Understanding Japan's Export Dynamics

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Abstract

Although a number of studies estimate export functions for Japan, their results entail several puzzling features that beg explanation. This paper shows that these apparent anomalies stem in part from a failure to recognize a special relationship between the electronics industry and macroeconomic variables that enter the standard export function. This relationship is quantitatively so important as to cast doubt over the accuracy of the existing estimates.

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1 Introduction

As is shown in Figure 1, Japan's exports fell sharply between late 2008 and early 2009. Although trade contracted around the world during this period, Japan's export decline was among the most serious in the industrialized world. What made its export slump so serious? Was it because of its dependence on the U.S. market, the epicenter of the recent global financial crisis, or because of the yen appreciation that took place along with this financial crisis? Did other special factors play a role, and if so, to what extent? Will Japanese exporters recover the lost ground once the world economy revives?

Needless to say, one cannot address such questions effectively without having an accurate understanding of what determines the amount of Japanese exports under normal circumstances. The economist's main tool for examining the latter question is the empirical export function, which relates the export volume of a country to foreign income, real exchange rates, and other prominent macroeconomic variables. However, not only do existing estimates of Japanese export functions vary considerably but they also present several puzzling features, such as theoretically inconsistent price elasticities and wide variations in income elasticity across importer countries and over time.

This paper argues that these apparent anomalies stem in part from a failure to understand the special relationship between the electronics industry and Japan's exports. Not only do cyclical fluctuations of the international electronics market exert direct impact on Japan's exports, but they are also correlated with other variables that enter the standard export function. Moreover, since the state of international division of labor in electronics production changes much more rapidly than in other industries, this industry has been a central force behind recent evolution of Japan's export structure. As will be shown in this paper, by recognizing these effects explicitly one reaches a very different estimate for Japan's export function from those reported in the existing literature.

This paper is organized as follows. The next section provides an intuitive account of why electronics matter so much for Japan's export dynamics. Sections 3 and 4 describe this paper's empirical methodology and report estimation results. Section 5 concludes the paper with a note on how the role of electronics in Japan's exports might evolve in the future.

2 Electronics and Japanese exports

First consider the following demand and supply schedules for aggregate exports:

$$Q^d = Q^d\left(S^{x*}, Y^*; Z^d\right), \quad S^{x*} = P^{x*}/P^*, \tag{1}$$

$$Q^s = Q^s\left(S^x; Z^s\right), \quad S^x = P^x/P, \tag{2}$$

where Q^d and Q^s represent the volumes of the demand for and the supply of the exports of a country. Y^* denotes real foreign income, P^* and P are the price levels of the home and foreign countries, P^{x*} and P^x are the average prices of export goods measured in foreign and home currencies, and Z^d and Z^s represent other factors that shift the demand and supply schedules. Letting E denote the nominal exchange rate defined as the home-currency price of one foreign-currency unit, we can relate S^{x*} and S^x as follows:

$$S^{x*} = \frac{P^{x*}}{P^*} = \frac{P^x}{EP^*} = \frac{P^x}{P}\frac{P}{EP^*} = S^x \times S, \tag{3}$$

where $S = P/\left(EP^*\right)$ is the real exchange rate between the home and foreign currencies.

Equating Eqs. (1) and (2) and using (3) to eliminate S^{x*} and S^x, one obtains

$$Q = Q^d = Q^s = Q\left(Y^*, S; Z\right), \tag{4}$$

where Z^d and Z^s are merged into a single vector Z to simplify presentation. Lastly, noting that changes in the foreign income and the real exchange rate may affect the size of exports with certain time lags, one arrives at a dynamic version of Eq. (4):

$$Q_t = Q\left(Y_t^*, Y_{t-1}^*, Y_{t-2}^*, \ldots, S_t, S_{t-1}, S_{t-2}, \ldots; Z_t\right), \tag{5}$$

where subscript t indicates time.

Eq. (5) is a standard export function that highlights the foreign income and the real exchange rate as the main determinants of aggregate exports. Existing studies apply variants of this equation to numerous countries and estimate income and price elasticities for their exports (Hooper et al. 2000).

The main thrust of this paper is that Eq. (5) is not appropriate for Japan and must be augmented with a variable that accounts for the influence of the electronics industry, *even when the dependent variable includes a wide range of non-electronic products.* For the purpose of this paper, the reader can regard the electronics industry as a collection of firms that produce semiconductor devices and other products that make intensive use of semiconductor chips, such as information technology (IT) equipment. The electronics industry is characterized by extremely fast technological progress, rapid turnovers in market leaders in terms of both firms and products, and incessant reconfiguration of the geographical distribution of production and consumption in the world. These features electronics cast a long shadow over Japan's exports in both the short and long runs.

2.1 Impact on short-run export dynamics

During the past four decades, electronics has been the fastest growing and yet the most volatile segment of the manufacturing industry. Although fluctuations in the world electronics market in part reflect the business cycles of major countries, they also arise from industry-specific shocks such as the development of new types of products and corporate IT investment cycles. Not only does the cyclicality of the world electronics market exert a direct impact on Japanese exports but it also complicates the relationship between the dependent and the independent variables in Eq. (5). Figure 2 shows why.

Figure 2(i) compares the growth rates of Japan's exports and the worldwide shipments of semiconductor chips. Japan's exports are measured by two quantum indexes compiled by the Ministry of Finance (MoF). One of these indexes refers to the exports of all products whereas the other measures those of machinery and equipment, which include electrical and electronic machinery, transport equipment, precision instruments, and other machinery. For the sake of brevity, the following sections refer to the set of these products as "machinery". The dynamics of machinery exports are similar to those of aggregate exports since the former account for the bulk of the latter in Japan (see below).

Global semiconductor sales are measured by a quantum index compiled by World Semiconductor Trade Statistics Inc. (WSTS) and comprise chips shipped by manufacturers in

North America, Europe, Japan and other Asian countries within and across national borders. Since the volume of semiconductor sales depends primarily on the demand from IT equipment manufacturers, the growth rate of the former can be regarded as an indicator of the cyclical condition of the wider electronics industry.[1] While not shown here, the growth rate of chips sales is highly synchronized internationally because of extensive cross-border production networks and demand co-movement in the electronics industry. The following sections will refer to the cyclicality of the world electronics industry measured by this indicator as the *global IT cycle*.[2]

As is shown in Figure 2(i), the growth rate of Japanese exports has been correlated *very* closely with the global IT cycle. While this is in part a reflection of the fact that Japan is a major exporter of electronics, that is not the whole story; their synchronicity also reflects correlations between the IT cycle and other variables in Eq. (5).

Figure 2(ii) compares the IT cycle with the business cycles of Japan's major trade partners. Here the series for "Europe" refers to the simple average of the real GDP growth rates of France, Germany, Italy, Netherlands, Spain and the United Kingdom, whereas that for "East Asia" is the average for Korea, Malaysia, Singapore, Taiwan and Thailand. Since the United States and Europe account for the lion's share of world electronics consumption, the IT cycle is naturally correlated with the business cycles of these countries. Nevertheless, their correlations are by no means perfect and has become reasonably tight only since the mid-1990s. More interesting is the fact that the IT cycle is correlated much more closely with the macroeconomic cycles of the Asian countries, which collectively constitute a sizable market for Japanese exporters. Since all these countries are large net exporters of electronics, their economies are highly sensitive to the state of the international electronics market.[3]

Lastly, Figure 2(iii) compares the global IT cycle with the external value of the yen. This

[1] Manufacturers of computing, telecommunications and audiovisual equipment account for about 80 percent of the global demand for semiconductor chips (Brown and Linden 2009).

[2] The cyclicality of the semiconductor market is often dubbed the "silicon cycle" and is gauged by the growth rate of *nominal* semiconductor sales. However, since nominal sales are heavily influenced by exchange rates and chip prices, they do not provide a good indicator of the state of the electronics industry as a whole.

[3] See Kumakura (2006) for a formal analysis.

figure plots two exchange rates, the real dollar/yen exchange rate and the real effective value of the yen, of which the latter comes from the Bank of Japan (BoJ). Here both series are drawn such that a positive value indicates yen appreciation. As can be seen here, upturns in the world IT market often coincided with periods of yen appreciation, although this has not been the case since the mid-2000s. While space does not allow me to formally analyze what accounts for their empirical correlation, it should be intuitively clear that both the IT cycle and the movement of the yen exchange rate have substantial autonomous components, and that neither is a mere shadow of the other variable.[4] As long as this is the case, both variables demand a place in Eq. (5) – irrespective of the origin of their empirical correlation – for otherwise their effects cannot be distinguished properly.

What has been shown above raises questions about the existing estimates of Japan's export functions, which largely ignore the IT cycle. As noted above, many studies report the income elasticity of Japanese exports as extremely large and/or rising over time (Bahmani-Oskooee 2004; Cabinet Office of Japan 2005). This is not necessarily puzzling, however, since the amplitude of the IT cycle is much larger than that of a typical macroeconomic cycle, and since the relationship between the IT cycle and the business cycles of Japan's trade partners has strengthened over time. Other studies estimate importer-specific export functions and find extremely large income elasticities for exports to Asian countries (Mukunoki 2003; Iwatsubo and Karikomi 2006). However, such findings may be spurious to the extent that the IT cycle simultaneously affects both the business cycles of these countries and Japan's exports. Furthermore, given that the yen often strengthened in times of a booming world IT market, a strong yen may well appear to increase Japan's exports even if this is not the case (Bahmani-Oskooee 2004; Thorbecke 2008).

[4] Since Japan and the United States are a net exporter and importer of electronic goods, respectively, it is possible that an upturn in the global IT cycle strengthens the yen vis-à-vis the dollar by widening US-Japan trade imbalances. However, standard causality tests suggest that such effects are at best modest, which is not surprising since the dollar/yen rate is subject to a number of other forces. The result of causality tests is available on request.

2.2 Influence on the evolution of export structure

The second reason why electronics warrants attention is that this industry has been the central force behind the structural evolution of Japanese exports during the past two decades.

Figure 3 illustrates how the share of Japan's exports in global machinery trade has changed over time. Although Japan is a major producer of machinery, its share in the world market peaked in the mid-1980s and has since fallen substantially. Since Japanese firms have progressively relocated their manufacturing activity overseas, this observation is not surprising in itself. Of more interest is the fact that the share decline has been much sharper in electronic and electrical products than in other machinery. Moreover, despite the fact that the shares of other branches of the machinery sector have been more or less stable since the late 1990s, that of electronic and electrical goods has been shrinking to this day.

Lying behind the previous observation are enormous structural changes that have unfolded in the world electronics industry. To illustrates its significance, Table 1 shows how the country shares in the production and consumption of two major electronic products — IT equipment and active components — have changed over time. Here "active components" refer to a subset of electronic components that have the ability to change the amplitude of signals in electronic circuits, the majority of which are accounted for by integrated circuits (ICs) and other semiconductor devices.

As shown in Table 1(i), although production of IT equipment was once dominated by industrial countries, during the 1990s some of the Asian Newly Industrializing Economies (ANIES) and second-tier Asian "tigers", notably Korea, Malaysia, Singapore and Taiwan, increased their shares. In the early 2000s, however, these countries were overtaken by China, whose output has since been growing at a phenomenal speed. Meanwhile, Japan has steadily lost market share and no longer registers a meaningful trade surplus for these products.

According to Table 1(ii), in the late 1980s the United States and Japan accounted for two thirds of global output of active electronic components.[5] During the following two

[5] However, the share of Japan's *exports* in world output was much smaller, since the majority of components produced by Japanese firms are either used in-house or sold to other firms in Japan.

decades, these countries have lost more than half of their market shares, which have been taken up mainly by the ANIES (excluding Hong Kong) and a few other Southeast Asian countries. Although the components industry is also burgeoning in China, its output growth has thus far been outstripped by the growth of its consumption, which derived mostly from the explosive growth of its IT hardware production. China's growing imports of advanced electronic components are primarily sourced from such countries as Korea, Singapore and Taiwan, with the share of Japan's exports falling steadily (Kumakura 2009).

Figure 4 illustrates how these structural changes in the world electronics industry has been reflected in Japan's export structure. According to Figure 4(i), machinery accounts for close to 80 percent of the total manufacturing exports, and its share has remained remarkably stable during the past quarter century.[6] During the latter half of the 1980s the share of electronics rose marginally despite the fact that Japan's export share in the world market fell sharply, chiefly because the world electronics market itself was growing very rapidly. During the 1990s the share of electronics in Japan's exports remained more or less stable against the backdrop of, among other things, growing exports of parts and components to Southeast Asia whose output of personal computers (PCs) and PC-related products was increasingly rapidly (Kumakura 2009). Since the turn of the century, however, the share of electronics in Japanese exports has fallen visibly, partly because the world electronics market is no longer growing as fast as in the past, partly because of increasing concentration of IT equipment production in China, and also because Japanese firms are now losing export shares in both final and intermediate products.

Figure 4(ii) breaks down Japan's manufacturing exports by destination country. As is widely documented, while North America and Europe once constituted dominant markets for Japanese exports, the shares of the ANIES and Southeast Asian countries started rising in the late-1980s, and that of China began increasing even more sharply at the end of the last century. Less well-known is the fact that this marked shift in the geographical distribution of Japanese exports has been driven primarily by the electronics industry. As shown in panel

[6] A slightly larger share of "other products" during the last few years has been caused primarily by commodity price hikes that pushed up the prices of such items as basic chemicals and steels.

(iii), the evolution of the importer composition of electronics exports has essentially been an exaggerated image of the general trend in panel (ii). In contrast, panel (iv) shows that the shares of neighboring Asian countries have barely increased for transport equipment, despite the fact that this industry accounts for a sizable fraction of Japanese exports.

From the above observation emerge a few additional points that may be worth noting when estimating an export function for Japan. First, given that Japan's export structure has changed considerably during the past two decades, one should be cautious about using outdated data when estimating its export function. Although some authors estimate the income and price elasticities of Japanese exports using decades of statistics (e.g., Hooper et al. 2000), such estimation may prove hazardous unless careful attention is paid to the possibility of structural change. Second, to the extent that electronics has been a major force behind the structural transformation of Japanese exports, it seems sensible to recognize its influence explicitly rather than trying to control it indirectly with, for example, a general shift parameter. And thirdly, since the reconfiguration of world electronics production has affected both Japan and its trade partners, it seems a good idea to estimate both aggregate and destination-specific export functions. The latter will help us deal with idiosyncratic factors more flexibly and interpret the result for the aggregate function.

3 Estimation strategy

With the previous discussion in mind, the rest of this paper econometrically investigates determinants of Japan's short- and long-term export performance. This section explains my empirical framework and defines relevant variables. The estimation result will be presented in Section 4.

3.1 Econometric framework

The starting point of my analysis is the following augmented export function:

$$Q_t^{\mathcal{G}} = Q\left(Y_t^{\mathcal{G}}, Y_{t-1}^{\mathcal{G}}, \ldots, S_t^{\mathcal{G}}, S_{t-1}^{\mathcal{G}}, \ldots, IT_t^{\mathcal{G}}, IT_{t-1}^{\mathcal{G}}, \ldots; Z_t^{\mathcal{G}}\right), \tag{6}$$

where superscript $\mathcal{G}$ is an importer identifier, which may represent a particular foreign country, a group of countries, or all foreign countries. $IT_t^{\mathcal{G}}$ is a variable that controls the short- and long-term effects of the electronics industry on the export volume. By letting lower-case letters denote natural logarithms, Eq. (6) can be written alternatively as

$$q_t^{\mathcal{G}} = q\left(y_t^{\mathcal{G}}, y_{t-1}^{\mathcal{G}}, \ldots, s_t^{\mathcal{G}}, s_{t-1}^{\mathcal{G}}, \ldots, it_t^{\mathcal{G}}, it_{t-1}^{\mathcal{G}}, \ldots; z_t^{\mathcal{G}}\right). \tag{7}$$

Before proceeding, let us consider briefly if any other variable should be included explicitly in Eq. (7). One variable that may be worthy of attention is foreign direct investment (FDI) by Japanese firms, which is widely regarded as a substitute for exports. Since Japan's outward FDI has historically been correlated with the external value of the yen, adding the former to the equation may also help estimate the price elasticity of exports accurately. According to recent studies, however, the relationship between Japan's FDI and trade is more nuanced than is often presumed, particularly over relatively short time horizons, while the effect of the yen exchange rate on outward FDI has weakened substantially in recent years.[7] Given the complicated relationship between FDI and exports, and limited availability of disaggregated FDI data, this paper chooses to control its influence by minimal use of generic dummy variables, rather than by developing a specific variable that would inevitably involve measurement errors. However, being mindful of the potential effect of FDI will prove useful when interpreting the estimation result in Section 4.

Although the majority of recent studies estimate export functions using cointegration-based methods of Engle and Granger (1987) and Johansen (1991), there are a few reasons to suspect that these techniques may not be ideal for this paper. First, while this paper uses relatively recent data for the reasons discussed in Section 2, the Engle-Granger and Johansen procedures often perform badly when the sample size is small. Second, although these methods require an accurate knowledge of the order of integration of all variables, standard unit root tests do not speak clearly about the variables that will be developed

[7] See Kiyota and Urata (2008). Since the late 1990s, FDI by Japanese manufacturers has grown sharply by *value* but has remained low in terms of *the number of cases*, due in part to an increase in large-scale M&A deals whose purpose is rarely cost-cutting overseas redeployment of domestic production facilities.

below.[8] Third and most important, whilst these methods can be very powerful when there is a stable long-term relationship among a small number of variables, they are less flexible than traditional techniques in letting the researcher incorporate extraneous information and experiment with alternative model specifications. Therefore, this paper will refrain from explicit cointegration techniques and will approach Eq. (7) with the following two models.

In the first instance, I do not assume the presence of a long-run relationship among the variables in Eq. (7) and consider the following simple partial adjustment model (PAM) for the rate of change in the export volume:

$$\Delta q_t^{\mathcal{G}*} = \alpha_0 + \alpha_1 \Delta y_t^{\mathcal{G}} + \alpha_2 \Delta s_t^{\mathcal{G}} + \alpha_3 \Delta it_t^{\mathcal{G}}, \tag{8}$$

$$\Delta q_t^{\mathcal{G}} - \Delta q_{t-1}^{\mathcal{G}} = \theta \left(\Delta q_t^{\mathcal{G}*} - \Delta q_{t-1}^{\mathcal{G}} \right) + \alpha_4 z_t^{\mathcal{G}} + \varepsilon_t, \quad 0 < \theta \leq 1, \tag{9}$$

where $\Delta q_t^{\mathcal{G}*}$ denotes the long-run adjustment of exports to the explanatory variables in Eq. (8), whereas θ shows how much of this long-run adjustment takes place during the same period. Factors that interfere with this adjustment process are represented by $z_t^{\mathcal{G}}$ and ε_t, of which the latter denotes a white noise.

By substituting Eq. (8) into Eq. (9), one finds

$$\Delta q_t^{\mathcal{G}} = \alpha_0^* + \alpha_1^* \Delta y_t^{\mathcal{G}} + \alpha_2^* \Delta s_t^{\mathcal{G}} + \alpha_3^* \Delta it_t^{\mathcal{G}} + \theta^* \Delta q_{t-1}^{\mathcal{G}} + \alpha_4 z_t^{\mathcal{G}} + \varepsilon_t, \tag{10}$$

where $\alpha_j^* = \theta \alpha_j$, $j = 1, 2, 3$ and $\theta^* = 1 - \theta$. This equation comprises only observable variables except for the error term and can be estimated by OLS.[9] When θ^* is estimated to be small, the adjustment process can be interpreted as swift and involving few meaningful dynamics.

However, the above model assumes a very specific adjustment process that may not hold in practice. Moreover, this model tells us little about the long-term relationship among the relevant variables. Therefore, I also consider the following error correction model (ECM):

$$\begin{aligned} \Delta q_t^{\mathcal{G}} = {} & \alpha_0 + \alpha_1 q_{t-1}^{\mathcal{G}} + \alpha_2 y_{t-1}^{\mathcal{G}} + \alpha_3 s_{t-1}^{\mathcal{G}} + \alpha_4 it_{t-1}^{\mathcal{G}} + \alpha_5 z_{t-1}^{\mathcal{G}} \\ & + \sum_{j=1}^{k} \beta_j \Delta q_{t-j}^{\mathcal{G}} + \sum_{j=0}^{k} \gamma_j \Delta y_{t-j}^{\mathcal{G}} + \sum_{j=0}^{k} \lambda_j \Delta s_{t-j}^{\mathcal{G}} + \sum_{j=0}^{k} \delta_j \Delta it_{t-j}^{\mathcal{G}} + \varepsilon_t. \end{aligned} \tag{11}$$

[8] The results of the Augmented Dickey-Fuller and Phillips-Perron tests are available on request.

[9] Unit root tests suggest that all variables in Eq. (10) are stationary.

When all of the level terms in the first line remain stable, the first difference terms in the second line equal 0 and disappear. If the error term is also 0, Eq. (11) collapses to an equation that includes only the level variables:

$$\alpha_0 + \alpha_1 q^{\mathcal{G}} + \alpha_2 y^{\mathcal{G}} + \alpha_3 s^{\mathcal{G}} + \alpha_4 it^{\mathcal{G}} + \alpha_5 z^{\mathcal{G}} = 0. \quad (12)$$

Accordingly, if one estimates Eq. (11) and finds that $q_{t-1}^{\mathcal{G}}$ and at least one of $y_{t-1}^{\mathcal{G}}$, $s_{t-1}^{\mathcal{G}}$ and $it_{t-1}^{\mathcal{G}}$ are statistically significant, this signals the presence of a long-term (cointegrating) relationship among these variables, and Eq. (11) can indeed be regarded as an ECM. Under such circumstances, α_1 represents the speed at which a temporary discrepancy between $q_{t-1}^{\mathcal{G}}$ and its equilibrium value is eliminated, and the long-run income and price elasticities of exports can be estimated as $-\alpha_2/\alpha_1$ and $-\alpha_3/\alpha_1$, respectively.

Nevertheless, since Eq. (11) includes variables with different orders of integration, there is a risk that the estimated equation is spurious. Moreover, not only are some of these variables likely to be highly collinear, there is also no *a priori* reason to believe that all of them are important. For example, even if the IT cycle exerts important effects on short-run export dynamics, there may or may not be a meaningful long-term relationship between $q_t^{\mathcal{G}}$ and $it_t^{\mathcal{G}}$. Therefore, I take this general model as a point of departure and progressively eliminate unnecessary terms using the general-to-specific modelling (GSM) techniques developed by David F. Hendry and his associates (Hendry et al. 1984; Hendry 1995). The GSM procedure is applicable even when the estimating equation has a mix of stationary and non-stationary variables, provided that model selection is conducted systematically and a battery of diagnostic tests is performed at each stage of specification search to avoid spurious regressions. Jongwanich (2009) is one of the few recent applications of the GSM method to export functions.

3.2 Data and variables

Eqs. (10) and (11) will be estimated for Japan's machinery exports using quarterly data for 1994Q1-2009Q1 or 1999Q2-2009Q1. I focus on machinery for the following reasons. First, while Eqs. (1) and (2) implicitly assume differentiated products with finite price elasticities of demand and supply, this assumption may not hold for primary goods and resource-intensive semi-manufactures. Second and more importantly, recent studies stress the role of international fragmentation of production, and associated trade in parts and components of machinery, in Japan's growing trade with other East Asian countries (Kimura and Ando 2005). While the next section experiments with estimation that takes account of such trade, doing so will be made easier if we limit our attention to the machinery sector. However, since machinery dominates Japan's exports, the equations estimated below can be usefully compared with the aggregate export functions estimated by other authors.

For both Eqs. (10) and (11), the dependent variable is computed from the MoF export quantum index. The MoF index is available for both aggregate exports and a combination of major product groups and importer countries/regions. The importer-specific indexes are available from 1994 and for the United States, the European Union (EU), the ANIES,[10] the Association of Southeast Asian Nations (ASEAN) and China. I estimate Eqs. (10) and (11) for the total machinery exports as well as for exports to these five countries/regions. For the sake of brevity, these aggregate and importer-specific export functions will be referred to as the "world" and "regional" equations, respectively.

Among the five regional equations, those for the EU and China will be estimated with a shorter sample for 1999Q2-2009Q1. As for the EU, beside the fact that three countries joined the union in 1995,[11] the literature suggests that its trade structure has changed measurably after the introduction of the euro in 1999 (Baldwin 2006). In addition, there is evidence that Japan's FDI in and exports to the EU experienced a small boom prior to the currency unification. Exports to China were noticeably unstable until the late 1990s, due apparently to rapid transformation of its economy but possibly also to frequent changes in its trade policy. Moreover, while the following estimation makes use of real GDP data of importer countries, China does not report its quarterly GDP statistics in a standard format. Although its data are carefully converted to normal quarterly real GDP series, the accuracy of the latter may

[10] The ANIES includes Hong Kong, Korea, Singapore and Taiwan.

[11] These countries are Austria, Finland and Sweden. Although another ten countries joined the EU in 2005, these countries are smaller and less important as Japan's trade partners. The MoF adjusts the series for the EU and the ASEAN retrospectively to changes in their memberships to avoid a discontinuity.

decrease as one looks further into the past. These considerations have led me to confine the dataset for the EU and China to the recent ten years.

The other variables are developed as follows. The foreign income, $Y_t^{\mathcal{G}}$, is measured by the real GDP of relevant countries. For equations that involve more than one importer country, I take a weighted average of the real GDP of the relevant countries as follows:

$$\frac{Y_t^{\mathcal{G}}}{Y_{t-1}^{\mathcal{G}}} = \prod_{i \in \mathcal{G}} \left(\frac{Y_{i,t}}{Y_{i,t-1}} \right)^{w_{i,t}^{\mathcal{G}}}, \tag{13}$$

where $Y_{i,t}$ denotes the real GDP of country i. $w_{i,t}^{\mathcal{G}}$ is the weight of country i in the regional GDP index and hence $\sum_{i \in \mathcal{G}} w_{i,t}^{\mathcal{G}} = 1$. In the first instance, I equate $w_{i,t}^{\mathcal{G}}$ to the share of country i in Japan's machinery exports to group $\mathcal{G}$.[12] To avoid potential endogeneity and mitigate effects from transitory factors, the weights for period t are calculated from data for ten quarters up to $t-1$. This treatment applies to all country weights in this section.

In the presence of fragmentation trade, the above variable may not accurately measure the income of countries that ultimately consume Japan's exports, since countries that import intermediate goods from Japan may export them as part of another product. To take account of such trade, I develop the following alternative variable:

$$\frac{Y_t^{\mathcal{G}*}}{Y_{t-1}^{\mathcal{G}*}} = \prod_{i} \left(\frac{Y_{i,t}}{Y_{i,t-1}} \right)^{w_{i,t}^{\mathcal{G}*}}. \tag{14}$$

Eq. (14) differs from Eq. (13) in two respects. First, $i = 1, 2, \ldots$ are no longer confined to countries within group $\mathcal{G}$ but also include other countries. Second, country shares are adjusted to take account of fragmentation trade. Accordingly, even if $\mathcal{G}$ is, for example, China, $Y_t^{\mathcal{G}*}$ is a weighted average of the real GDP of China and its trade partners. The Appendix explains how $w_{i,t}^{\mathcal{G}*}$ is calculated.

The real exchange rate $S_t^{\mathcal{G}}$ is also computed with two alternative methods. The first variable is calculated similarly as $Y_t^{\mathcal{G}}$ in terms of the following chain-linked formula:

$$\frac{S_t^{\mathcal{G}}}{S_{t-1}^{\mathcal{G}}} = \prod_{i \in \mathcal{G}} \left(\frac{S_{i,t}}{S_{i,t-1}} \right)^{w_{i,t}^{\mathcal{G}}}, \tag{15}$$

[12] Japan's exports to Hong Kong and Singapore contain entrepôt trade. I estimated the size of such trade using data from these countries and redistributed them to China, Indonesia and Malaysia.

where $S_{i,t} = P_{J,t}/(E_{i,t}P_{i,t})$ is the bilateral real exchange rate defined analogously as in Eq. (3) with J denoting Japan. The price level in each country is measured by the producer price index (PPI) for manufactures or an equivalent index.[13] Eq. (15) is perhaps the most popular method for calculating real effective exchange rates.

Nevertheless, one might wonder if the effective exchange rate calculated in this manner is the most appropriate one as an explanatory variable in the export function. In particular, this variable only measures the relative price (cost) between Japanese firms and those of the importer countries, and ignores competition vis-à-vis exporters from third countries. However, in the United States, for example, Japanese exporters are competing not only with local American firms but also with exporters from a number of other countries. To accommodate this consideration, I develop the following alternative variable:

$$\frac{S_t^{\mathcal{G}*}}{S_{t-1}^{\mathcal{G}*}} = \prod_{i \in \mathcal{G}} \left(\frac{S_{i,t}^*}{S_{i,t-1}^*} \right)^{w_{i,t}^{\mathcal{G}}}, \tag{16}$$

where

$$\frac{S_{i,t}^*}{S_{i,t-1}^*} = \prod_{j \neq J} \left(\frac{S_{j,t}}{S_{j,t-1}} \right)^{v_{j,t}^i} \quad \text{and} \quad v_{j,t}^i = \frac{X_{j,t}^i}{\sum_{l \neq J} X_{l,t}^i}. \tag{17}$$

The meaning of $S_t^{\mathcal{G}*}$ is as follows. In Eq. (17), $X_{l,t}^i$ denotes the value of machinery that is produced in country l and sold in country i. It corresponds to exports from country l to country i when $l \neq i$ and domestic sales by local firms when $l = i$. $l = 1, 2, \ldots$ includes all countries but Japan, including those outside region $\mathcal{G}$. Accordingly, $S_{i,t}^*$ can be interpreted as an index of the price competitiveness of Japanese firms in the market of country i vis-à-vis producers in *all* countries, including local firms. Eq. (16) averages this index for countries that belong to $\mathcal{G}$, using as the weight the share of each country in Japan's exports to $\mathcal{G}$. While the calculation of $S_t^{\mathcal{G}*}$ may look complicated, this variable is conceptually similar to multilateral exchange rates compiled by the IMF and the BIS.

[13] Japan's price level is measured by its Corporate Goods Price Index (CGPI) for manufactures. I do not use a price index for machinery because such indexes are available only for a small number of countries (but see Section 4.1).

Lastly, the electronics variable $IT_t^{\mathcal{G}}$ is defined as follows:

$$\frac{IT_t^{\mathcal{G}}}{IT_{t-1}^{\mathcal{G}}} = \left(\frac{IT_t}{IT_{t-1}}\right)^{\eta_t^{\mathcal{G}}} = \left(\frac{Q_t^{it}/Y_t^{it}}{Q_{t-1}^{it}/Y_{t-1}^{it}}\right)^{\eta_t^{\mathcal{G}}}, \tag{18}$$

where

$$\frac{Y_t^{it}}{Y_{t-1}^{it}} = \prod_i \left(\frac{Y_{i,t}}{Y_{i,t-1}}\right)^{\pi_{i,t}}, \tag{19}$$

and

$$\begin{aligned} \eta_t^{\mathcal{G}} &= \text{Share of electronics in Japan's machinery exports to } \mathcal{G}; \\ Q_t^{it} &= \text{Total real shipments of semiconductor devices in the world;} \\ \pi_{i,t} &= \text{Share of country } i \text{ in the global consumption of IT equipment.} \end{aligned}$$

To understand the meaning of this variable, let us take the log of eq. (18) to find

$$\begin{aligned} \Delta it_t^{\mathcal{G}} &= \eta_t^{\mathcal{G}} \times \left(\Delta q_t^{it} - \Delta y_t^{it}\right) \\ &\simeq \eta_t^{\mathcal{G}} \times [(\text{Growth rate of real global semiconductor sales}) \\ &\quad - (\text{Growth rate of real income in electronics-consumer countries})]. \end{aligned} \tag{20}$$

Since the value in the square brackets is the gap between the growth rates of global semiconductor shipments and the economies of countries that constitute the market for electronic products, it can be regarded as the part of the global IT cycle that stems from demand/supply factors specific to the electronics industry. This value is multiplied by $\eta_t^{\mathcal{G}}$ because, as discussed in Section 2.2, the importance of electronics in Japan's exports varies considerably across importer countries and has changed measurably over time. Whilst the value of $IT_t^{\mathcal{G}}$ is primarily governed by IT_t in the short run, it will become more reflective of changes in $\eta_t^{\mathcal{G}}$ over longer time horizons.

In addition to the previous variables, a series of dummy variables will be added to the estimating equations. First, all equations are augmented with period dummy variables for 2008Q3, 2008Q4, and 2009Q1. As shown in Figure 1, the export contraction during this period was so steep that, without special treatment, the result of estimation would be heavily influenced by this episode. Although I could simply exclude these periods from the sample, doing so risks discarding potentially useful information. While the export decline in this period was indeed extremely serious, a closer inspection of data reveals that its size and timing varied perceptively across importer countries. Moreover, this episode was preceded by a sharp downturn in the world IT market and a rapid yen appreciation (Figure 2). Not only do the three dummy variables prevent these quarters from becoming leverage points, but their estimated coefficients will also tell us how much of the recent export slump was due to factors not incorporated in my models.

For the regional equations for the ANIES and the ASEAN, I add dummies for 1997Q3 and 1997Q4 to control the effect of the Asian crisis.[14] For the equation for China, I include a dummy for 2007Q1 to control for an apparent discontinuity in data,[15] and another (set of) dummy variables to account for temporary acceleration of export growth between 2001 and 2002. Existing studies report that China's external trade relations changed measurably in the early 2000s, due in part to successive tariff reductions and deregulation of inward FDI as conditions for its entry into the WTO in December 2001 (Aziz and Li 2007). For the purpose of this paper, it is also noteworthy that subsequent to its WTO accession, China ratified the Information Technology Agreement (ITA), a sectoral trade liberation initiative within the WTO framework, which commits its signatories to duty-free imports of a wide range of electronic goods. When estimating the PAM, I control the export boom during this period with a single dummy variable that takes 1 between 2001Q4 and 2002Q3 and 0 for all other periods. For the ECM, I employ two dummy variables, one that takes 0 in all quarters up to 2001Q3 and 1 from 2001Q4 onward, and the other taking 0 until 2002Q3 and 1 thereafter.[16]

For the ECM, I further add a trend dummy variable and five dummies for each quarter between 2000Q4 and 2001Q4. The former is a catch-all variable that is meant to subsume all factors not explicitly modelled in Eq. (11). The latter controls for the steep contraction of the world electronics market between late 2000 and 2001 (Figure 2). While the proximate

[14] Dummy variables for subsequent quarters were insignificant and therefore dropped.

[15] Not conducting this treatment makes this period an extreme outliner in all subsequent estimations.

[16] Although the next section refers to the first dummy variable as $D(\text{WTO})$, this does not imply that the export acceleration during this period was all WTO related. For example, it is known that Japanese manufacturers' investment in China has a distinct cyclicality.

cause of this episode was the bursting of the dot.com bubble in the United States, it also reflected a serious supply glut in the international market after dissipation of Y2K concerns and thus may have arguably been a special event. These dummy variables are included only in the ECM because my preliminary analysis suggested that they had little explanatory power in the PAM. Lastly, the maximum lag length for the ECM is set at three quarters, after estimating the VAR model for the relevant variables with varying lag lengths and comparing their performance in a standard manner.

4 Estimation results

4.1 Partial adjustment model

Table 2 presents the baseline estimation result for the PAM. For each of the six world and regional equations there are eight alternative specifications. Among these, (a1) - (a4) and (b1) - (b4) are identical except that the latter include $\Delta it_t^{\mathcal{G}}$. Although the results for individual equations are varied, there are several general features worthy of attention.

First of all, $\Delta it_t^{\mathcal{G}}$ is highly significant except in the equation for the USA. Moreover, the estimated coefficients on $\Delta it_t^{\mathcal{G}}$ are large and not sensitive to the choice of other explanatory variables. Among the five regional equations, the estimated coefficients on $\Delta it_t^{\mathcal{G}}$ are smaller for the USA and the EU than for the East Asian countries. This result is as expected, since exports to the former countries include a relatively large share of final products, whose trade is more stable than that for intermediate goods.

Second, although the foreign income is also significant in many equations, the estimated coefficients differ considerably between (a1) - (a4) and (b1) - (b4). For example, in Table 2[A] the estimated coefficients on $\Delta y_t^{\mathcal{G}}$ and $\Delta y_t^{\mathcal{G}*}$ range between 2.17 and 2.51 in (a1) - (a4) but are barely above unity in (b1) - (b4). The contrast between these two sets of equations clearly reflects the fact that the market for electronics is much more volatile than those for other machinery, and that the global IT cycle is not a mere reflection of the macroeconomic cycles of major electronics-consumer countries. It also casts doubt over previous studies reporting the income elasticity of Japanese exports as high and/or rising.[17]

However, the foreign income tends to be statistically insignificant in the equations for the USA, the EU and China, although the estimated coefficient is always of the expected sign. As for the USA and the EU, large standard errors for $\Delta y_t^{\mathcal{G}}$ and $\Delta y_t^{\mathcal{G}*}$ are in part an outcome of their relatively high collinearity with $\Delta it_t^{\mathcal{G}}$. As for China, although one reason may be that a substantial fraction of its imports derive from its export demand, this cannot be the whole reason since $\Delta y_t^{\mathcal{G}*}$ is also insignificant at conventional levels of confidence. Moreover, among the five regional equations, that for China is estimated least precisely with or without the electronics variable. While there is a possibility of model misspecification, another reason may be measurement errors in China's GDP data.[18]

Third, the lagged dependent variable is often significant in (a1) -(a4) but never significant in (b1) - (b4). Insignificance in the latter equations points to the possibility that Japanese exports adjust to changes in underlying variables faster than is commonly believed. It also underlines the importance of paying attention to the IT cycle when estimating the income and price elasticities of Japanese exports.

Fourth, the estimated coefficients on the dummy variables for 2008Q3, 2009Q4 and 2009Q1 vary among the five regional equations. The absolute value of the sum of the three coefficients is largest for the USA (about 0.74 - 0.77) and smallest for the ANIES (0.18 - 0.23), with the implication that unusual factors played a much larger role in the former country during the recent export slump. Moreover, the dummy for 2008Q3 is significantly negative for the USA and China but positive for the ANIES and the ASEAN. In this connection, it is interesting that during the run-up to the recent worldwide economic crisis, financial troubles in the USA and China had surfaced earlier than in other countries, the former due to the subprime problem and the latter because of the burst of domestic equity price bubbles.

[17] In (a1) - (a4) the estimated coefficients on $\Delta y_t^{\mathcal{G}*}$ are often markedly higher than the those for $\Delta y_t^{\mathcal{G}}$ whilst this is not the case in (b1) - (b4). Since fragmentation trade is particularly intensive in the electronics industry (Kumakura 2009), the effect of the IT cycle tends to appear in the coefficient on $\Delta y_t^{\mathcal{G}*}$ when $\Delta it_t^{\mathcal{G}}$ is excluded from the estimating equation.

[18] When $\Delta y_t^{\mathcal{G}}$ for China is computed from its Economic Climate Indicator (ECI) rather than from its GDP, this variable becomes highly significant in all specifications. The ECI is a composite index developed by the China Economic Monitoring and Analysis Center, an affiliate of the Chinese National Bureau of Statistics.

Lastly, the real exchange rate is statistically insignificant or has a coefficient with a "wrong" sign, in *all* of the $8 \times 6 = 48$ equations. Upon closer inspection, however, we notice an interesting difference between (a1) - (a4) and (b1) - (b4). In the former equations the estimated coefficients on $\Delta s_t^{\mathcal{G}}$ and $\Delta s_t^{\mathcal{G}*}$ are comparatively large and at times statistically significant, whereas in the latter equations their values are smaller and never statistically significant. This difference clearly reflects the correlation between the IT cycle and the yen exchange rate, suggesting that past estimates of theoretically inconsistent price elasticities were indeed spurious.

However, the insignificance of the real exchange rate may still look puzzling, particularly in light of the popular perception that Japanese exporters are highly vulnerable to yen appreciation. One possibility is that the deflators used for $\Delta s_t^{\mathcal{G}}$ and $\Delta s_t^{\mathcal{G}*}$ were too broad as a measure of the relative price/cost competitiveness of Japanese and foreign producers. Another possibility is that strategic pricing-to-market by Japanese exporters obscures the relationship between exchange rates and exports. To test these conjectures, I experimented with another real exchange rate index in which Japan's price level was measured by an export price index for machinery.[19] This real exchange rate index behaves very differently from the other variables in the long run because the prices of machinery, and particularly those of electronics, fall much more rapidly than those of other manufactures. As it turned out, however, this variable was also insignificant in the majority of equations.

While the results in Table 2 are broadly in accord with my discussion in Section 2, one may be concerned about endogeneity between $\Delta q_t^{\mathcal{G}}$ and $\Delta it_t^{\mathcal{G}}$. Since both variables incorporate Japan's exports of semiconductors they are strictly speaking not independent of each other, although their direct overlap is limited. To test if the previous results are biased by this relationship, I apply instrumental variables (IVs) to $\Delta it_t^{\mathcal{G}}$ and repeat estimation of (b1) - (b4) using two-stage least squares (2SLS). As the explanatory variables in the first-stage equation, I use the lagged value of $\Delta it_t^{\mathcal{G}}$ and Semiconductor Equipment and Materials International's (SEMI) Book-to-Bill (B/B) Ratio for semiconductor production equipment, as

[19] This index was compiled from BoJ export price indexes for relevant product groups. Although the MoF also reports unit export value indexes, unit value indexes suffer from a number of well-known shortcomings.

well as other regressors in the second-stage equation. SEMI's B/B Ratio is highly correlated with global chips shipments and used frequently by industry analysts to gauge the condition of semiconductor markets. Moreover, since this index draws solely on data from equipment firms headquartered in North America, it is almost certainly exogenous to Japanese exports.

The result of the 2SLS estimation is presented in Table 3. This result is very similar to those shown in Table 2 except that, as expected, the former tend to be less precise than the latter. As before, $\Delta it_t^{\mathcal{G}}$ is highly significant in all equations but those for the USA, and its coefficient is particularly large for the ANIES and the ASEAN. Moreover, the coefficients on the exchange rate are very small and rarely significant. While not shown here, applying IVs to $\Delta q_{t-1}^{\mathcal{G}}$ generates qualitatively similar results.

4.2 Error correction model

Table 4 presents results from the GSM estimation of the ECM. Due to space limitation this table only reports a single final specification for each of the six world and regional equations, in which the foreign income and the real exchange rate are represented by $y_t^{\mathcal{G}}$ and $s_t^{\mathcal{G}}$, respectively.[20] The upper part of the table reports the estimated coefficients on the variables in the first line of Eq. (11), including various dummy variables. The lower part presents the coefficients on the first difference terms in the second line of Eq. (11), a series of diagnostic statistics and, when available, the implied long-run elasticities of the export volume to the foreign income, the real exchange rate and the electronics variable. As in the case of the PAM, the regression results contain several noteworthy features.

First of all, both $q_{t-1}^{\mathcal{G}}$ and at least one of $y_{t-1}^{\mathcal{G}}$, $s_{t-1}^{\mathcal{G}}$ and $it_{t-1}^{\mathcal{G}}$ remain in all of the six final equations. Moreover, these variables are statistically significant and have coefficients with a theoretically consistent sign. Therefore, these equations can be regarded as an ECM.

Second, except in the equations for the USA and the ANIES, the coefficient on $it_{t-1}^{\mathcal{G}}$ is not only statistically significant but also numerically large. In the world equation, the long-run elasticity of exports to $it_{t-1}^{\mathcal{G}}$ is estimated at 0.827, although, as discussed below, this value

[20] Using $y_t^{\mathcal{G}*}$ and $s_t^{\mathcal{G}*}$ does not materially change the estimation results, although the fit of the final specification tends to be less precise.

may need to be interpreted with some caution. Meanwhile, whereas the contemporaneous first-difference term, $\Delta it_t^{\mathcal{G}}$, is mostly significant and of the expected sign, the majority of the lagged electronics terms are eliminated from the final equations. Therefore, Japan's exports seem to adjust to the world IT cycle fairly quickly, consistent with the result for the PAM.

Third, although $y_{t-1}^{\mathcal{G}}$ appears in five out of the six equations, this variable is dropped for the EU and is only weakly significant in the world equation. However, this result does not necessarily imply that the conditions of the world and European economies does not matter for Japanese exports. Since $y_{t-1}^{\mathcal{G}}$ in the world and EU equations reflects the GDP of a large number of countries, its growth is naturally more stable than those for the other equations, making it difficult to identify its effect on the dependent variable. Doing so is also made difficult by a relatively strong correlation between the world and EU business cycles on the one hand, and the global IT cycle on the other. This may be a factor behind the rather low estimate of the income elasticity in the world equation.

Fourth, the coefficient on $s_{t-1}^{\mathcal{G}}$ is highly significant and of the expected sign in the world equation, despite the fact that this variable is dropped from all regional equations. Whereas these results may look inconsistent, one can think of a few plausible explanations. One possibility is that the significance of $s_{t-1}^{\mathcal{G}}$ in the world equation reflects causal effects from $q_{t-1}^{\mathcal{G}}$ to $s_{t-1}^{\mathcal{G}}$ rather than the other way round. Suppose, for example, that how much Japan exports to individual foreign countries is determined primarily by non-monetary factors while nominal exchange rates adjust to the macroeconomic balance of payments of which aggregate exports constitute an important part. Under such circumstances, there may arise a long-run relationship between $q_{t-1}^{\mathcal{G}}$ and $s_{t-1}^{\mathcal{G}}$ in the world equation even if no equivalent relationship exists at the bilateral and regional levels.

Another possibility is that in the world equation the causality does run from $s_{t-1}^{\mathcal{G}}$ to $q_{t-1}^{\mathcal{G}}$, but through a different channel from what is assumed in the standard export function. Although the standard function assumes that exchange rate movements affect exports by changing the relative price/cost competitiveness of domestic and foreign producers, a prolonged home currency appreciation may also encourage domestic firms to shift their production to foreign countries. As noted in Section 3.1, such effects were clearly present during the 1980s and 1990s, although the main destination for outward FDI by Japanese manufacturers has changed over time from advanced countries to the ANIES and the ASEAN, and more recently to China. To the extent that overseas production and exports are more substitutable than complementary in the long run, as they are likely to be, the volume of *aggregate* exports may be related negatively with the value of the yen, even when such regularity cannot be identified clearly at high frequencies and/or for bilateral trade.

Fifth, the trend dummy T is retained in the equations for the USA, the EU and the ASEAN, with negative and highly significant coefficients. Note that these coefficients are numerically sizable: if my estimation is correct, Japans' machinery exports to the USA and the ASEAN have been decreasing at the annualized rates of 5.1 and 3.0 percent, respectively, for reasons not incorporated in my model. Although space does not allow me to investigate what accounts for this finding, it is interesting to note that all of the three countries/regions for which the trend dummy is significant have been engaged in major regional trade liberalization programs from which Japan is excluded.

Incidentally, it may again look puzzling that T is not present in the world equation in spite of its high significance in three of the five regional equations. Although one might suppose that the declining exports to the USA, the EU and the ASEAN are somehow compensated for by growing exports to countries not covered by the five regional equations, this is unlikely to be the case since these countries account for a relatively small fraction of Japanese exports (Figure 4). A more plausible reason can be found in the fact that, as noted above, the world economy had grown at a fairly steady pace until the recent economic crisis. The fact that $y_t^{\mathcal{G}}$ for the world equation is relatively close to a linear trend makes it difficult to isolate its effect from that of T.[21] To the extent that this is the case, the small estimate of the income elasticity in the world equation may also reflect a secular deterioration of the export performance of Japanese manufacturers.

Lastly, the period dummy variables for 2008Q3, 2008Q4 and 2009Q1 play very different

[21] The hypothesis that $y_t^{\mathcal{G}}$ for the world equation follows a stationary process with a deterministic trend is soundly rejected for the full sample but may or may not be rejected for data up to 2008Q2, depending on the test used.

roles in the six equations. As in the PAM, the estimated coefficients on these variables are all highly negative for the USA, whereas only the 2009Q1 dummy is significant for the ANIES and the ASEAN. By comparing the coefficients for the six equations, one can surmise that much of the recent export crisis can be attributable to the collapse of exports to the USA and, to lesser extents, the EU and China, and that the subsequent declines in the other Asian countries has largely been repercussion from the global economic and financial crises that ensued. To the extent that this is the case, even if the world economy will continue recovering as it has been during the past few months, how long it will take for Japanese exporters to regain the lost ground is likely to vary across importer countries.

5 Conclusion

Whilst a number of studies estimate Japan's export functions, their estimates feature notable anomalies, such as unstable and/or implausibly large income elasticities, theoretically inconsistent price elasticities, and income and price elasticities that vary considerably among trade partner countries. These studies, however, tend to rely exclusively on macroeconomic variables and ignore distinct effects from the electronics industry. Not only has the electronics industry been a major driver of the dynamics of and the structural changes in Japan's exports, but it is also correlated with macroeconomic variables that constitute arguments for the standard export function. The central thesis of this paper has been that one needs to recognize these effects explicitly when estimating Japan's export functions, *even when the dependent variable includes a wide range of non-electronic products.*

This hypothesis has been tested formally by estimating two sets of tailor-made export functions. Not only do the estimated equations confirm the decisive effects of electronics on the short- and long-term performance of Japanese exports, but they also suggest that a failure to control these effects could significantly bias estimation of other parameters. In addition, the estimation results reveal substantial cross-importer heterogeneity in the manner in which the IT cycle and other variables affect Japan's exports. This observation, together with the finding that Japanese manufacturers are structurally losing market shares in certain parts of the world, suggests that their recovery from the recent export collapse may likely prove patchy and take more time than they might be hoping.

Whereas the findings of this paper are hopefully of some interest to students of Japan's trade, how long these findings will remain relevant is an open question, not least because electronics is such a fast-changing industry. As shown in Section 2, the share of electronics in Japanese exports has fallen measurably in recent years, in part because of growing overseas production by Japanese firms but also due to keener competition from their foreign rivals. In recent years, moreover, the center of gravity in the world electronics market has shifted from corporate IT equipment to consumer audiovisual and networking devices, whose demand may be less prone to the kind of extreme boom-bust cycles that plagued the industry until the early 2000s. As the IT cycle becomes more synchronized with the world business cycle and as electronics become less important for Japanese manufacturers, its impact on Japan's exports might conceivably diminish in the future.

Nevertheless, such effects must be set against other forces that might work in the opposite direction. As discussed in Section 2, manufacturing of consumer IT equipment is increasingly dominated by China and a handful of other developing countries, and these countries are now busy expanding the domain of their activity. The competitive pressures from these countries are pushing Japanese firms into a narrower range of upstream products, such as advanced electronic components and semiconductor fabrication facilities, whose market is naturally more volatile than those for consumer electronics. Moreover, although the business cycle of China has until recently been largely independent of the world IT cycle, the ongoing growth of its domestic electronics market suggests that their relationship can strengthen in the near future. To the extent that this is the case, it is also conceivable that the electronics industry will continue to shake Japan's exports by interacting with China's technical progress and macroeconomic fluctuations.

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Appendix: Calculation of $w_{i,t}^{\mathcal{G}*}$

This Appendix explains how country weights in Eq. (14) are calculated. To this end, let $k = 1, 2, \ldots$ denote individual machinery products. For a reason that will soon become clear, I classify $k = 1, 2, \ldots$ into two disjoint sets, one for final products ($\mathcal{F}$) and the other for intermediates ($\mathcal{I}$).

Next, let $X_{m,t}^{i}(k)$ denote the value of good k that is produced in country m and sold to country i in period t. When $m \neq i$ this value represents exports from country m to i; when $m = i$ it is domestic sales in country m. When $m = J$ and $i \neq J$, $X_{m,t}^{i}(k)$ denotes the exports from Japan to country i.

When $k \in \mathcal{F}$, it would be reasonable to assume that $X_{m,t}^{i}(k)$ derives primarily from country i's domestic demand.[22] When $k \in \mathcal{I}$, however, country i may use $X_{m,t}^{i}(k)$ as an input to an export good, in which case the fundamental demand for $X_{m,t}^{i}(k)$ comes from elsewhere. To account for this possibility, I adjust the value of $X_{J,t}^{i}(k)$ as follows:

$$X_{J,t}^{i,\mathcal{G}}(k) = \begin{cases} X_{J,t}^{i}(k) & \text{if } k \in \mathcal{F} \\ \sum_{m \in \mathcal{G}} \delta_{m,t}^{i} X_{J,t}^{m}(k) & \text{if } k \in \mathcal{I}, \end{cases}$$

where

$$\delta_{m,t}^{i} = \frac{\sum_k X_{m,t}^{i}(k)}{\sum_l \sum_k X_{m,t}^{l}(k)} = \frac{\sum_k X_{m,t}^{i}(k)}{\sum_k O_{m,t}(k)}.$$

In the above, $\sum_l \sum_k X_{m,t}^{l}(k) = \sum_k O_{m,t}(k)$ corresponds to the total output of machinery in country m, while $\delta_{m,t}^{i}$ indicates the proportion of this output that is sold to country i. $\delta_{m,t}^{m}$ represents the share of domestic shipments in the total output, which ought to be high for large countries like the USA but may be minimal for small countries heavily engaged in fragmentation trade. Accordingly, $X_{J,t}^{i,\mathcal{G}}(k)$ gives us a rough estimate of how much of good k that Japan exports to region $\mathcal{G}$ is ultimately consumed in country i.[23] Note that $i = 1, 2, \ldots$ are not confined to members of $\mathcal{G}$, since machinery produced by members of region $\mathcal{G}$ may well be exported to countries outside $\mathcal{G}$.

[22] When k is a capital good that is used for production of export goods, the value of $X_{m,t}^{i}(k)$ may depend indirectly on the demand from other countries. I ignore this possibility for the sake of simplicity.

[23] Although goods exported by country m may be exported again as part of another product, this possibility is also ignored to simplify calculation.

Let us next aggregate $X_{J,t}^{i,\mathcal{G}}(k)$ over $k = 1, 2, \ldots$ according to the following rules:

$$X_{J,t}^{i,\mathcal{G}} = \begin{cases} \sum_k X_{J,t}^{i,\mathcal{G}}(k) & \text{if } i \in \mathcal{G} \\ \sum_{k \in \mathcal{I}} X_{J,t}^{i,\mathcal{G}}(k) & \text{if } i \notin \mathcal{G}. \end{cases}$$

This value tells us how much of Japan's machinery exports to region $\mathcal{G}$, including both final and intermediate products, depends on the demand from country i. We are now in a position to define $w_{i,t}^{\mathcal{G}*}$. This value is computed as follows:

$$w_{i,t}^{\mathcal{G}*} = \frac{X_{J,t}^{i,\mathcal{G}}}{\sum_l X_{J,t}^{l,\mathcal{G}}}.$$

Note that $i = 1, 2, \ldots$ include Japan, since Japan's exports of intermediates to region $\mathcal{G}$ may be shipped back as parts of other products.

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Table 1 Evolution of regional shares in the global electronics market (%)

(i) IT equipment

Country / region	Production (A)						Consumption (B)						Net exports (A) - (B)					
	1989	1993	1997	2001	2005	2008	1989	1993	1997	2001	2005	2008	1989	1993	1997	2001	2005	2008
North America	33.8	30.9	31.2	30.9	21.6	19.5	39.7	39.5	39.5	40.2	36.3	33.5	-5.8	-8.7	-8.4	-9.3	-14.7	-13.9
West Europe	22.0	19.4	19.6	17.1	14.4	11.5	29.8	28.0	24.2	23.7	24.1	23.1	-7.8	-8.6	-4.5	-6.6	-9.7	-11.7
East Europe	N/A	0.5	0.9	1.8	2.9	4.0	N/A	1.1	1.6	2.1	2.5	2.5	N/A	-0.6	-0.7	-0.3	0.5	1.5
Japan	*28.3*	*25.9*	*19.7*	*14.5*	*11.1*	*8.5*	*19.0*	*16.6*	*16.3*	*13.2*	*9.8*	*8.1*	*9.3*	*9.3*	*3.5*	*1.3*	*1.3*	*0.4*
Korea & Taiwan	5.2	6.4	7.3	9.5	8.7	6.5	1.8	2.5	3.0	3.0	2.6	2.4	3.4	4.0	4.3	6.4	6.2	4.0
Southeast Asia	3.6	8.2	11.3	10.9	9.9	9.4	1.7	3.2	4.0	3.2	3.7	3.9	1.9	5.0	7.3	7.6	6.2	5.6
China & Hong Kong	2.7	4.1	5.4	11.4	26.9	34.5	1.7	2.8	3.7	7.9	11.5	13.7	0.9	1.3	1.7	3.5	15.4	20.8
Other countries	4.4	4.5	4.6	3.9	4.5	6.2	6.4	6.4	7.8	6.8	9.6	12.7	-2.0	-1.8	-3.2	-2.8	-5.1	-6.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0

(ii) Active electronic components

Country / region	Production (A)						Consumption (B)						Net exports (A) - (B)					
	1989	1993	1997	2001	2005	2008	1989	1993	1997	2001	2005	2008	1989	1993	1997	2001	2005	2008
North America	27.2	25.4	27.8	23.9	17.3	16.1	34.2	35.6	38.4	29.5	22.0	19.4	-7.0	-10.2	-10.6	-5.6	-4.7	-3.3
West Europe	11.4	9.5	9.5	12.3	10.6	11.0	18.5	16.5	16.6	15.2	13.5	12.8	-7.1	-7.0	-7.1	-3.0	-3.0	-1.8
East Europe	N/A	0.2	0.3	0.5	0.6	0.0	N/A	0.3	0.8	2.5	3.3	3.3	N/A	-0.1	-0.5	-1.9	-2.7	-3.3
Japan	*40.1*	*38.1*	*29.0*	*28.0*	*23.4*	*20.4*	*30.4*	*26.0*	*19.5*	*19.6*	*16.7*	*14.4*	*9.7*	*12.2*	*9.5*	*8.3*	*6.7*	*6.0*
Korea & Taiwan	9.5	11.1	15.7	13.7	21.5	21.4	6.9	8.7	9.6	8.2	9.9	9.3	2.7	2.5	6.1	5.5	11.7	12.1
Southeast Asia	8.3	11.5	13.9	15.6	19.9	21.9	2.8	5.4	6.5	7.4	9.2	9.8	5.4	6.2	7.4	8.2	10.7	12.1
China & Hong Kong	1.7	1.7	2.5	4.1	5.3	7.7	3.5	4.4	5.1	13.8	21.6	26.8	-1.8	-2.6	-2.6	-9.7	-16.4	-19.1
Other countries	1.9	2.4	1.4	1.9	1.4	1.5	3.6	3.3	3.4	3.7	3.9	4.3	-1.8	-0.9	-2.1	-1.9	-2.4	-2.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0

(Notes) IT equipment comprises computer equipment and related products, mobile telephone sets and other radio communications products, and digital audiovisual products. Active electronic components include such items as electronic integrated circuits, transistors and diodes. Data for 2008 include estimates.
(Source) Author's calculation with data from Reed Electronics Research, *Yearbook of World Electronics Data* (various issues).

Table 2 Estimation of the partial adjustment model (OLS)

[A] World (1994Q1－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.017 (0.007) **	-0.016 (0.007) **	-0.019 (0.007) **	-0.018 (0.007) **	-0.007 (0.004) *	-0.007 (0.004) *	-0.007 (0.006)	-0.006 (0.006)
Δy^G	2.205 (0.541) ***	2.170 (0.549) ***			1.014 (0.427) **	1.002 (0.419) **		
Δy^{G*}			2.512 (0.613) ***	2.480 (0.634) ***			1.011 (0.599) *	1.002 (0.602) *
Δs^G	0.071 (0.084)		0.061 (0.087)		0.027 (0.068)		0.023 (0.069)	
Δs^{G*}		0.064 (0.086)		0.056 (0.090)		0.020 (0.072)		0.017 (0.073)
Δit^G					0.817 (0.173) ***	0.821 (0.171) ***	0.840 (0.172) ***	0.842 (0.171) ***
Δq^G(-1)	0.274 (0.080) ***	0.278 (0.079) ***	0.272 (0.083) ***	0.275 (0.082) ***	0.106 (0.084)	0.108 (0.084)	0.106 (0.088)	0.107 (0.088)
D (2008Q3)	0.012 (0.008)	0.011 (0.008)	0.012 (0.007)	0.012 (0.008)	-0.004 (0.005)	-0.004 (0.005)	-0.005 (0.005)	-0.005 (0.005)
D (2008Q4)	-0.144 (0.025) ***	-0.143 (0.027) ***	-0.142 (0.027) ***	-0.142 (0.029) ***	-0.125 (0.021) ***	-0.124 (0.023) ***	-0.127 (0.024) ***	-0.125 (0.026) ***
D (2009Q1)	-0.292 (0.024) ***	-0.292 (0.025) ***	-0.286 (0.025) ***	-0.286 (0.026) ***	-0.327 (0.015) ***	-0.327 (0.016) ***	-0.327 (0.016) ***	-0.327 (0.017) ***
R^2 (adj.)	0.862	0.861	0.858	0.858	0.897	0.897	0.895	0.895
SER	0.024	0.024	0.024	0.024	0.021	0.021	0.021	0.021
LM(2)	0.971 [0.615]	0.989 [0.610]	1.636 [0.441]	1.662 [0.436]	1.366 [0.505]	1.446 [0.485]	1.416 [0.493]	1.475 [0.478]

[B] USA (1994Q1－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.008 (0.008)	-0.008 (0.008)	-0.009 (0.008)	-0.009 (0.008)	-0.009 (0.007)	-0.008 (0.007)	-0.008 (0.007)	-0.008 (0.007)
Δy^G	1.469 (0.683) **	1.434 (0.692) **			1.150 (0.787)	1.125 (0.791)		
Δy^{G*}			1.539 (0.748) **	1.499 (0.761) *			1.090 (0.817)	1.059 (0.822)
Δs^G	0.224 (0.155)		0.224 (0.156)		0.179 (0.149)		0.181 (0.148)	
Δs^{G*}		0.224 (0.159)		0.223 (0.159)		0.174 (0.151)		0.177 (0.150)
Δit^G					0.522 (0.372)	0.528 (0.372)	0.513 (0.379)	0.520 (0.378)
Δq^G(-1)	-0.091 (0.126)	-0.091 (0.127)	-0.093 (0.125)	-0.094 (0.126)	-0.125 (0.124)	-0.126 (0.125)	-0.124 (0.123)	-0.125 (0.124)
D (2008Q3)	-0.095 (0.012) ***	-0.097 (0.011) ***	-0.094 (0.012) ***	-0.097 (0.012) ***	-0.098 (0.011) ***	-0.100 (0.010) ***	-0.099 (0.011) ***	-0.101 (0.010) ***
D (2008Q4)	-0.190 (0.034) ***	-0.197 (0.038) ***	-0.188 (0.036) ***	-0.195 (0.040) ***	-0.171 (0.034) ***	-0.175 (0.039) ***	-0.172 (0.036) ***	-0.177 (0.040) ***
D (2009Q1)	-0.476 (0.028) ***	-0.479 (0.029) ***	-0.473 (0.030) ***	-0.476 (0.031) ***	-0.473 (0.025) ***	-0.475 (0.026) ***	-0.474 (0.027) ***	-0.476 (0.028) ***
R^2 (adj.)	0.717	0.715	0.716	0.714	0.723	0.721	0.722	0.720
SER	0.043	0.043	0.043	0.043	0.042	0.042	0.042	0.042
LM(2)	0.897 [0.639]	1.266 [0.531]	0.896 [0.639]	1.271 [0.530]	0.755 [0.685]	1.057 [0.589]	0.629 [0.730]	0.905 [0.636]

[C] EU (1999Q2－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.017 (0.015)	-0.016 (0.015)	-0.019 (0.017)	-0.018 (0.017)	-0.018 (0.013)	-0.017 (0.013)	-0.018 (0.015)	-0.017 (0.015)
Δy^G	3.050 (1.974)	2.923 (1.966)			2.326 (1.832)	2.196 (1.840)		
Δy^{G*}			3.349 (2.109)	3.212 (2.106)			2.343 (2.032)	2.206 (2.042)
Δs^G	0.219 (0.125) *		0.206 (0.124)		0.103 (0.131)		0.105 (0.131)	
Δs^{G*}		0.266 (0.125) **		0.254 (0.123) **		0.147 (0.134)		0.150 (0.134)
Δit^G					0.746 (0.215) ***	0.734 (0.204) ***	0.730 (0.225) ***	0.718 (0.214) ***
Δq^G(-1)	0.161 (0.187)	0.155 (0.188)	0.151 (0.180)	0.146 (0.182)	0.057 (0.109)	0.056 (0.112)	0.057 (0.109)	0.055 (0.113)
D (2008Q3)	0.027 (0.027)	0.025 (0.027)	0.029 (0.028)	0.027 (0.028)	0.020 (0.020)	0.018 (0.021)	0.020 (0.022)	0.018 (0.022)
D (2008Q4)	-0.205 (0.064) ***	-0.216 (0.063) ***	-0.194 (0.067) ***	-0.206 (0.066) ***	-0.146 (0.049) ***	-0.159 (0.050) ***	-0.147 (0.054) ***	-0.160 (0.054) ***
D (2009Q1)	-0.300 (0.077) ***	-0.307 (0.078) ***	-0.295 (0.078) ***	-0.302 (0.080) ***	-0.312 (0.056) ***	-0.319 (0.058) ***	-0.314 (0.060) ***	-0.321 (0.062) ***
R^2 (adj.)	0.840	0.843	0.842	0.844	0.873	0.875	0.872	0.874
SER	0.033	0.033	0.033	0.033	0.029	0.029	0.030	0.029
LM(2)	1.315 [0.518]	1.068 [0.586]	1.183 [0.553]	0.979 [0.613]	2.241 [0.326]	2.154 [0.341]	2.415 [0.299]	2.317 [0.314]

(Continued)

[D] ANIES (1994Q1－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.037 (0.009) ***	-0.036 (0.009) ***	-0.043 (0.011) ***	-0.043 (0.011) ***	-0.023 (0.005) ***	-0.023 (0.005) ***	-0.028 (0.006) ***	-0.027 (0.006) ***
Δy^G	3.119 (0.613) ***	3.102 (0.612) ***			1.670 (0.336) ***	1.665 (0.336) ***		
Δy^{G*}			3.782 (0.761) ***	3.765 (0.760) ***			2.073 (0.418) ***	2.068 (0.417) ***
Δs^G	0.184 (0.110) *		0.170 (0.110)		0.082 (0.090)		0.077 (0.089)	
Δs^{G*}		0.197 (0.110) *		0.178 (0.110)		0.085 (0.090)		0.080 (0.089)
Δit^G					1.103 (0.230) ***	1.101 (0.231) ***	1.102 (0.230) ***	1.100 (0.231) ***
$\Delta q^G(-1)$	0.245 (0.115) **	0.241 (0.113) **	0.249 (0.115) **	0.245 (0.114) ***	0.082 (0.116)	0.081 (0.115)	0.082 (0.116)	0.081 (0.116)
D (1997Q3)	-0.029 (0.009) ***	-0.031 (0.009) ***	-0.026 (0.009) ***	-0.027 (0.009) ***	-0.032 (0.007) ***	-0.033 (0.007) ***	-0.030 (0.007) ***	-0.031 (0.007) ***
D (1997Q4)	0.050 (0.009) ***	0.050 (0.009) ***	0.051 (0.010) ***	0.051 (0.009) ***	0.039 (0.006) ***	0.040 (0.006) ***	0.040 (0.006) ***	0.040 (0.006) ***
D (2008Q3)	0.069 (0.013) ***	0.068 (0.013) ***	0.069 (0.013) ***	0.069 (0.013) ***	0.037 (0.012) ***	0.037 (0.012) ***	0.038 (0.012) ***	0.037 (0.012) ***
D (2008Q4)	-0.072 (0.044)	-0.072 (0.043) *	-0.058 (0.047)	-0.059 (0.046)	-0.016 (0.026)	-0.016 (0.026)	-0.008 (0.026)	-0.008 (0.026)
D (2009Q1)	-0.227 (0.022) ***	-0.228 (0.022) ***	-0.215 (0.022) ***	-0.216 (0.022) ***	-0.217 (0.020) ***	-0.217 (0.002) ***	-0.210 (0.021) ***	-0.211 (0.021) ***
R^2 (adj.)	0.659	0.660	0.660	0.661	0.754	0.754	0.757	0.757
SER	0.042	0.042	0.042	0.041	0.035	0.035	0.035	0.035
LM(2)	2.871 [0.238]	2.832 [0.243]	2.167 [0.338]	2.148 [0.342]	1.288 [0.525]	1.285 [0.526]	1.005 [0.605]	1.004 [0.605]

[E] ASEAN (1994Q1－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.007 (0.006)	-0.007 (0.006)	-0.013 (0.008)	-0.013 (0.008)	-0.011 (0.004) ***	-0.011 (0.004) ***	-0.014 (0.004) ***	-0.014 (0.004) ***
Δy^G	1.293 (0.406) ***	1.282 (0.408) ***			1.121 (0.306) ***	1.120 (0.303) ***		
Δy^{G*}			1.993 (0.655) ***	1.974 (0.658) ***			1.567 (0.449) ***	1.565 (0.445) ***
Δs^G	0.082 (0.096)		0.087 (0.095)		0.004 (0.089)		0.010 (0.088)	
Δs^{G*}		0.087 (0.107)		0.089 (0.106)		0.006 (0.101)		0.011 (0.100)
Δit^G					1.052 (0.183) ***	1.052 (0.181) ***	1.010 (0.180) ***	1.011 (0.178) ***
$\Delta q^G(-1)$	0.368 (0.115) ***	0.370 (0.115) ***	0.324 (0.114) ***	0.326 (0.114) ***	0.181 (0.078) **	0.181 (0.078) **	0.170 (0.083) **	0.170 (0.084) **
D (1997Q3)	-0.079 (0.015) ***	-0.076 (0.012) ***	-0.079 (0.015) ***	-0.076 (0.012) ***	-0.074 (0.012) ***	-0.074 (0.010) ***	-0.075 (0.012) ***	-0.075 (0.010) ***
D (1997Q4)	-0.107 (0.013) ***	-0.103 (0.010) ***	-0.103 (0.014) ***	-0.099 (0.011) ***	-0.109 (0.009) ***	-0.108 (0.006) ***	-0.106 (0.009) ***	-0.106 (0.006) ***
D (2008Q3)	0.001 (0.006)	0.003 (0.006)	0.007 (0.006)	0.008 (0.006)	0.003 (0.003)	0.003 (0.003)	0.006 (0.003) *	0.006 (0.003) **
D (2008Q4)	-0.062 (0.030) **	-0.064 (0.032) *	-0.046 (0.035)	-0.048 (0.038)	0.032 (0.031)	0.032 (0.033)	0.036 (0.031)	0.036 (0.033)
D (2009Q1)	-0.348 (0.014) ***	-0.348 (0.014) ***	-0.339 (0.016) ***	-0.339 (0.017) ***	-0.320 (0.010) ***	-0.320 (0.010) ***	-0.316 (0.011) ***	-0.316 (0.011) ***
R^2 (adj.)	0.763	0.763	0.771	0.771	0.855	0.855	0.854	0.854
SER	0.037	0.037	0.037	0.037	0.029	0.029	0.029	0.029
LM(2)	0.187 [0.911]	0.179 [0.914]	0.032 [0.984]	0.038 [0.981]	1.555 [0.460]	1.579 [0.454]	1.728 [0.422]	1.740 [0.419]

[E] China (1999Q2－2009Q1)

Independent variable	(a1)	(a2)	(a3)	(a4)	(b1)	(b2)	(b3)	(b4)
Constant	-0.038 (0.057)	-0.037 (0.057)	-0.043 (0.058)	-0.042	-0.001 (0.051)	0.000 (0.051)	0.002 (0.049)	0.003 (0.049)
Δy^G	2.532 (2.224)	2.502 (2.214)			0.959 (2.087)	0.922 (2.097)		
Δy^{G*}			2.875 (2.364)	2.840 (2.353)			0.858 (2.114)	0.818 (2.125)
Δs^G	-0.138 (0.265)		-0.147 (0.267)		-0.259 (0.205)		-0.259 (0.204)	
Δs^{G*}		-0.126 (0.266)		-0.135 (0.267)		-0.252 (0.210)		-0.253 (0.209)
Δit^G					1.112 (0.247) ***	1.110 (0.248) ***	1.110 (0.254) ***	1.109 (0.255) ***
$\Delta q^G(-1)$	0.245 (0.152)	0.244 (0.152)	0.246 (0.152)	0.246 (0.151)	0.168 (0.146)	0.168 (0.145)	0.168 (0.146)	0.167 (0.146)
D (2007Q1)	-0.161 (0.047) ***	-0.160 (0.047) ***	-0.164 (0.047) ***	-0.163 (0.047) ***	-0.140 (0.042) ***	-0.138 (0.042) ***	-0.136 (0.040) ***	-0.135 (0.040) ***
D (2008Q3)	-0.053 (0.014) ***	-0.052 (0.014) ***	-0.051 (0.014) ***	-0.051 (0.014) ***	-0.058 (0.011) ***	-0.057 (0.011) ***	-0.057 (0.011) ***	-0.057 (0.011) ***
D (2008Q4)	-0.168 (0.057) ***	-0.168 (0.059) ***	-0.159 (0.061) **	-0.160 (0.064) **	-0.077 (0.044) *	-0.076 (0.047)	-0.077 (0.045) *	-0.076 (0.048)
D (2009Q1)	-0.200 (0.087) ***	-0.201 (0.086) **	-0.189 (0.092) **	-0.190 (0.092) **	-0.204 (0.071) ***	-0.205 (0.071) ***	-0.207 (0.071) ***	-0.208 (0.071) ***
D (WTO)	0.092 (0.013) ***	0.092 (0.013) ***	0.092 (0.013) ***	0.092 (0.013) ***	0.071 (0.011) ***	0.071 (0.011) ***	0.071 (0.011) ***	0.071 (0.011) ***
R^2 (adj.)	0.654	0.653	0.656	0.655	0.728	0.727	0.728	0.727
SER	0.052	0.052	0.052	0.052	0.046	0.046	0.046	0.046
LM(2)	3.375 [0.185]	3.462 [0.177]	3.349 [0.187]	3.433 [0.180]	2.279 [0.320]	2.247 [0.325]	2.224 [0.329]	2.192 [0.334]

(Notes) Values in ( ) are robust standard errors. *, ** and *** indicate significance at 10, 5 and 1 percent levels, respectively. *D* (WTO) = a dummy variable taking the value of 1 during 2001Q4-2002Q3 and 0 in other periods; R^2 (adj.) = coefficient of determination (adjusted for degree of freedom); SER = standard error of regression; LM(2) = LM test for second-order serial correlation (χ^2-statistic); p-values in [ ].

Table 3　Estimation of the partial adjustment model (2SLS)

Indep. variable	World (1994Q1－2009Q1)				USA (1994Q1－2009Q1)				EU (1999Q2－2009Q1)			
	(c1)	(c2)	(c3)	(c4)	(c1)	(c2)	(c3)	(c4)	(c1)	(c2)	(c3)	(c4)
Constant	-0.005 (0.006)	-0.005 (0.006)	-0.004 (0.007)	-0.004 (0.007)	-0.009 (0.007)	-0.008 (0.007)	-0.008 (0.007)	-0.008 (0.007)	-0.018 (0.012)	-0.017 (0.012)	-0.017 (0.014)	-0.016 (0.014)
Δy^{G}	0.791 (0.636)	0.776 (0.614)			1.086 (0.866)	1.061 (0.866)			1.809 (1.734)	1.676 (1.770)		
Δy^{G*}			0.725 (0.837)	0.714 (0.826)			1.003 (0.923)	0.971 (0.922)			1.554 (1.961)	1.414 (2.002)
Δs^{G}	0.019 (0.072)		0.015 (0.072)		0.169 (0.153)		0.173 (0.152)		0.020 (0.169)		0.026 (0.175)	
Δs^{G*}		0.012 (0.076)		0.010 (0.076)		0.163 (0.156)		0.167 (0.155)		0.062 (0.179)		0.068 (0.185)
Δit^{G}	0.970 (0.437) **	0.979 (0.434) **	1.000 (0.441) **	1.007 (0.438) **	0.628 (0.521)	0.637 (0.522)	0.613 (0.538)	0.623 (0.539)	1.279 (0.337) ***	1.258 (0.334) ***	1.302 (0.359) ***	1.283 (0.357) ***
Δq^{G}(-1)	0.075 (0.125)	0.075 (0.125)	0.074 (0.127)	0.074 (0.127)	-0.132 (0.125)	-0.134 (0.126)	-0.130 (0.124)	-0.131 (0.125)	-0.016 (0.110)	-0.015 (0.110)	-0.018 (0.115)	-0.016 (0.115)
D (2008Q3)	-0.007 (0.009)	-0.007 (0.008)	-0.008 (0.009)	-0.008 (0.009)	-0.099 (0.011) ***	-0.101 (0.010) ***	-0.099 (0.011) ***	-0.101 (0.011) ***	0.015 (0.018)	0.013 (0.019)	0.012 (0.020)	0.010 (0.021)
D (2008Q4)	-0.121 (0.025) ***	-0.120 (0.027) ***	-0.124 (0.027) ***	-0.122 (0.029) ***	-0.167 (0.037) ***	-0.171 (0.042) ***	-0.169 (0.038) ***	-0.173 (0.042) ***	-0.103 (0.059) *	-0.118 (0.059) *	-0.109 (0.064) *	-0.124 (0.064) *
D (2009Q1)	-0.334 (0.022) ***	-0.334 (0.021) ***	-0.335 (0.023) ***	-0.335 (0.023) ***	-0.473 (0.025) ***	-0.475 (0.026) ***	-0.474 (0.027) ***	-0.476 (0.027) ***	-0.321 (0.049) ***	-0.327 (0.049) ***	-0.330 (0.053) ***	-0.336 (0.054) ***
SER	0.021	0.021	0.021	0.021	0.042	0.042	0.042	0.042	0.032	0.031	0.032	0.032
LM(2)	2.735 [0.255]	2.945 [0.229]	2.530 [0.282]	2.678 [0.262]	0.757 [0.685]	1.119 [0.571]	0.617 [0.735]	0.948 [0.622]	1.441 [0.487]	1.408 [0.495]	1.636 [0.441]	1.604 [0.448]

Indep. variable	ANIES (1994Q1－2009Q1)				ASEAN (1994Q1－2009Q1)				China (1999Q2－2009Q1)			
	(c1)	(c2)	(c3)	(c4)	(c1)	(c2)	(c3)	(c4)	(c1)	(c2)	(c3)	(c4)
Constant	-0.018 (0.010) *	-0.018 (0.010) *	-0.020 (0.011) *	-0.020 (0.011) *	-0.012 (0.005) **	-0.012 (0.005) **	-0.014 (0.005) ***	-0.014 (0.005) ***	-0.002 (0.056)	-0.001 (0.056)	0.000 (0.055)	0.001 (0.055)
Δy^{G}	1.016 (0.935)	1.022 (0.938)			1.062 (0.290) ***	1.065 (0.288) ***			0.098 (2.323)	0.958 (2.328)		
Δy^{G*}			1.284 (1.032)				1.417 (0.405) ***	1.422 (0.399) ***			0.930 (2.423)	0.911 (2.428)
Δs^{G}	0.037 (0.098)		0.034 (0.095)	1.290 (1.036)	-0.023 (0.101)		-0.016 (0.101)		-0.257 (0.233)		-0.255 (0.232)	
Δs^{G*}		0.038 (0.100)		0.034 (0.096)		-0.022 (0.114)		-0.016 (0.114)		-0.249 (0.238)		-0.247 (0.237)
Δit^{G}	1.601 (0.707) **	1.593 (0.710) **	1.611 (0.683) **	1.604 (0.685) **	1.414 (0.368) ***	1.412 (0.366) ***	1.367 (0.373) ***	1.365 (0.371) ***	1.098 (0.533) **	1.085 (0.532) **	1.070 (0.555) *	1.058 (0.555) *
Δq^{G}(-1)	0.008 (0.143)	0.009 (0.142)	0.005 (0.142)	0.006 (0.141)	0.117 (0.113)	0.117 (0.113)	0.116 (0.112)	0.115 (0.112)	0.169 (0.147)	0.170 (0.146)	0.170 (0.147)	0.171 (0.146)
D (1997Q3)	-0.033 (0.007) ***	-0.034 (0.007) ***	-0.032 (0.007) ***	-0.033 (0.007) ***	-0.072 (0.013) ***	-0.073 (0.011) ***	-0.074 (0.013) ***	-0.074 (0.010) ***				
D (1997Q4)	0.035 (0.010) ***	0.035 (0.010) **	0.035 (0.010) ***	0.036 (0.009) ***	-0.109 (0.010) ***	-0.110 (0.007) ***	-0.107 (0.010) ***	-0.108 (0.007) ***				
D (2007Q1)									-0.140 (0.044) ***	-0.139 (0.044) ***	-0.137 (0.043) ***	-0.137 (0.043) ***
D (2008Q3)	0.022 (0.023)	0.022 (0.023)	0.023 (0.021)	0.023 (0.021)	0.003 (0.004)	0.003 (0.004)	0.006 (0.004)	0.006 (0.004)	-0.058 (0.011) ***	-0.057 (0.011) ***	-0.057 (0.012) ***	-0.056 (0.012) ***
D (2008Q4)	0.009 (0.042)	0.008 (0.042)	0.016 (0.041)	0.016 (0.041)	0.065 (0.048)	0.065 (0.051)	0.065 (0.048)	0.065 (0.051)	-0.078 (0.064)	-0.078 (0.068)	-0.080 (0.064)	-0.080 (0.068)
D (2009Q1)	-0.212 (0.026) ***	-0.213 (0.026) ***	-0.208 (0.026) ***	-2.082 (0.026) ***	-0.310 (0.016) ***	-0.310 (0.016) ***	-0.308 (0.017) ***	-0.308 (0.017) ***	-0.204 (0.071) ***	-0.205 (0.071) ***	-0.207 (0.072) ***	-0.207 (0.072) ***
D (WTO)									0.072 (0.015) ***	0.071 (0.016) ***	0.072 (0.016) ***	0.072 (0.016) ***
SER	0.037	0.037	0.037	0.037	0.030	0.030	0.030	0.030	0.046	0.046	0.046	0.046
LM(2)	0.849 [0.654]	0.834 [0.659]	0.828 [0.661]	0.810 [0.667]	0.494 [0.781]	0.516 [0.773]	0.640 [0.726]	0.661 [0.719]	2.268 [0.322]	2.252 [0.324]	2.282 [0.320]	2.265 [0.322]

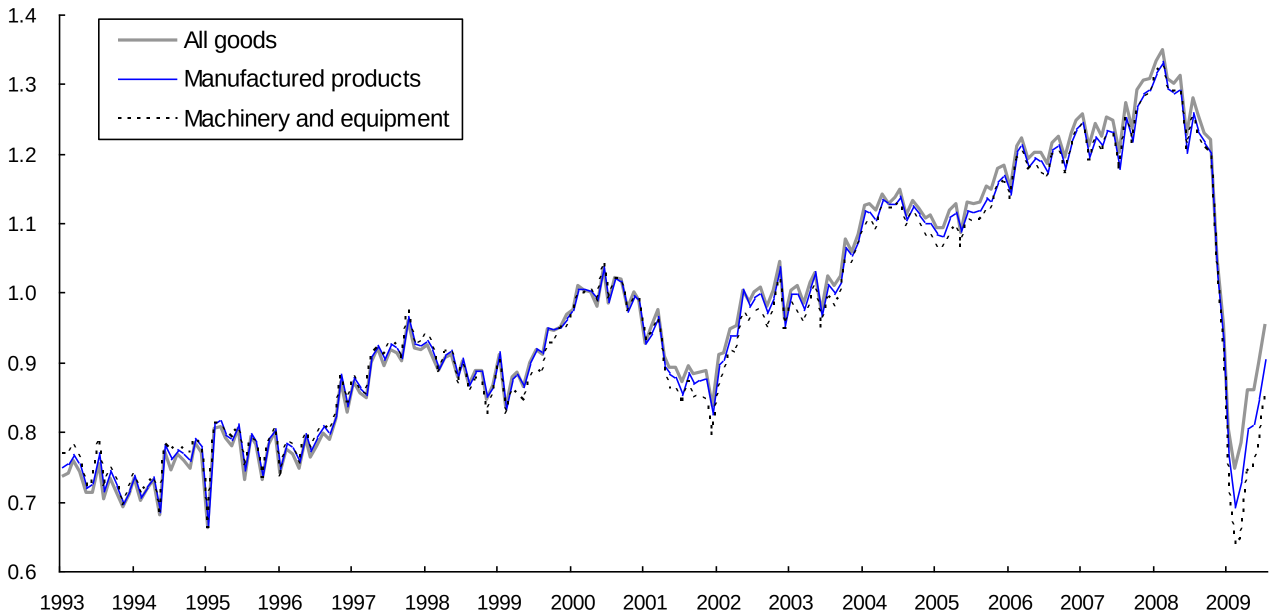
(Notes) See Table 2. R^2 is omitted because this statistic does not permit standard interpretation for 2SLS.

Table 4 Estimation of the error correction model (GSM)

Independent variables	World	USA	EU	ANIES	ASEAN	China
Constant	-0.048 (0.008) ***	-0.054 (0.014) ***	-0.011 (0.014)	-0.034 (0.009) ***	-0.025 (0.011) **	-0.157 (0.052) ***
$q^G(-1)$	-0.342 (0.048) ***	-0.402 (0.100) ***	-0.844 (0.097) ***	-0.275 (0.065) ***	-0.356 (0.081) ***	-0.514 (0.105) ***
$y^G(-1)$	0.094 (0.054) *	1.903 (0.383) ***		0.180 (0.041) ***	0.654 (0.199) ***	0.294 (0.142) **
$s^G(-1)$	-0.110 (0.032) ***					
$it^G(-1)$	0.282 (0.107) **		0.880 (0.161) ***		0.408 (0.100) ***	0.943 (0.223) ***
T		-0.013 (0.003) ***	-0.004 (0.001) ***		-0.008 (0.002) ***	
F(2001Q4)						0.200 (0.040) ***
F(2002Q4)						0.108 (0.038) ***
D(1997Q3)				-0.039 (0.008) ***	-0.050 (0.008) ***	
D(1997Q4)				0.044 (0.007) ***	-0.117 (0.008) ***	
D(2000Q4)	-0.017 (0.006) ***	-0.049 (0.011) ***		-0.031 (0.010) ***		-0.073 (0.020) ***
D(2001Q1)		-0.068 (0.017) ***				
D(2001Q2)	-0.032 (0.006) ***	-0.089 (0.017) ***			-0.021 (0.012) *	
D(2001Q4)	-0.030 (0.006) ***	-0.063 (0.015) ***				
D(2007Q1)						-0.118 (0.010) ***
D(2008Q3)		-0.080 (0.014) ***				
D(2008Q4)	-0.134 (0.013) ***	-0.217 (0.021) ***	-0.147 (0.026) ***			-0.154 (0.024) ***
D(2009Q1)	-0.369 (0.012) ***	-0.508 (0.041) ***	-0.324 (0.021) ***	-0.199 (0.019) ***	-0.258 (0.017) ***	-0.171 (0.040) ***
$\Delta q^G(-1)$		-0.196 (0.159)	0.319 (0.087) ***		0.252 (0.131) *	0.371 (0.129) ***
$\Delta q^G(-2)$			0.221 (0.095) ***		0.296 (0.132) **	
$\Delta q^G(-3)$			0.390 (0.089) **	0.386 (0.085) ***		
Δy^G	0.555 (0.349)		4.523 (0.925) ***	1.193 (0.257) ***	1.007 (0.333) ***	
$\Delta y^G(-1)$				1.450 (0.325) ***		
$\Delta y^G(-2)$	2.060 (0.610) ***	2.647 (1.013) **	2.031 (0.992) *		0.459 (0.219) **	
$\Delta y^G(-3)$		1.317 (0.887)				
Δs^G			0.152 (0.083) *			-0.463 (0.183) **
$\Delta s^G(-1)$		-0.164 (0.096) *				
$\Delta s^G(-2)$		-0.176 (0.108)	0.261 (0.103) **			
$\Delta s^G(-3)$		-0.152 (0.126)				
Δit^G	0.697 (0.122) ***		0.383 (0.120) ***	1.054 (0.142) ***	0.478 (0.254) *	0.486 (0.274) *
$\Delta it^G(-1)$		0.567 (0.398)			0.310 (0.247)	
$\Delta it^G(-2)$			-0.871 (0.253) ***		-0.788 (0.296) **	
$\Delta it^G(-3)$					-0.198 (0.151)	
Diagnostics						
R^2 (adj.)	0.940	0.859	0.960	0.843	0.894	0.844
SER	0.016	0.030	0.016	0.029	0.025	0.035
LM(2)	1.610 [0.447]	1.857 [0.395]	1.791 [0.408]	0.611 [0.737]	4.311 [0.116]	0.099 [0.906]
BPG	0.547 [0.872]	0.545 [0.910]	0.346 [0.979]	0.876 [0.561]	1.035 [0.444]	0.343 [0.972]
JB	0.936 [0.626]	2.233 [0.327]	1.196 [0.550]	0.387 [0.824]	0.330 [0.848]	0.757 [0.685]
RESET(2)	0.083 [0.775]	0.758 [0.389]	0.001 [0.975]	0.857 [0.360]	0.660 [0.523]	0.199 [0.659]
RESET(3)	0.931 [0.402]	1.233 [0.303]	0.047 [0.955]	1.815 [0.175]	0.621 [0.606]	0.323 [0.727]
Long-run elasticity						
y^G	0.276	4.729	-	0.653	1.837	0.571
s^G	-0.321	-	-	-	-	-
it^G	0.827	-	1.043	-	1.144	1.837

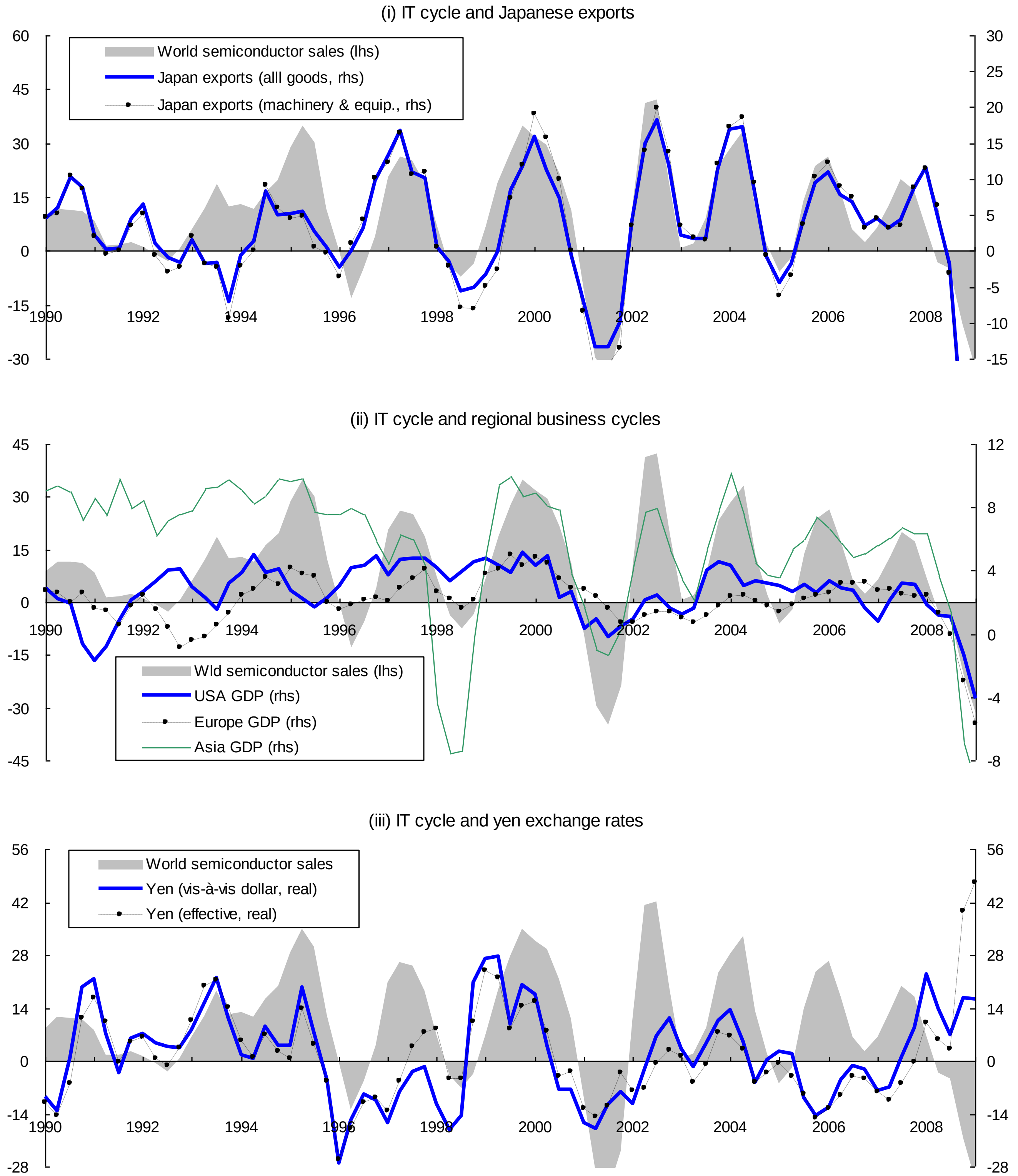
(Notes) See Table 2. T = a trend dummy variable; $F(i)$ = a shift dummy variable taking 0 in all quarters until i - 1 and 1 thereafter; BPG = Breusch-Pagan-Godfrey test for heteroskedasticity (F-value); JB = Jarque-Bera statistic for normality; RESET(i) = RESET test with up to the i-th degree polynomials of the estimated regressand (F-value); p-values in [ ].

Figure 1 Volume of Japan’s exports (natural logarithm, 2000=1)



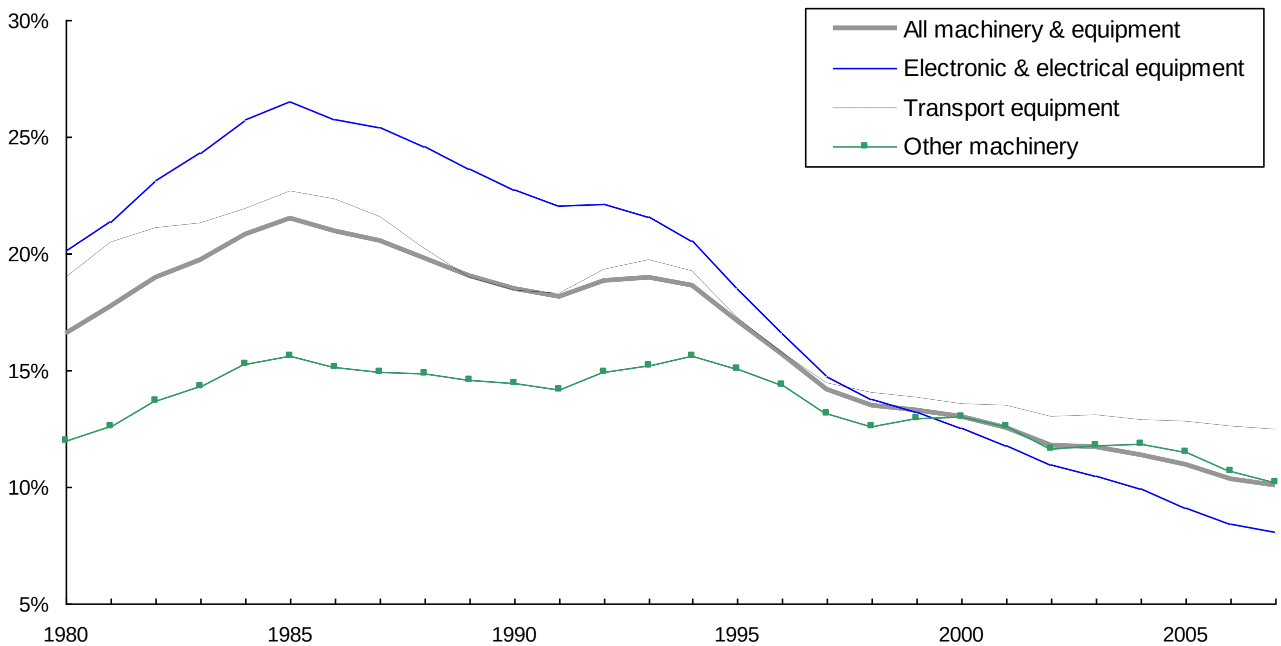
(Source) Ministry of Finance.

Figure 2 Global IT cycle and macroeconomic variables



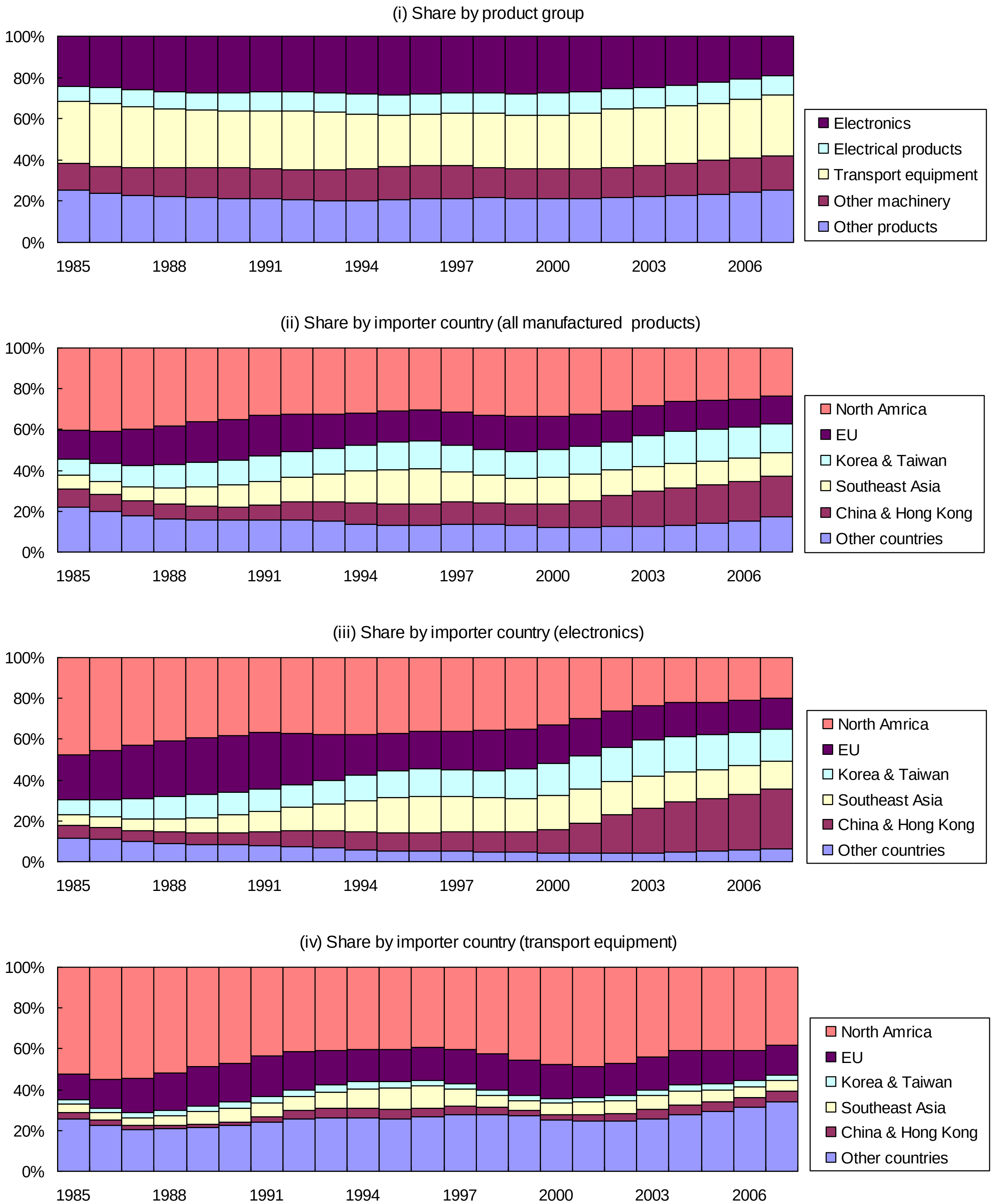
(Notes) All series are measured in terms of annualized quarterly rates of change (three-quarter moving average in percentage). Real dollar-yen exchange rates are computed using Japanese CGPI and US ex-fuels PPI. The real effective value of the yen is based on a Bank of Japan index whose deflators are CGPI/PPI or equivalent. (Source) Author's calculation with data from MoF, BOJ, IMF, OECD and WSTS.

Figure 3 Share of Japan's exports in global machinery trade



(Note) Machinery in this figure comprises ISIC rev.3 29-33. All shares are measured in terms of three-year moving average. Global trade excludes Japan's imports. (Source) Author's calculation with data from CEPII CHELEM Database.

Figure 4 Evolution of Japan's manufacturing exports



(Note) All shares are measured in terms of three-year moving average. Manufactured products are defined as the sum of ISIC rev.3 15-36 less 22 (printing & publishing) and 23 (coke, refined petroleum & nuclear fuel). Southeast Asia includes Indonesia, Malaysia, Singapore, the Philippines, Thailand and Vietnam. (Source) CEPII CHELEM Database.