting of 19 sectors by rearranging the original matrix with 108 sectors (Table 1). The fixed capital matrix with 19 sectors is constructed in a similar manner (Table 2). Capital shares (α_j) are calculated as the ratio of the cost of inputs (raw materials and capital inputs) to gross value added excluding indirect taxes (Table 3). The calculation of capital shares is the same as in FSW. As for structural parameters other than those from the input-output matrix, we use standard values ($\beta = 0.99$, $\sigma = 1.0$, $\psi = 1.0$, $\delta = 0.025$) widely used in theoretical studies, including FSW. Appendix 3 examines the sensitivity of our results to the choice of parameter values.

3 The importance of aggregate and sectoral shocks for Japan's IP

3.1 Results of shock decomposition

In this section, we apply the structural factor analysis to Japan's IP since the late 1970s and decompose the sources of variations in IP into aggregate and sectoral shocks. We start by decomposing

[7] FSW use data for 117 sectors for their main analysis. However, they also use other levels of industry aggregation, consisting of, e.g., 26 sectors. Doing so, they find that the relative importance of aggregate and sectoral shocks remains largely unchanged when using alternative levels of industry aggregation.

the variance of structural shocks ε_t into aggregate shocks S_t and sectoral shocks ν_t. The results are shown in Table 4. We then also decompose the variance of the average of structural shocks across sectors ($\bar{\varepsilon}_t = \sum_{i=1}^{N} \omega_{it}\varepsilon_{it}$), where ω_{it} is the sectoral share in total IP. The result suggests that aggregate shocks accounted for 72.1% and hence the largest part of structural shocks to IP for the observation period as a whole.[8]

Figure 3 shows the results of the decomposition of average structural shocks ($\bar{\varepsilon}_t$) for each quarter from 2000 to 2012. As can be seen, aggregate shocks explain a substantial part of the variation in $\bar{\varepsilon}_t$. In particular, the large negative $\bar{\varepsilon}_t$ after the global financial crisis is explained almost solely by aggregate shock. However, in other periods with large negative structural shocks, such as after the collapse of the dot-com bubble in 2000-2001 and the Great East Japan Earthquake in 2011, sectoral shocks appear to have played an important role. Therefore, although aggregate shocks are a very important determinant of $\bar{\varepsilon}_t$, there are some periods in which sectoral shocks have played an important role.

3.2 Impulse responses

Next, we examine the impulse responses of the structural factor model. Figure 4 shows the impulse responses of sectoral output growth to a negative aggregate shock with one standard deviation for the observation period from 1978:Q1 to 2012:Q4. In almost all sectors, growth rates decline after a negative aggregate shock. Next, we examine the impulse responses to sectoral shocks. Since there are too many combinations of the responses of sectoral production growth to sectoral shocks, we select two examples, namely shocks to the electronic parts and devices sector and to the motor vehicle parts sector, to illustrate intersectoral spillovers from upstream to downstream industries. Specifically, we look at the impact of a negative shock of one standard deviation and again focus on the observation period as a whole. Figure 5 shows the results. Starting with the electronic parts and devices sector (panel (a)), we find that the responses to a sectoral shock in this sector are relatively large in sectors which use a relatively large amount of electronic parts and devices as intermediate inputs, such as information and communication electronics equipment, precision instruments, electrical machinery, and general machinery. Turning to motor vehicle parts, panel (b) shows that the response to a sectoral shock in this sector is particularly large in the transport equipment (excl. motor vehicle parts) sector, which is a downstream sector of the motor vehicle parts sector. In the impulse responses, we define the impact of a sectoral shock on production in other sectors – such as the impact of a sectoral shock in the electronic parts and devices industry on production in the electrical machinery industry – as “intersectoral spillover effects”.

In order to check the plausibility of our results and the properties of the model, we carry out a

[8] For the subperiod before the Lehman shock (i.e., 1978:Q1 to 2007:Q4), aggregate shocks still explain nearly half of the variations in structural shocks to IP.

Monte-Carlo simulation. Specifically, we assume that the structural shocks ε_t follow a multivariate normal distribution in which the mean and variance are given by the estimated series for aggregate shocks S_t and sectoral shocks v_t. That is:

$$E(\varepsilon_t) = \Lambda_s \frac{1}{t}\sum_t S_t + \frac{1}{t}\sum_t \nu_t, \quad Var(\varepsilon_t) = \Lambda_s \frac{1}{t}\sum_t S_t S_t' \Lambda_s' + \frac{1}{t}\sum_t \nu_t \nu_t'.$$

Based on the generated series of structural shocks ε_t, we calculate the simulated path of sectoral IP and compute the cross-sectional correlations in the simulated IP growth path. Table 5 compares the actual correlation matrix of sectoral growth rates with the simulation results. We find that the simulated covariance matrix is generally consistent with the actual matrix, since the differences between simulated and actual cross-correlations are small (less than 0.2) in most sectoral combinations. This means that our model is a good approximation of the data-generating process of Japan's IP and that our assumptions regarding the properties of structural shocks – namely that (i) ε_t follows a multivariate normal distribution, (ii) S_t and v_t are independent, and (iii) $E\nu_t\nu_t'$ is diagonal – are plausible.

3.3 Decomposition of Japan's IP

Using structural factor analysis allows us to decompose growth rates of sectoral IP into the sum of aggregate shocks and the sum of sectoral shocks by converting the vector ARMA(1, 1) model of (7) into an MA(∞) model. The growth rate of aggregate IP is then calculated as the weighted average of the sum of aggregate shocks and the sum of sectoral shocks. The results of this decomposition for the period from 2000 to 2012 are shown in Figure 6 and indicate that aggregate shocks play an important role in the variations in Japan's aggregate IP. For example, the huge decline in total output during the global financial crisis is almost solely explained by aggregate shocks. Table 6 shows that aggregate shocks explain 87.5% of the variations in aggregate growth rate during the entire period.

For the case of the U.S. economy, FSW report that in the period of 1984-2007, aggregate shocks accounted for 53% of aggregate fluctuations in IP, when using two-digit level industry classifications (26 sectors). Although a direct comparison with our analysis is difficult because of differences in the number of sectors and the observation period, it seems reasonable to observe that the importance of aggregate shocks in Japan is at least not smaller than in the United States. In sum, it can be said that aggregate shocks explain a major part of the fluctuations in Japan's IP in the entire observation period from the late 1970s to 2012.

3.4 The sources of aggregate shocks

Given our finding that aggregate shocks play quite an important role in explaining fluctuations in Japan's IP, the next thing to explore is the sources of those aggregate shocks. To this end, we examine the correlations between aggregate shocks and various economic variables that can be viewed as exogenous to domestic IP and that may have an impact on a broad range of manufacturing sectors. Specifically, we focus on the following four potential factors: (i) domestic financial conditions, (ii) foreign economic growth, (iii) the real exchange rate, and (iv) service sector activity. As for the data, we use the diffusion index of the lending attitude of financial institutions published in the Bank of Japan's *TANKAN* survey for (i), foreign GDP growth for (ii), the real effective exchange rate released by the Bank for International Settlements for (iii), and the index of tertiary industry activity published by METI for (iv).[9]

Table 7 shows the correlation between aggregate shocks and the different variables between 1985:Q1 and 2012:Q4.[10] We find that the correlation is highest (0.59) with respect to foreign GDP growth.[11] Further, Figure 7 shows the correlation coefficients for five-year rolling windows for each of the four variables. The correlation with domestic financial conditions was relatively high in the 1990s – Japan's "lost decade" when the economy experienced a long period of stagnation mainly due to the deteriorating situation in the financial sector.[12] However, the correlation sharply declined in the early 2000s. The correlation with foreign GDP growth was relatively low until the mid-1990s. However, it increased sharply in the late 1990s and reached a very high level (of almost 0.8) in the first half of the 2000s. Although it declined somewhat in the mid-2000s, it then increased again following the Lehman shock. The correlation with the real exchange rate and with service sector activity is relatively small on the whole, and in some cases, even though the correlation is relatively large, it has the opposite sign of what theoretical considerations would suggest.[13]

The analysis thus suggests that the source of aggregate shocks changed over time. In the 1990s, aggregate shocks were largely driven by domestic financial problems. However, from the early 2000s onward, they have been influenced more by world economic conditions, reflecting the

[9] The data for foreign GDP growth are constructed by weighting each country's GDP growth with the country's share in Japan's exports.

[10] It should be noted that the correlation with the index of tertiary industry activity is calculated from 1988:Q2, the first period for which data are available.

[11] We checked the correlation of aggregate shocks with several hundred different time series. However, we did not find any series whose correlation with aggregate shocks is as high and stable as foreign GDP growth.

[12] Muto, Sudo, and Yoneyama (2013), using an estimated DSGE model with financial frictions, show that financial factors explain a large part of the stagnation during Japan's lost decade.

[13] From a theoretical point of view, we would expect the real effective exchange to be negatively correlated with exports (and hence domestic production). However, for much of the period we examine, the correlation coefficient is actually positive, and considerably so in the early and mid-2000s. Turning to service sector activity, we find that the correlation with aggregate shocks in manufacturing was relatively small until the onset of the financial crisis brought on by the Lehman shock, when a large jump in the correlation can be observed. However, because service sector activity, like IP, was greatly affected by the global financial crisis, a natural interpretation is that the jump in the correlation is the result of a decline in foreign GDP growth.

increased linkages between manufacturing activity in Japan and the global economy.[14]

4 Reasons for the recent increase in fluctuations in Japan's IP

4.1 The recent increase in the importance of sectoral shocks

In Section 3, we showed that aggregate shocks played a dominant role in explaining fluctuations in Japan's aggregate IP for the observation period from the late 1970s until 2012 as a whole. However, this does not mean that the increase in fluctuations in Japan's aggregate IP in recent years, and especially since the Lehman shock, has been brought by aggregate shocks. In fact, as seen in Figure 3, the contribution of sectoral shocks to structural shocks has increased notably in recent years. Further, Figure 6 indicated that the large fall in aggregate IP growth right after the Lehman shock was almost exclusively explained by aggregate shocks; it also suggested, however, that the relative importance of sectoral shocks greatly increased following the Great East Japan Earthquake.

Table 8 shows the relative contribution of aggregate and sectoral shocks to the variance of structural shocks ε_t for the three years from 2010 to 2012. The table indicates that the contribution of aggregate shocks was 21.1%, which is considerably smaller than that for the whole observation period, which was 72.1% (Table 4). Moreover, comparing the results at the sectoral level for 2010-2012 (Table 8) with those for the period 1978-2012 (Table 4) shows that in some industries where aggregate shocks played an important role in the observation period as a whole (such as iron and steel, non-ferrous metals, electronic parts and devices, motor vehicle parts, and ceramics, stone and clay products), sectoral shocks have dominated in the subperiod since 2010.

In order to understand the reasons for the increase in the importance of sectoral shocks, it is necessary to examine in detail the nature of the shocks in recent years and their propagation mechanisms, including the period following the Great East Japan Earthquake.

4.2 Intersectoral spillover effects of sectoral shocks in the period following the Great East Japan Earthquake

In this subsection we investigate the reasons for the decline in aggregate IP after the Great East Japan Earthquake. Figures 3 and 6 showed that in 2011:Q2 – that is, immediately after the earthquake – Japan experienced a substantial decline in IP and that much of this was due to sectoral shocks. However, our analysis so far has not examined how a sectoral shock in one particular sector affects production in other sectors. Yet, there are clear indications that in the period following

[14] Setting the ratio of real exports to aggregate IP for 1990:Q1 to 100 (using real export data published by the Bank of Japan), this index increased to 151.7 in 2000 and 234.7 in 2010.

the Great East Japan Earthquake, supply chain disruptions had a severe impact on production activities in certain sectors such as the automobile and electronics industries. In order to gauge the size of this impact, it is necessary to quantify the intersectoral spillover effects of sectoral shocks.

In the impulse responses presented in Section 3.2, we defined the impact of a sectoral shock on production in other sectors as intersectoral spillover effects. We employ the same definition here and decompose changes in total IP into those due to aggregate shocks and sectoral shocks, which we further decompose into the contribution of spillovers from one specific sector to all other sectors. Table 9 shows the results. Specifically, the table shows that aggregate IP fell by 4.8% in 2011:Q2, and the contribution of intersectoral spillovers to this was about 0.9 percentage points or approximately 20%. This result indicates that intersectoral spillovers contributed to the sectoral shocks and hence the decline in aggregate IP in the wake of the Great East Japan Earthquake.

These intersectoral spillovers are likely to have been brought about by the disruption of supply chains, which particularly affected the automobile and electronics industries. In order to examine this issue, we calculate the spillover effects of sectoral shocks in the motor vehicle parts and electronic parts and devices industries. The results indicate that spillovers from sectoral shocks in the motor vehicle parts industry accounted for 0.7 percentage points of the decline in aggregate IP and those in the electronic parts and devices industry for 0.4 percentage points. This suggests that the interruption of intermediate goods production had a considerable negative impact on final goods productions in the automobile and electronics sectors.[15] Further, Figure 8 shows the effect of sectoral shocks in the motor vehicle parts and electronic parts and devices industries through spillover effects on production in the transport equipment (excl. motor vehicle parts) and electrical machinery industries. As can be seen, the effects were clearly negative in the period immediately following the earthquake.[16]

Next, let us consider possible reasons why the negative spillover effects due to the disruption of supply chains were particularly large in the automobile and electronics industries. The 2009 *Census of Manufactures* shows that the disaster-stricken area (Aomori, Iwate, Miyagi, Fukushima, Ibaraki, and Chiba) accounted for more than a tenths (12.7%) of total shipments of electronic parts and devices sector. On the other hand, in the case of the automobile industry, the share of this area in total shipments was relatively small (2.9%). However, the statistics of the demand structure of motor vehicle sector (Table 10) shows that the ratio of intermediate input is relatively high in Tohoku area, compared to those in other regions. In addition, concerning firms' inventory

[15] Following FSW, our model is based on a Cobb-Douglas production function in which the elasticity of substitution is assumed to be unity. If we take account of the bottlenecks in motor vehicle and electronic parts, which seem to have caused serious problems in the period following the earthquake, it might be better to view that the actual impact of intersectoral spillover effects was at least more than our estimate.

[16] Arai et al. (2012) calculate the impact of the disruption of supply chain networks due to the Great East Japan Earthquake using a regional input-output matrix. They find that the impact was especially large in the automobile and electronics industries. Although their finding is qualitatively similar to ours, their analysis does not identify aggregate shocks and sectoral shocks.

management, Japanese automobile companies traditionally have very small inventory ratios, which, moreover, are far below those in the electronic industry (Figure 9). As a result, the interruption of production in motor vehicle parts led to serious shortages of intermediate goods, which caused the large decline in Japan's automobile production.

4.3 Reasons for the recent increase in the importance of sectoral shocks

The previous subsection focused on the role of intersectoral spillovers in the period following the Great East Japan Earthquake. However, Figures 3 and 6 above suggested that even if the period following the earthquake is excluded, the role of sectoral shocks in fluctuations in aggregate IP has greatly increased. Therefore, in order to examine the impact of sectoral shocks in each sector on movements in aggregate IP in recent years, we decompose the level of aggregate IP from 2010:Q1 onward into the contribution of aggregate shocks and sectoral shocks in each sector. The results are shown in Figure 10 and suggest that, during this period, sectoral shocks in certain sectors have had a large impact on fluctuations in aggregate IP. Sectors experiencing particularly large negative sectoral shocks include transport equipment (excl. motor vehicle parts), electronic parts and devices, and information and communication electronics equipment. Taken together, sectoral shocks in these sectors explain 5.1 percentage points of the total decline in IP of 6.2% from 2010:Q1 to 2012:Q4; that is, more than 80%. Another sector that is worth mentioning is general machinery. The decomposition in Figure 10 suggests that general machinery consistently made a positive contribution to changes in aggregate IP. However, this positive contribution rapidly diminished during the latter half of 2012, which appears to have greatly contributed to the decline in aggregate IP.

The next issue we need to examine is whether the recent fluctuations in IP in the above four sectors were brought by similar or by different factors. Figure 11 compares the cumulative sum of sectoral shocks and the sectoral production capacity index, which is published by METI, for the four industries.[17] Starting with transport equipment, the figure indicates that production capacity has remained more or less unchanged, although there have been large fluctuations in the cumulative sum of sectoral shocks. Similarly, production capacity in general machinery has also been quite stable, although the cumulative sum of sectoral shocks has shown large fluctuations. In contrast, production capacity in electronic parts and devices followed an upward trend until 2011, but has stagnated since then, while the cumulative sum of sectoral shocks has declined since the beginning of 2011. Finally, production capacity in information and communication electronics equipment has clearly declined since the latter half of 2011, while the cumulative sum of sectoral shock has been on a downward trend.

[17] The production capacity index measures the maximum output possible under certain conditions over a given period of time, for a given labor supply and a given capital stock. In Figure 11, we use production capacity for transport equipment instead of that for transport equipment (excl. motor vehicle parts), because information on the latter is not available.

The results suggest that sectoral shocks in the transport equipment and general machinery sectors seem to be qualitatively different from those in the electronic parts and devices and information and communication electronics equipment sectors in terms of their impact on production capacity. For example, as explained in the previous subsection, the large fall in IP in transport equipment was caused by the earthquake, which brought about negative intersectoral spillovers through supply chain networks. In addition, some part of the large decline in IP in transport equipment during 2012 is likely to have been the result of the ending of subsidies for purchasing energy-efficient cars and the change in the bilateral relationship between Japan and China in the second half of the year. As for general machinery, weakness in domestic and global demand for business fixed investment may have had a negative impact on production especially in this sector, but this does not appear to have resulted in a reduction in production capacity. On the other hand, as for electronic parts and devices as well as information and communication electronics equipment, at least part of the recent fall in production is likely to have been brought about by a decrease in production capacity as a result of a decline in international competitiveness and the shift to overseas production.

Thus, the recent increase in fluctuations in Japan's IP cannot be explained by a single cause. Rather, it appears that the decline in aggregate IP is due to a series of independent negative sectoral shocks simultaneously affecting different sectors. However, the decline in international competitiveness and the shift to overseas production, which appears to be currently going on in some sectors, can be viewed as a structural trend, and it is possible that this trend may have a long-lasting impact on Japan's aggregate IP.

5 Conclusion

In this study, we examined the reasons for the recent fluctuations in Japan's IP by applying the structural factor analysis developed by FSW. Our analysis for the entire observation period from the late 1970s suggested that the most important factor underlying fluctuations in Japan's IP was aggregate shocks, which affected manufacturing sectors across the board. Specifically, we found that, from the early 2000s onward, fluctuations in foreign economic growth were the most important source of aggregate shocks, reflecting the growing interconnectedness between Japan's manufacturing activities and the global economy.

However, focusing on the increase in the fluctuations in IP in recent years, we find that the relative importance of sectoral shocks has greatly increased. Our detailed analysis showed that negative intersectoral spillover effects due to disruptions of supply chain networks played an important part in the large decline in Japan's IP during the period following the Great East Japan Earthquake. However, we also found that, more generally, in recent years sectoral shocks to certain industries, such as the transport equipment, general machinery, electronic parts and devices, and information and communication electronics equipment industries, have played an important role in explaining fluctuations in Japan's aggregate IP.[18]

As outlined in the introduction, FSW, who developed the structural factor analysis employed here, report that the Great Moderation in the U.S. economy since the mid-1980s was brought by an increase in the relative importance of sectoral shocks. In contrast, the results obtained in this study suggest that, in the case of Japan in recent years, the increase in the importance of sectoral shocks has contributed to the increase in fluctuations in Japan's aggregate IP. Of course, the increased importance of sectoral shocks has been observed only in the past few years. In addition, the sectoral shocks have been partly driven by entirely non-economic factors, such as natural disasters and political problems. However, our analysis indicated that recent sectoral shocks include developments which lowered the production capacity in some sectors, such as the decline in international competitiveness and the shift to overseas production. This suggests that the increased importance of sectoral shocks may have partly been driven by structural factors. In any case, our results indicate that to understand the reasons for the fluctuations in aggregate IP it is important to examine sectoral factors which directly affect sectoral IP rather than to focus only on aggregate factors which affect all sectors.

[18] Another possible reason why we find that the importance of sectoral shocks has increased is that our analysis does not take account of possible structural changes in the input-output matrix after 2005, since the base year of the input-output matrix in our analysis is 2005. It is difficult for us to test this hypothesis, since the 2010 version of the input-output matrix has not yet been published. However, in Appendix 3, we show that the main results of our analysis remain almost unchanged even if we use the input-output matrixes for alternative base years (1995 and 2000). This result suggests that, unless Japan's industrial structure changed dramatically after 2005, our main results are fairly robust.

Appendix 1: The importance of sectoral output shares and intersectoral correlations

Table A.1 shows that the weights of individual sectors in Japan's IP vary considerably. In addition, the standard deviation of sectoral IP growth across sectors also varies. This being so, it could be the case that most of the fluctuations in Japan's aggregate IP are due to developments in the IP in a particular sector with a large overall output share. If this is indeed the case, we do not need to use all sectors in our analysis in order to understand the reasons for the fluctuations in aggregate IP. To examine whether this is the case, following FSW, we decompose the growth of aggregate IP into the following three components:

$$g_t = \frac{1}{N}\sum_{i=1}^{N} x_{it} + \sum_{i=1}^{N}\left(\overline{\omega}_i - \frac{1}{N}\right) x_{it} + \sum_{i=1}^{N}\left(\omega_{it} - \overline{\omega}_i\right) x_{it},$$

where ω_{it} is the weight (output share) and x_{it} is growth rate of output in sector i at period t. In the above equation, the first term on the right hand side represents a hypothetical aggregate growth rate assuming that the sectoral weights are identical for all sectors. The second term represents the effect of deviations of the historical average of the sectoral weights ($\overline{\omega}_i$) from the identical weight ($1/N$). The third term represents the effect of historical variations of sectoral weights. If the first term closely traces the movements of the actual growth rate of aggregate IP, this suggests that the distribution of sectoral weights and their change over time are not important for fluctuations in aggregate IP.

Figure A.1 shows that the first term is very closely correlated with the actual growth rate of aggregate IP. This indicates that the fluctuations in the IP of any particular sector do not have a dominant effect on movements in aggregate IP.

Next, we check the importance of taking account of sectoral correlations in analyzing fluctuations in aggregate IP. To do so, we decompose the variance of the growth rate of aggregate IP into the sum of the variances of the growth rates of sectoral IP and the covariance of the growth rates of sectoral IP:

$$Var\left(\sum_{i=1}^{N} \omega_{it} x_{it}\right) = \sum_{i=1}^{N} Var(\omega_{it} x_{it}) + \sum_{i=1}^{N}\sum_{j\neq i}^{N} Cov(\omega_{it} x_{it}, \omega_{jt} x_{jt}).$$

If there is no correlation among sectoral growth rates, the second term should be zero. Therefore, the difference between the left hand side and the first term of the right hand side shows the importance of sectoral correlations. Table A.2 shows that the first term accounts for less than half of the variance on the left hand side. This suggests that it is important to take account of the sectoral correlations to understand the reasons for the fluctuations in Japan's aggregate IP.

Appendix 2: Interpretation of structural shock ε_t

In the dynamic stochastic general equilibrium model presented in Section 2, structural shock ε_t is interpreted as a productivity shock. However, if we slightly extend the model, ε_t can be interpreted as a demand shock. To show this, we add exogenous demand D_t, which follows a random walk ($\ln D_t = \ln D_{t-1} + \xi_t$), to the resource constraint (2) in the model. If we solve the model, the reduced form of the model can be expressed as follows:

$$(I - \Phi L)X_t = (\Pi_0 + \Pi_1 L)\varepsilon_t + (\Psi_0 + \Psi_1 L)\xi_t,$$

where Ψ_0 and Ψ_1 are constant matrices determined by the structural parameters in the model. This equation indicates that the shock terms of the vector ARMA(1,1), which is the reduced form of the model, include both productivity and demand shocks. This result does not suggest that it is appropriate to assume that the estimated series of ε_t includes only productivity shocks.

Appendix 3: Sensitivity analysis

In this study, we use the 2005 versions of Japan's input-output matrix and fixed capital matrix. However, the observation period for IP used in our structural factor analysis is from 1978:Q1 to 2012:Q4. Therefore, our analysis is based on a snapshot of Japan's industrial structure in a single year which is relatively close to the end of the observation period. As for other structural parameters, we use the standard values widely used in theoretical studies, but one may wonder whether these values are appropriate for Japan. In addition, although we use only the first principal component of structural shock ε_t as aggregate shocks in our structural factor analysis, it is useful to carry out some sensitivity analyses to examine how the results change if a different number of principal components is used.

Table A.3 shows the results of the sensitivity analysis with regard to (i) the base year of the input-output matrix and fixed capital matrix, (ii) the values of structural parameters, and (iii) the number of principal components. Table A.3 presents the results of the variance decomposition of structural shocks and the growth rate of aggregate IP for the whole observation period and for the period from 2010 to 2012. For the whole observation period, the results suggest that aggregate shocks are relatively important both in terms of their contribution to structural shocks and their impact on the growth rate of aggregate IP, even when changing (i), (ii), and (iii). Next, if we compare the results for the period from 2010 to 2012 with those for the whole observation period, both the variance decomposition of structural shocks and the growth rate of aggregate IP show that the relative importance of sectoral shocks has increased even when changing (i), (ii), and (iii). These results indicate that the main results of our analysis are fairly robust to different specifications with regard to (i), (ii), and (iii).

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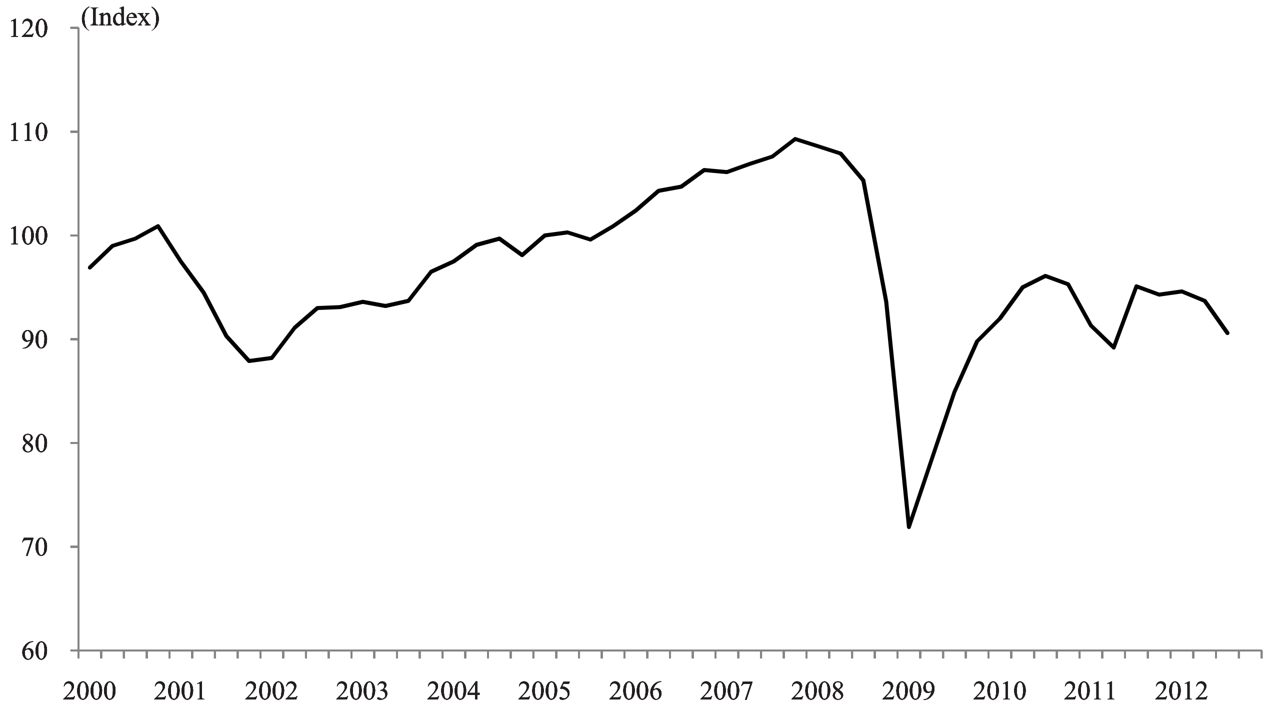
Figure 1: Japan's industrial production



Source: Ministry of Economy, Trade and Industry.

Figure 2: Growth rate of Japan's aggregate industrial production

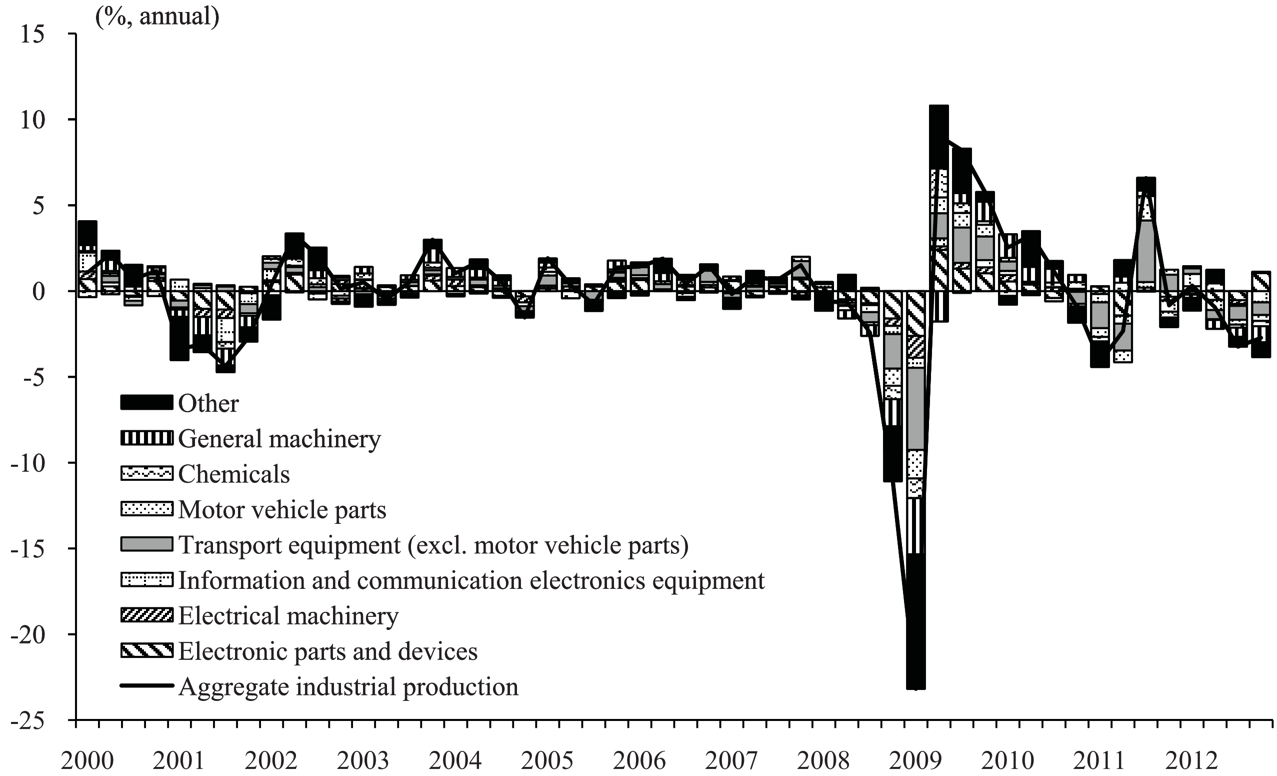


Figure 3: Decomposition of average structural shocks

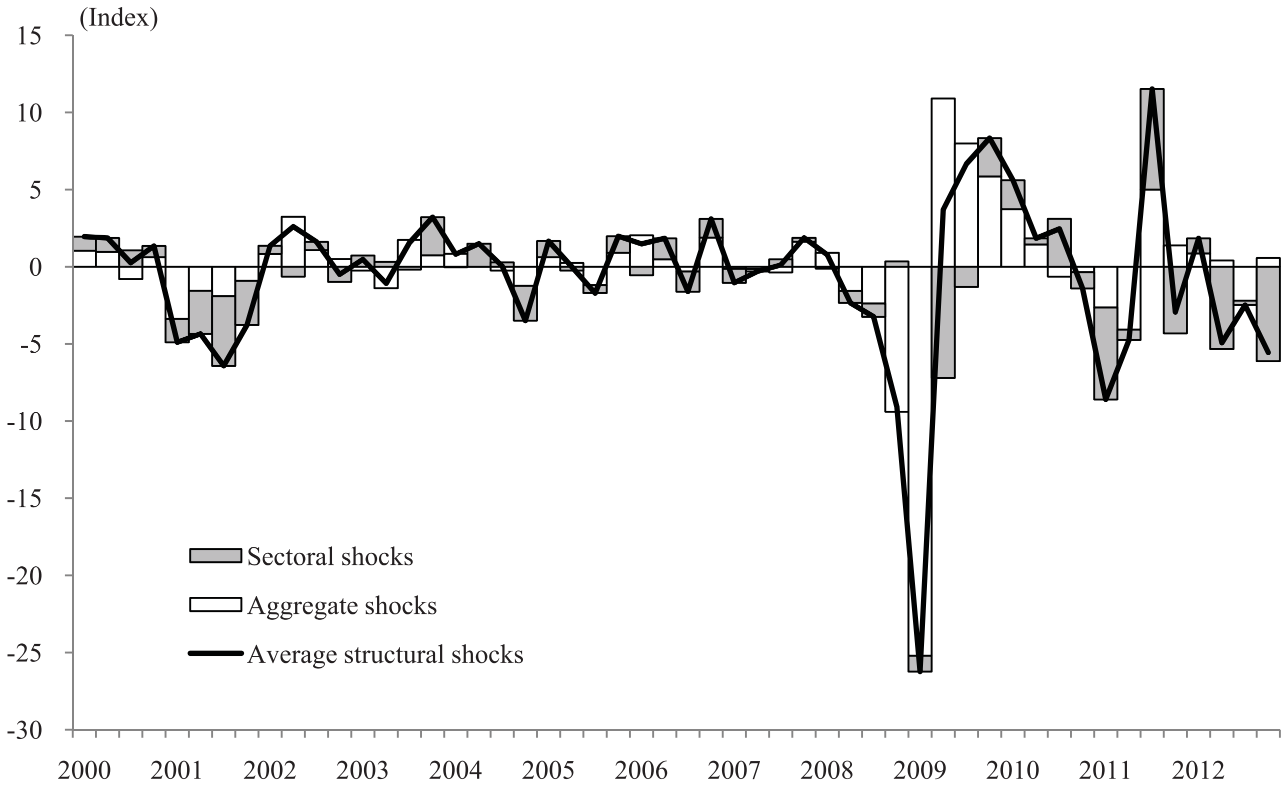
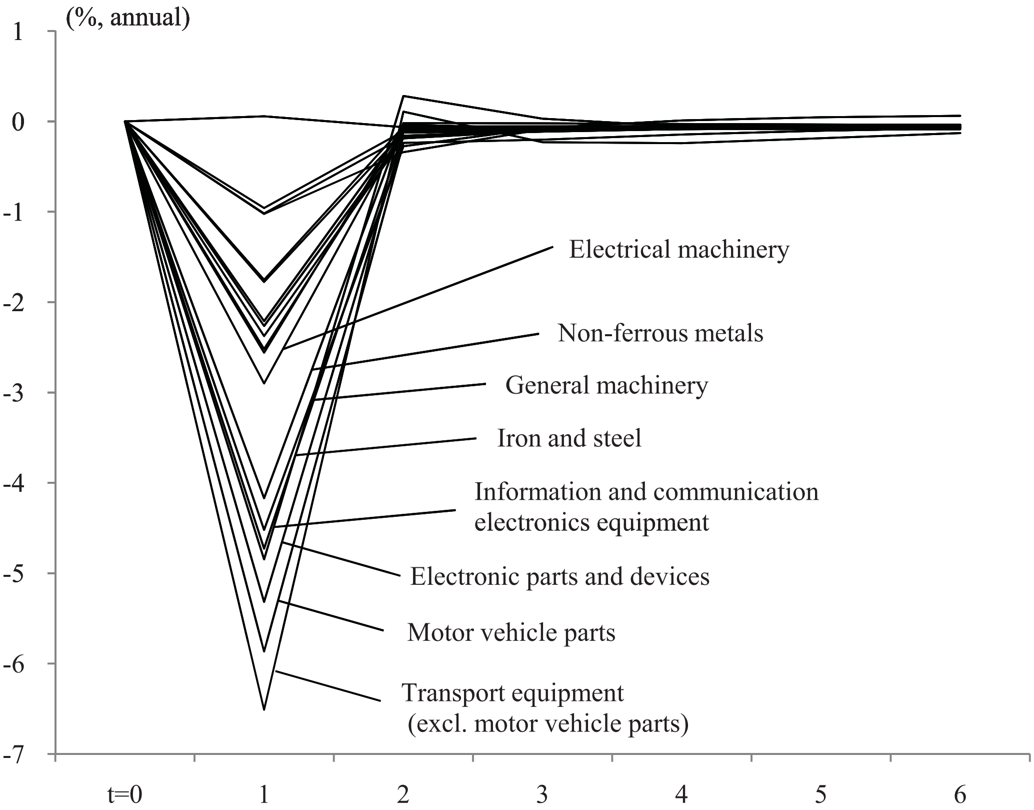


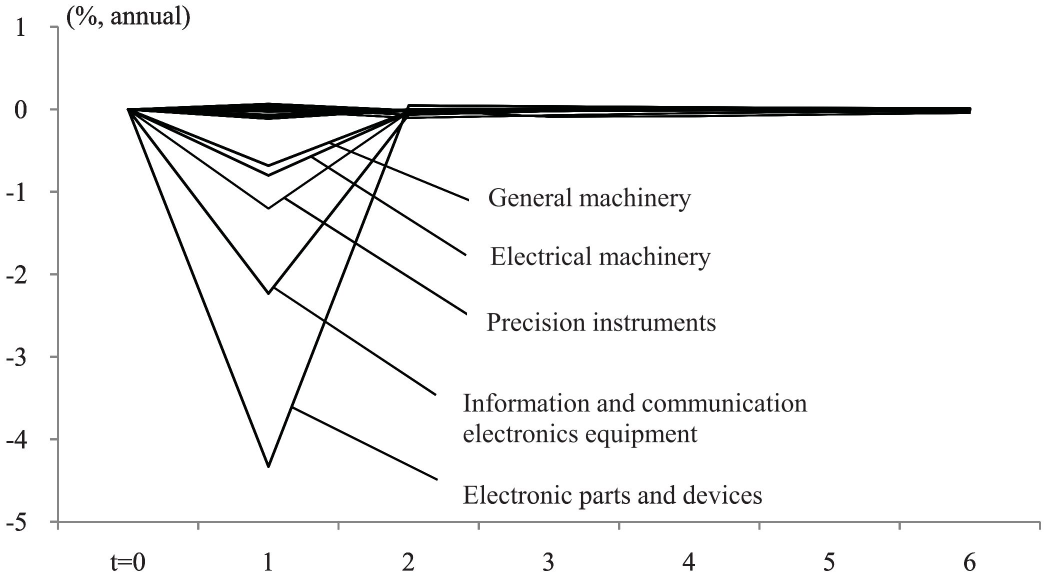
Figure 4: Impulse responses of sectoral production growth to a negative aggregate shock



Note: The size of the shock is one standard deviation in the observation period (1978:Q1 - 2012:Q4).

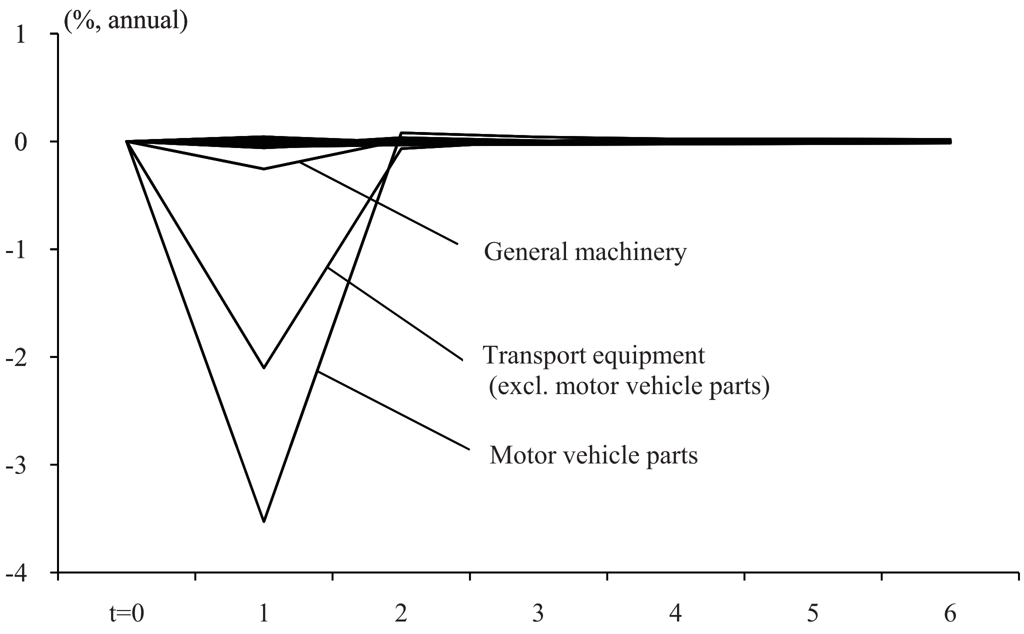
Figure 5: Impulse responses of sectoral production growth to a negative sectoral shock

(a) Sectoral shock to the electronic parts and devices industry



Note: The size of the shock is one standard deviation in the observation period (1978:Q1 - 2012:Q4).

(b) Sectoral shock to the motor vehicle parts industry



Note: The size of shock is one standard deviation in the observation period (1978:Q1 - 2012:Q4).

Figure 6: Decomposition of the growth rate of Japan's aggregate industrial production

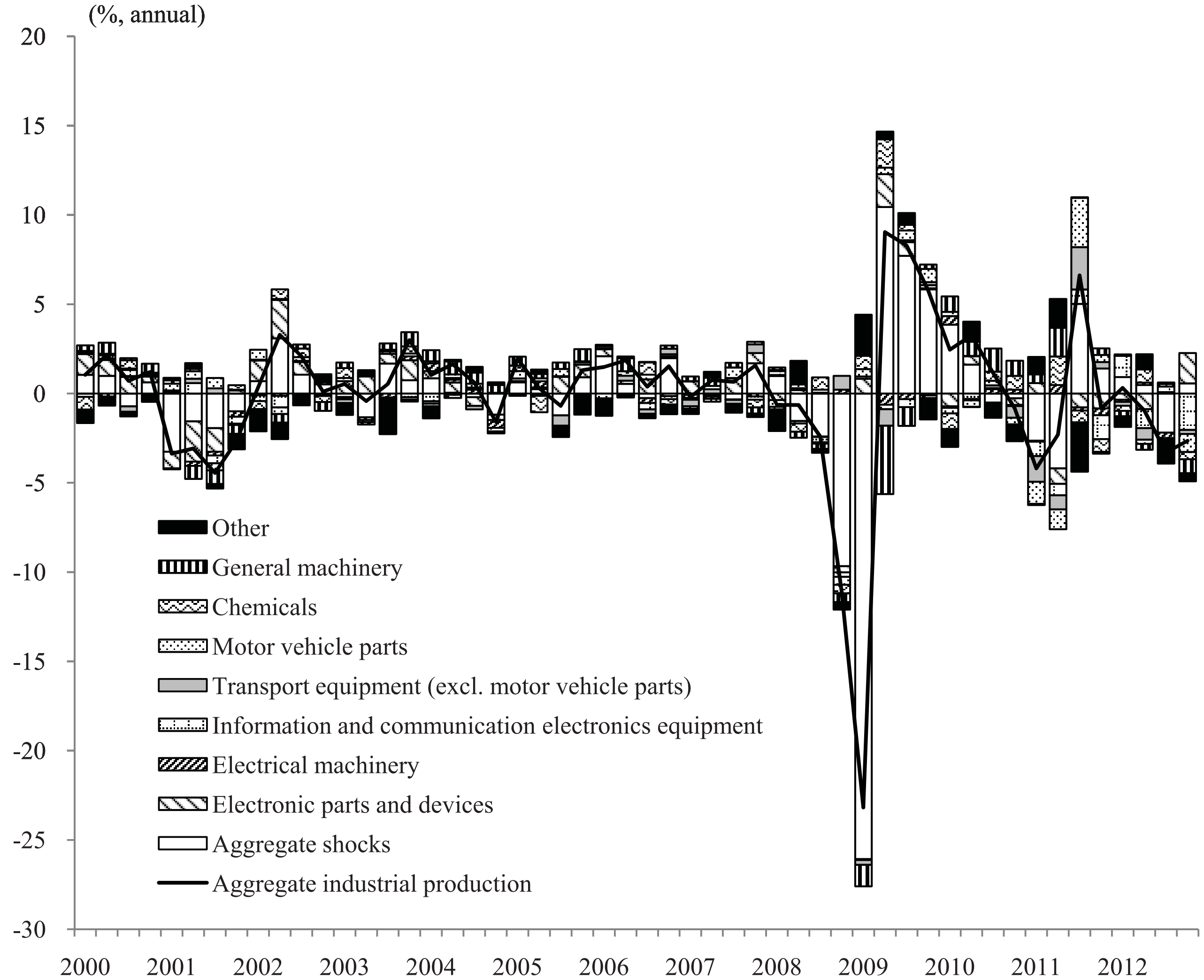


Figure 7: Correlation coefficients between aggregate shocks and economic variables

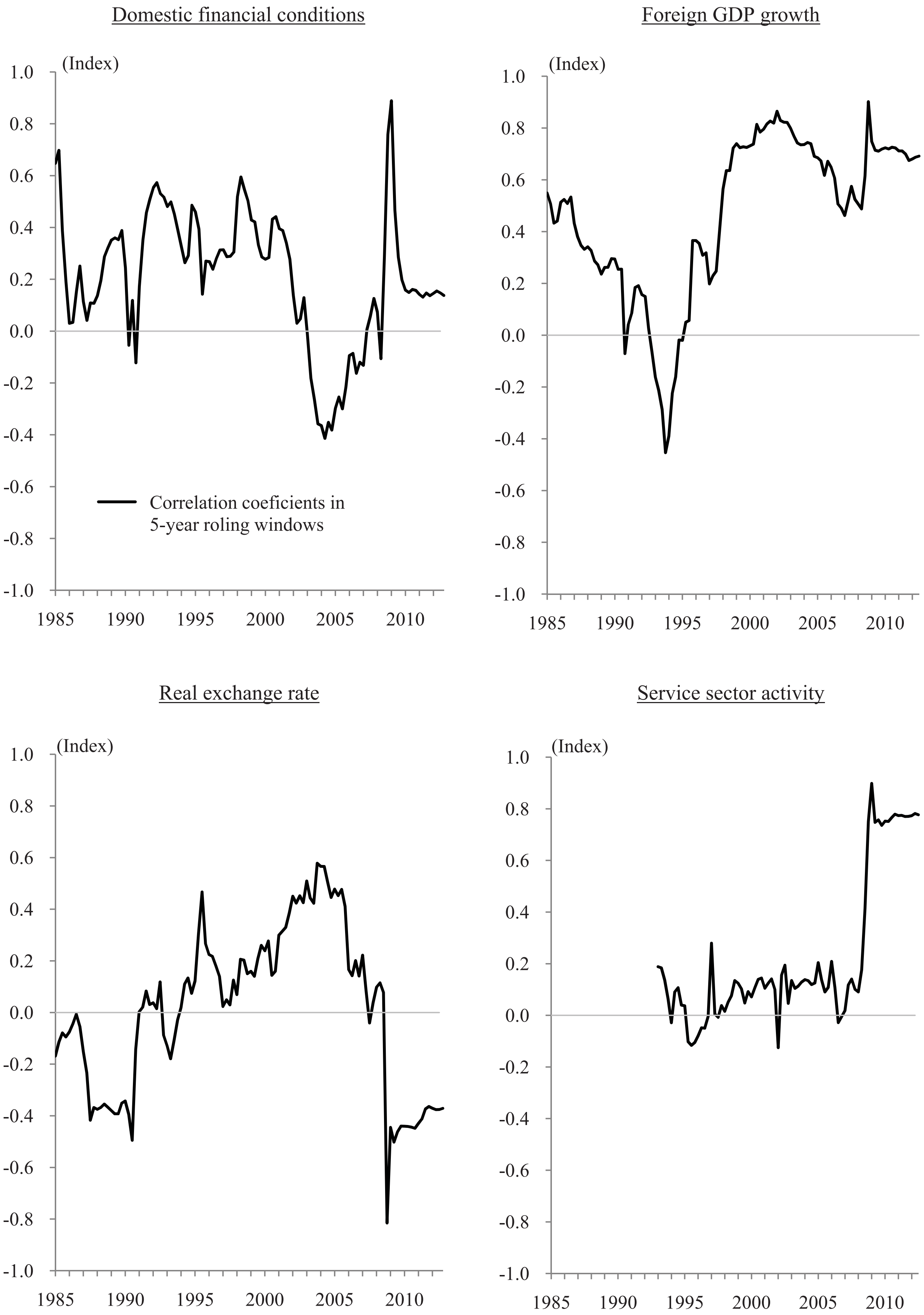
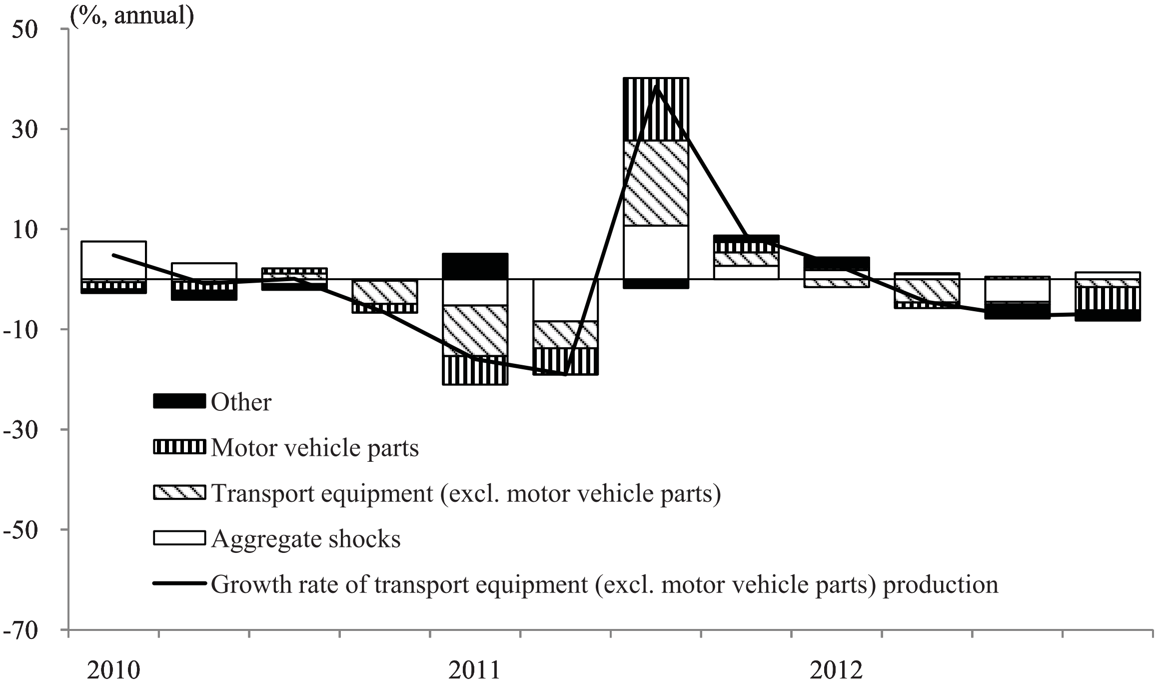


Figure 8: Intersectoral spillover effects on the growth rate of Japan's sectoral industrial production (2010-2012)

Transport equipment (excl. motor vehicle parts)



Electrical machinery

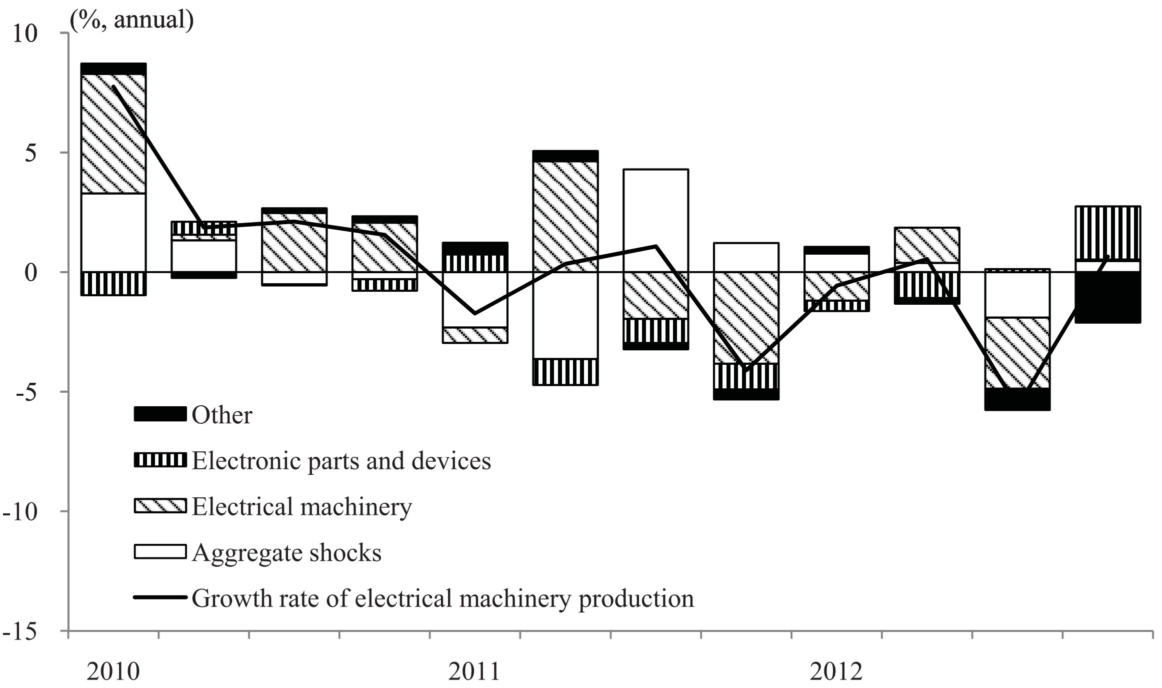


Figure 9: Inventory ratio

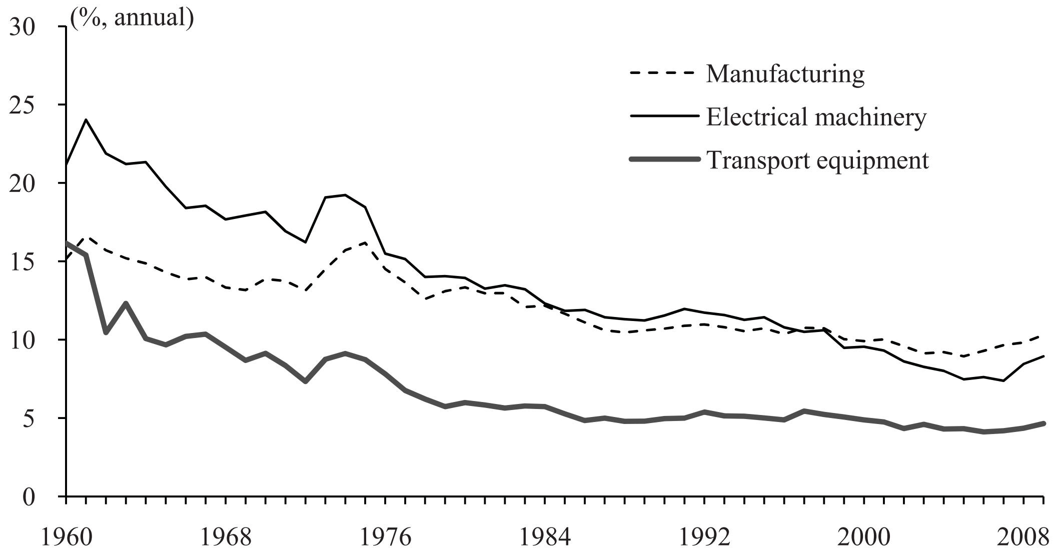


Figure 10: Decomposition of Japan's industrial production (2010-2012)

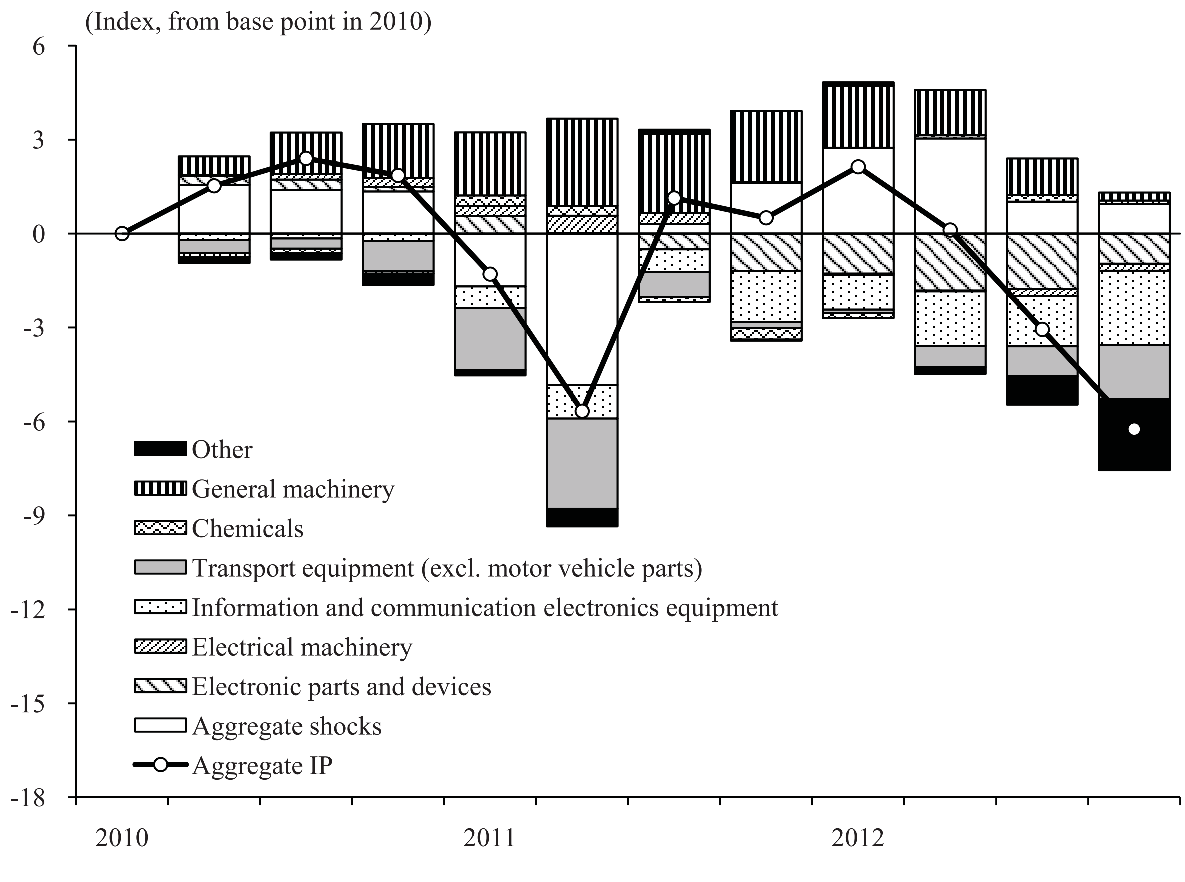


Figure 11: Sectoral shocks and sectoral production capacity

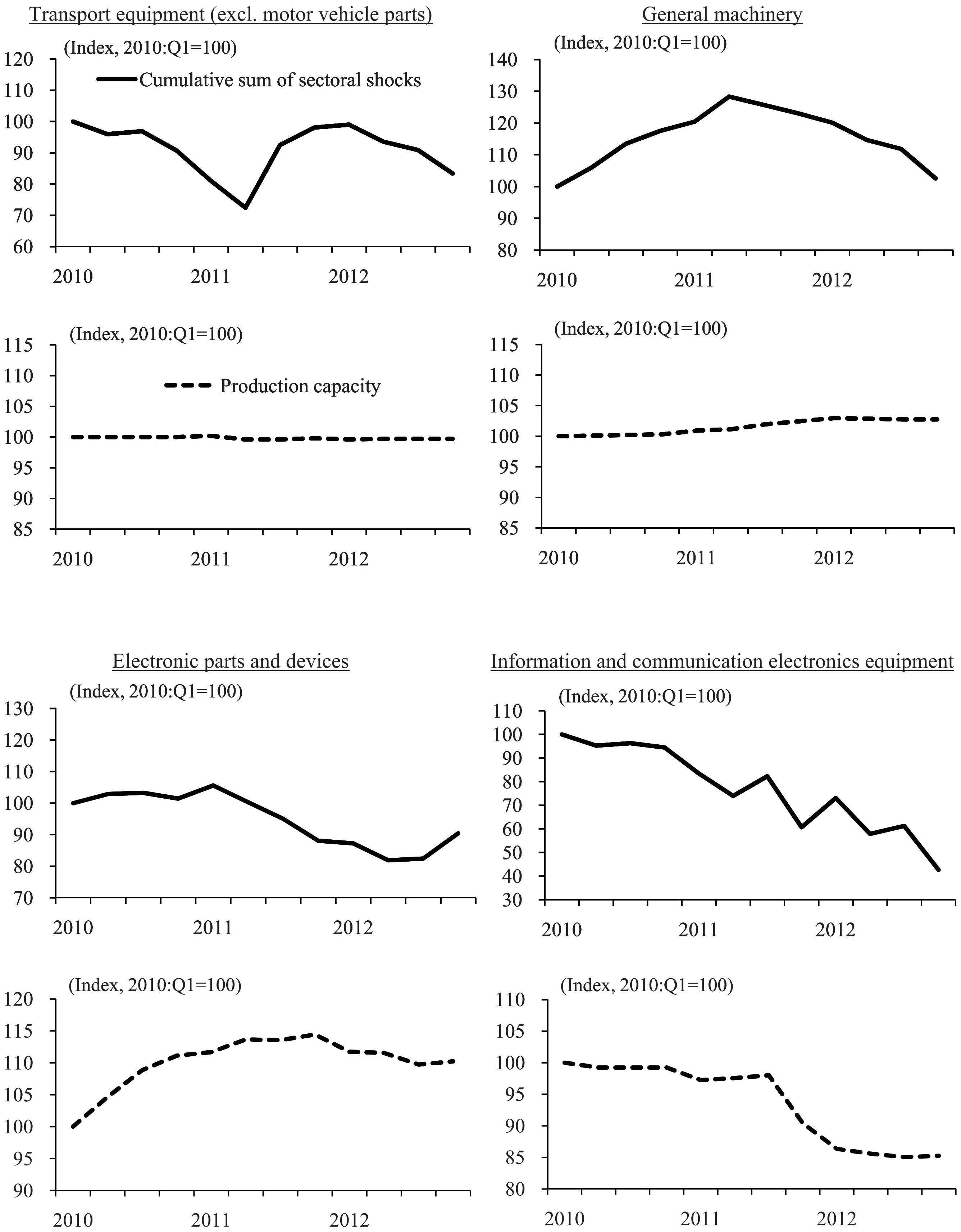


Figure A.1: Share weight decomposition of industrial production

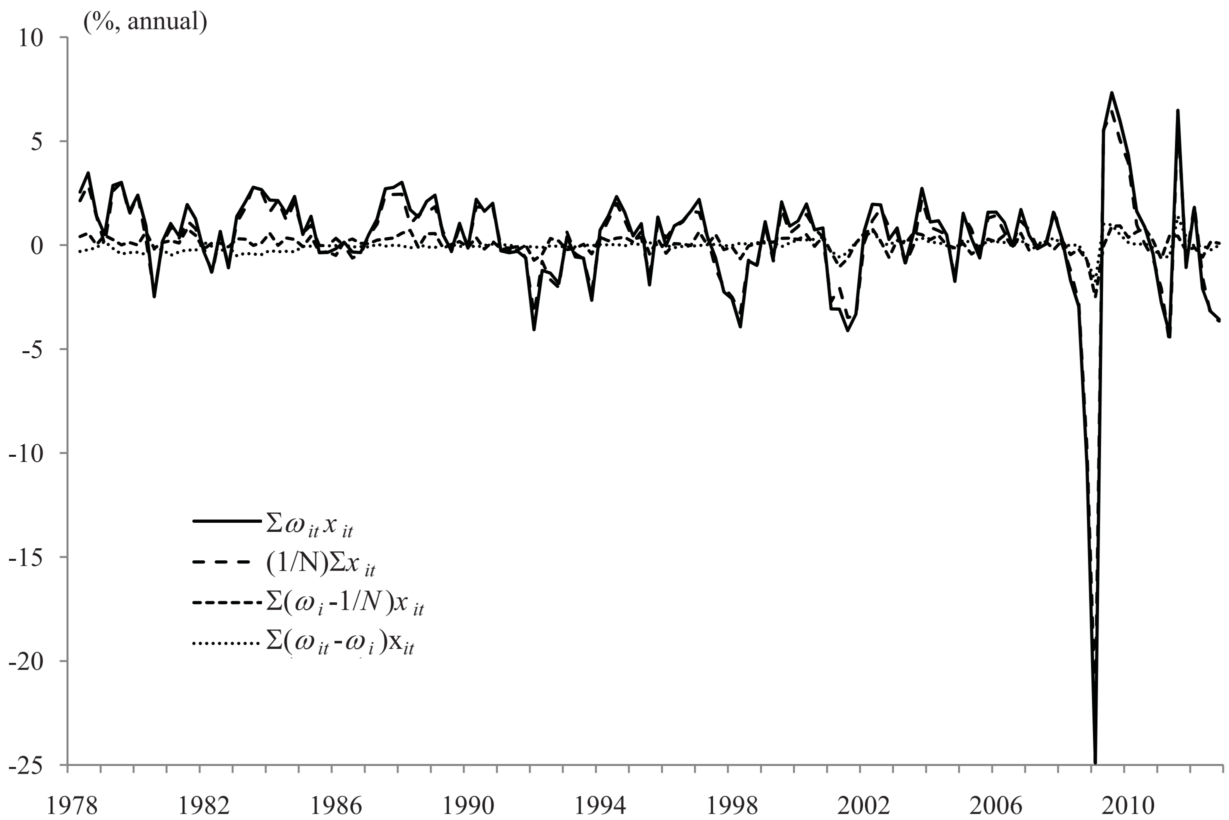


Table 1: Japan's input-output matrix (2005)

(billion yen)

Sector	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	Total
(1) Iron and steel	14,375	13	3,112	2,809	689	96	83	924	1,900	55	77	1	0	21	0	0	0	209	2	24,369
(2) Non-ferrous metals	225	3,234	966	758	1,196	319	566	182	1,013	113	48	137	0	27	2	0	63	226	0	9,077
(3) Fabricated metals	26	27	878	1,362	476	199	313	245	423	89	97	281	13	25	15	14	716	456	33	5,690
(4) General machinery	20	12	75	7,378	341	134	155	288	418	52	47	107	1	76	69	21	303	90	6	9,593
(5) Electrical machinery	0	0	15	953	1,939	355	435	811	969	86	0	1	0	0	0	0	0	12	0	5,575
(6) Information and communication electronics equipment	0	0	1	21	2	422	4	412	0	0	0	3	0	0	0	0	0	2	0	870
(7) Electronic parts and devices	0	2	50	996	1,849	4,131	5,299	18	450	714	0	0	0	0	0	0	0	119	0	13,629
(8) Transport equipment (excl. motor vehicle parts)	0	0	0	0	0	0	0	1,258	0	0	0	0	0	0	0	0	0	0	0	1,258
(9) Transport equipment	0	0	0	5	0	0	0	11,710	12,794	0	0	0	0	0	0	0	0	0	0	24,509
(10) Precision instruments	0	0	1	279	24	38	9	26	28	87	0	1	0	1	1	0	0	5	0	501
(11) Ceramics, stone and clay products	181	68	55	215	152	27	554	426	70	102	726	182	9	71	11	3	158	126	0	3,135
(12) Chemicals	130	103	140	473	248	103	336	182	471	28	221	9,873	38	2,685	306	375	385	1,071	10	17,179
(13) Petroleum and coal products	686	50	45	72	21	6	38	72	71	5	185	2,161	753	17	63	50	206	46	20	4,567
(14) Plastic products	0	76	50	718	627	435	409	605	925	151	40	490	3	2,952	199	47	770	600	1	9,096
(15) Pulp, paper and paper products	6	11	43	1,054	124	39	105	3	23	24	138	467	0	96	2,983	53	658	215	0	6,043
(16) Textiles	17	15	23	63	68	26	78	91	39	10	46	26	6	18	81	1,732	84	213	7	2,642
(17) Foods and tobacco	0	0	0	0	0	0	0	0	0	0	5	162	0	1	31	18	6,992	30	0	7,241
(18) Other manufacturing	273	151	62	511	150	134	80	459	539	78	130	82	9	127	382	147	120	1,983	16	5,436
(19) Mining	1,066	1,026	1	2	0	0	0	0	4	0	689	157	10,532	0	60	5	0	14	4	13,560
Total	17,008	4,790	5,516	17,669	7,905	6,463	8,465	17,708	20,137	1,596	2,451	14,130	11,365	6,119	4,204	2,466	10,458	5,420	100	163,969

Table 2: Japan's fixed capital matrix (2005)

(billion yen)

Sector	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	Total
(1) Iron and steel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2) Non-ferrous metals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(3) Fabricated metals	1	1	15	8	2	1	2	2	1	1	3	1	0	3	7	8	18	9	0	82
(4) General machinery	341	91	170	1,015	329	197	1,329	703	1,083	192	135	637	184	427	158	130	599	430	23	8,171
(5) Electrical machinery	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(6) Information and communication electronics equipment	18	8	13	43	67	104	39	31	31	14	8	45	5	4	19	11	52	58	1	572
(7) Electronic parts and devices	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(8) Transport equipment (excl. motor vehicle parts)	40	17	27	55	23	8	6	33	19	23	19	74	4	30	26	7	71	67	8	557
(9) Transport equipment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10) Precision instruments	16	14	6	41	36	43	61	24	25	25	13	63	7	11	2	5	51	20	1	464
(11) Ceramics, stone and clay products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(12) Chemicals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(13) Petroleum and coal products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(14) Plastic products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(15) Pulp, paper and paper products	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(16) Textiles	0	0	3	3	1	0	1	0	0	0	1	0	0	1	2	3	2	3	0	21
(17) Foods and tobacco	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(18) Other manufacturing	2	1	8	9	3	2	2	2	2	2	3	4	0	4	7	9	9	16	0	88
(19) Mining	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	418	133	241	1,172	462	356	1,439	796	1,162	258	181	824	200	480	221	173	802	604	34	9,955

Table 3: Capital shares

	Capital share
Iron and steel	0.139
Non-ferrous metals	0.096
Fabricated metals	0.128
General machinery	0.154
Electrical machinery	0.131
Information and communication electronics equipment	0.113
Electronic parts and devices	0.098
Transport equipment (excl. motor vehicle parts)	0.071
Motor vehicle parts	0.054
Precision instruments	0.148
Ceramics, stone and clay products	0.241
Chemicals	0.189
Petroleum and coal products	0.031
Plastic products	0.092
Pulp, paper and paper products	0.178
Textiles	0.087
Foods and tobacco	0.264
Other manufacturing	0.160
Mining	0.388

Note: The observation period is 1978:Q1 - 2012:Q4.

Table 4: Decomposition of the variances of structural shocks

	Structural shocks	Aggregate shocks		Sectoral shocks	
	Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share
Iron and steel	32.4	24.6	76.1%	7.7	23.9%
Non-ferrous metals	42.7	33.9	79.3%	8.8	20.7%
Fabricated metals	37.7	0.2	0.5%	37.6	99.5%
General machinery	33.4	1.5	4.4%	31.9	95.6%
Electrical machinery	110.2	3.6	3.2%	106.6	96.8%
Information and communication electronics equipment	338.2	11.8	3.5%	326.4	96.5%
Electronic parts and devices	168.0	83.3	49.6%	84.7	50.4%
Transport equipment (excl. motor vehicle parts)	131.1	45.3	34.5%	85.8	65.5%
Motor vehicle parts	119.8	76.4	63.8%	43.4	36.2%
Precision instruments	205.3	0.0	0.0%	205.3	100.0%
Ceramics, stone and clay products	58.1	44.4	76.5%	13.7	23.5%
Chemicals	19.6	5.7	29.2%	13.8	70.8%
Petroleum and coal products	164.3	3.1	1.9%	161.2	98.1%
Plastic products	23.5	13.4	57.1%	10.1	42.9%
Pulp, paper and paper products	9.3	3.0	31.9%	6.3	68.1%
Textiles	8.1	2.4	30.0%	5.7	70.0%
Foods and tobacco	20.1	0.0	0.0%	20.1	100.0%
Other manufacturing	26.1	9.1	34.9%	17.0	65.1%
Mining	143.5	2.2	1.5%	141.3	98.5%
Average structural shocks	12.2	8.8	72.1%	3.4	27.9%

Note: The observation period is 1978:Q1 - 2012:Q4.

Table 5: Comparison of the actual correlation matrix of sectoral growth rates with the simulation results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) Iron and steel		0.8	0.6	0.7	0.6	0.4	0.6	0.6	0.7	0.5	0.8	0.5	0.1	0.7	0.6	0.6	0.0	0.7	0.2
(2) Non-ferrous metals	0.8		0.6	0.5	0.6	0.4	0.7	0.8	0.8	0.4	0.8	0.7	0.2	0.8	0.7	0.5	0.0	0.7	0.1
(3) Fabricated metals	0.8	0.7		0.6	0.6	0.3	0.5	0.5	0.5	0.4	0.7	0.6	0.1	0.8	0.6	0.6	0.0	0.6	0.2
(4) General machinery	0.6	0.6	0.6		0.6	0.4	0.4	0.4	0.4	0.6	0.6	0.3	0.1	0.5	0.5	0.6	0.0	0.6	0.1
(5) Electrical machinery	0.6	0.6	0.5	0.4		0.3	0.5	0.4	0.4	0.4	0.6	0.5	0.1	0.6	0.5	0.5	0.0	0.5	0.1
(6) Information and communication electronics equipment	0.3	0.3	0.2	0.1	0.4		0.4	0.5	0.5	0.3	0.4	0.3	0.2	0.4	0.3	0.3	0.0	0.4	0.0
(7) Electronic parts and devices	0.7	0.7	0.6	0.4	0.6	0.5		0.5	0.6	0.3	0.6	0.5	0.1	0.7	0.6	0.4	0.0	0.5	0.1
(8) Transport equipment (excl. motor vehicle parts)	0.8	0.8	0.6	0.4	0.5	0.4	0.7		0.9	0.5	0.6	0.3	0.1	0.6	0.5	0.4	0.0	0.6	0.1
(9) Transport equipment	0.8	0.7	0.6	0.4	0.5	0.3	0.7	0.9		0.5	0.6	0.4	0.2	0.6	0.6	0.4	0.0	0.5	0.0
(10) Precision instruments	0.4	0.5	0.3	0.4	0.4	0.3	0.5	0.4	0.4		0.5	0.2	0.0	0.3	0.4	0.5	0.0	0.5	0.0
(11) Ceramics, stone and clay products	0.8	0.8	0.7	0.5	0.6	0.3	0.7	0.7	0.7	0.4		0.6	0.1	0.8	0.7	0.7	0.0	0.8	0.2
(12) Chemicals	0.6	0.6	0.5	0.4	0.4	0.2	0.4	0.4	0.4	0.3	0.7		0.2	0.7	0.6	0.4	0.1	0.5	-0.1
(13) Petroleum and coal products	0.3	0.3	0.3	0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.4	0.6		0.2	0.2	0.1	0.0	0.1	0.0
(14) Plastic products	0.8	0.8	0.7	0.6	0.5	0.2	0.6	0.6	0.6	0.4	0.8	0.7	0.3		0.8	0.6	0.1	0.7	0.1
(15) Pulp, paper and paper products	0.7	0.8	0.6	0.4	0.4	0.3	0.6	0.7	0.6	0.3	0.8	0.7	0.3	0.8		0.5	0.1	0.6	0.1
(16) Textiles	0.6	0.6	0.5	0.2	0.4	0.3	0.5	0.5	0.5	0.3	0.7	0.6	0.4	0.6	0.7		0.0	0.7	0.1
(17) Foods and tobacco	0.2	0.3	0.3	0.1	0.2	0.0	0.1	0.2	0.2	0.2	0.3	0.4	0.3	0.5	0.4	0.4		0.0	0.0
(18) Other manufacturing	0.8	0.8	0.6	0.4	0.4	0.2	0.6	0.7	0.7	0.3	0.8	0.6	0.3	0.7	0.7	0.6	0.3		0.1
(19) Mining	0.3	0.4	0.4	0.2	0.3	0.0	0.1	0.3	0.2	0.1	0.4	0.5	0.7	0.4	0.4	0.4	0.3	0.3	

Note: The shaded cells show the actual correlation of sectoral growth rates, while the white cells show the simulation results.

Table 6: Decomposition of the variance of aggregate industrial production

		Aggregate shocks		Sectoral shocks	
	Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share
Aggregate IP	10.5	9.2	87.5%	1.3	12.5%

Note: The observation period is 1978:Q1 - 2012:Q4.

Table 7: Correlations between aggregate shocks and economic variables

	Domestic financial condition	Foreign economic growth	Real exchange rate	Service sector activity
Period	1985:Q1 - 2012:Q4	1985:Q1 - 2012:Q4	1985:Q1 - 2012:Q4	1988:Q2 - 2012:Q4
Correlation coefficient	0.13	0.59	-0.14	0.35

Table 8: Decomposition of the variances of structural shocks (2010-2012)

	Structural shocks	Aggregate shocks		Sectoral shocks	
	Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share
Iron and steel	31.5	17.7	56.0%	13.9	44.0%
Non-ferrous metals	52.4	24.3	46.4%	28.1	53.6%
Fabricated metals	30.5	0.1	0.4%	30.3	99.6%
General machinery	59.9	1.1	1.8%	58.9	98.2%
Electrical machinery	73.0	2.6	3.5%	70.4	96.5%
Information and communication electronics equipment	2443.5	8.5	0.3%	2435.0	99.7%
Electronic parts and devices	158.0	59.7	37.8%	98.2	62.2%
Transport equipment (excl. motor vehicle parts)	603.6	32.5	5.4%	571.1	94.6%
Motor vehicle parts	419.3	54.8	13.1%	364.5	86.9%
Precision instruments	495.7	0.0	0.0%	495.7	100.0%
Ceramics, stone and clay products	26.7	31.9	119.4%	-5.2	-19.4%
Chemicals	24.8	4.1	16.5%	20.7	83.5%
Petroleum and coal products	419.4	2.2	0.5%	417.2	99.5%
Plastic products	41.9	9.6	22.9%	32.3	77.1%
Pulp, paper and paper products	13.4	2.1	15.9%	11.2	84.1%
Textiles	6.7	1.7	26.0%	4.9	74.0%
Foods and tobacco	15.3	0.0	0.0%	15.3	100.0%
Other manufacturing	22.9	6.5	28.5%	16.4	71.5%
Mining	465.8	1.6	0.3%	464.2	99.7%
Average structural shocks	31.0	6.5	21.1%	24.4	78.9%

Note: The observation period is 2010:Q1 - 2012:Q4.

Table 9: Intersectoral spillover effects on the growth rate of aggregate industrial production (2010-2012)

(%)

	2010				2011				2012			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Aggregate IP	4.5	1.7	0.9	-0.6	-3.4	-4.8	7.9	-0.7	1.8	-2.1	-3.4	-3.6
Total spillover effects from sectoral shocks	-0.2	-0.3	0.2	-0.1	1.0	-0.9	1.0	-0.4	0.8	-0.6	-1.1	-1.8
Spillover effect from motor vehicle parts to other industries	-0.2	-0.2	0.2	-0.2	-0.8	-0.7	1.8	0.3	0.1	-0.2	0.1	-0.6
Spillover effect from information and communication electronics equipment to other industries	-0.3	0.2	0.0	-0.1	0.3	-0.4	-0.3	-0.4	-0.2	-0.4	0.0	0.7

Table 10: Demand structure of motor vehicle parts sector in each Japanese region

(%)

	All regions	Hokkaido region	Tohoku region	Kanto region	Chubu region	Kinki region	Chugoku region	Shikoku region	Kyushu region
Intermediate input	85.8	86.2	94.9	87.9	84.9	83.1	89.8	95.7	64.7
Domestic final demand	0.5	0.8	0.5	0.4	0.5	0.8	0.4	2.0	0.4
Export	13.7	13.0	4.6	11.6	14.6	16.1	9.8	2.3	34.8
Total demand	100	100	100	100	100	100	100	100	100

Source: Ministry of Economy, Trade and Industry, "White Paper on International Economy and Trade 2011."

Table A.1: Sectoral output shares and standard deviation of growth rates in Japan's industrial production

Sector	Share	Standard deviation of quarterly growth rates
Iron and steel	5.9	19.8
Non-ferrous metals	2.1	16.3
Fabricated metals	5.8	10.3
General machinery	12.8	19.4
Electrical machinery	5.5	17.4
Information and communication electronics equipment	5.0	25.3
Electronic parts and devices	7.3	26.8
Transport equipment (excl. motor vehicle parts)	9.7	29.9
Motor vehicle parts	3.0	28.0
Precision instruments	1.2	18.8
Ceramics, stone and clay products	4.6	10.8
Chemicals	10.6	9.9
Petroleum and coal products	1.4	9.0
Plastic products	3.7	10.7
Pulp, paper and paper products	2.9	8.2
Textiles	5.0	6.4
Foods and tobacco	7.3	6.7
Other manufacturing	5.9	10.2
Mining	0.4	12.5

Note: The observation period is 1978:Q1 - 2012:Q4.

Table A.2: Variance of the growth rate of Japan's industrial production

Variance of the growth rate of Japan's industrial production	12.9
Sum of the variances of growth rates of sectoral industrial productions	5.6

Note: The observation period is 1978:Q1 - 2012:Q4.

Table A.3: Sensitivity analysis of the decomposition of the variances of structural shocks and the growth rate of aggregate industrial production

(a) Period: 1978:Q1 - 2012:Q4

Model parameters					Number of factors	Structural shocks					Aggregate IP				
							Aggregate shocks		Sectoral Shocks			Aggregate shocks		Sectoral Shocks	
σ	ψ	β	δ	Year of γ		Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share	Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share
1.00	1.00	0.99	0.025	2005	1	12.2	8.8	72.1%	3.4	27.9%	11.3	9.8	87.1%	1.5	12.9%
0.50	1.00	0.99	0.025	2005	1	9.6	6.8	70.8%	2.8	29.2%	11.3	9.7	86.4%	1.5	13.6%
1.25	1.00	0.99	0.025	2005	1	15.6	11.9	76.7%	3.6	23.3%	11.3	10.1	89.4%	1.2	10.6%
1.50	1.00	0.99	0.025	2005	1	19.5	15.5	79.4%	4.0	20.6%	11.3	10.3	91.1%	1.0	8.9%
1.00	0.50	0.99	0.025	2005	1	12.2	8.8	72.1%	3.4	27.9%	11.3	9.8	87.1%	1.5	12.9%
1.00	1.25	0.99	0.025	2005	1	12.2	8.8	72.1%	3.4	27.9%	11.3	9.8	87.1%	1.5	12.9%
1.00	1.50	0.99	0.025	2005	1	12.2	8.8	72.1%	3.4	27.9%	11.3	9.8	87.1%	1.5	12.9%
1.00	1.00	0.85	0.025	2005	1	10.8	7.6	70.7%	3.2	29.3%	11.3	10.0	88.2%	1.3	11.8%
1.00	1.00	0.90	0.025	2005	1	11.0	8.0	73.1%	3.0	26.9%	11.3	9.9	87.8%	1.4	12.2%
1.00	1.00	0.95	0.025	2005	1	11.2	7.2	63.7%	4.1	36.3%	11.3	8.8	78.3%	2.5	21.7%
1.00	1.00	0.99	0.005	2005	1	10.6	7.9	74.1%	2.7	25.9%	11.3	10.0	88.7%	1.3	11.3%
1.00	1.00	0.99	0.015	2005	1	11.8	8.6	73.4%	3.1	26.6%	11.3	9.9	87.4%	1.4	12.6%
1.00	1.00	0.99	0.020	2005	1	12.1	8.8	72.9%	3.3	27.1%	11.3	9.8	87.3%	1.4	12.7%
1.00	1.00	0.99	0.030	2005	1	12.4	8.9	71.9%	3.5	28.1%	11.3	9.8	87.0%	1.5	13.0%
1.00	1.00	0.99	0.025	1995	1	15.1	13.4	88.6%	1.7	11.4%	11.4	9.6	84.6%	1.7	15.4%
1.00	1.00	0.99	0.025	2000	1	13.5	10.7	79.4%	2.8	20.6%	11.3	10.1	89.7%	1.2	10.3%
1.00	1.00	0.99	0.025	2005	2	12.2	10.3	84.0%	2.0	16.0%	11.3	9.8	87.3%	1.4	12.7%

(b) Period: 2010:Q1 - 2012:Q4

Model parameters					Number of factors	Structural shocks					Aggregate IP				
							Aggregate shocks		Sectoral Shocks			Aggregate shocks		Sectoral Shocks	
σ	ψ	β	δ	Year of γ		Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share	Variance	Contribution of aggregate shocks	Share	Contribution of sectoral shocks	Share
1.00	1.00	0.99	0.025	2005	1	31.0	6.5	21.1%	24.4	78.9%	13.8	6.8	48.8%	7.1	51.2%
0.50	1.00	0.99	0.025	2005	1	28.0	4.3	15.4%	23.7	84.6%	13.8	5.7	41.1%	8.2	58.9%
1.25	1.00	0.99	0.025	2005	1	37.9	9.4	24.7%	28.5	75.3%	13.8	7.4	53.2%	6.5	46.8%
1.50	1.00	0.99	0.025	2005	1	46.0	12.7	27.7%	33.3	72.3%	13.8	7.9	57.1%	5.9	42.9%
1.00	0.50	0.99	0.025	2005	1	31.0	6.5	21.1%	24.4	78.9%	13.8	6.8	48.8%	7.1	51.2%
1.00	1.25	0.99	0.025	2005	1	31.0	6.5	21.1%	24.4	78.9%	13.8	6.8	48.8%	7.1	51.2%
1.00	1.50	0.99	0.025	2005	1	31.0	6.5	21.1%	24.4	78.9%	13.8	6.8	48.8%	7.1	51.2%
1.00	1.00	0.85	0.025	2005	1	28.1	7.1	25.2%	21.0	74.8%	13.8	8.9	64.3%	4.9	35.7%
1.00	1.00	0.90	0.025	2005	1	27.5	7.2	26.4%	20.2	73.6%	13.8	8.7	62.8%	5.2	37.2%
1.00	1.00	0.95	0.025	2005	1	27.8	4.9	17.6%	22.9	82.4%	13.8	5.8	41.9%	8.1	58.1%
1.00	1.00	0.99	0.005	2005	1	28.4	6.0	21.2%	22.4	78.8%	13.9	7.0	50.9%	6.8	49.1%
1.00	1.00	0.99	0.015	2005	1	30.4	6.5	21.5%	23.9	78.5%	13.8	6.9	49.7%	7.0	50.3%
1.00	1.00	0.99	0.020	2005	1	30.8	6.6	21.4%	24.2	78.6%	13.8	6.8	49.3%	7.0	50.7%
1.00	1.00	0.99	0.030	2005	1	31.1	6.6	21.2%	24.6	78.8%	13.8	6.8	48.7%	7.1	51.3%
1.00	1.00	0.99	0.025	1995	1	22.8	9.1	40.0%	13.7	60.0%	13.9	6.6	47.8%	7.2	52.2%
1.00	1.00	0.99	0.025	2000	1	26.2	8.3	31.9%	17.8	68.1%	13.8	7.3	52.5%	6.6	47.5%
1.00	1.00	0.99	0.025	2005	2	31.0	13.4	43.1%	17.6	56.9%	13.8	8.0	57.9%	5.8	42.1%