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External shocks and the Japanese business cycles: Impact of the "Great Trade Collapse" on the automobile industry[*]

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Abstract

Why did the Japanese economy perform worst among major industrialized nations during the Lehman crisis period? This paper looks for an answer to this question. The country's poor performance was surprising because the Japanese financial system remained mostly stable, unlike its counterparts in the US and Europe. Obviously, Japan during this period was hit by a massive contraction in external demand for its products. However, even if one takes this factor into account, it is not immediately clear why it had to experience an output decline which was disproportionately larger than the extent of the external demand contraction. We shall investigate this puzzle by focusing on the automobile industry, the country's most important exporting sector.

A popular explanation for the strong negative response of Japan to the Lehman crisis is that the country is extremely "export dependent". It is often argued that, during the course of the long boom between 2002 and early 2008, Japan had become so much more dependent on exports that there was no surprise in its poor performance during the crisis period when worldwide demand collpased. In the first half of this paper, we investigate these claims by a time series estimation technique known as the time varying parameter VAR method. We find that there was no noticeable structural change in the relationship between external variables and automobile exports during the pre-crisis boom. We show that, based on the relationship that existed prior to the crisis, one could not have predicted the observed sharp declines in export and output during the crisis period, even if we knew that there was going to be a large negative external shock.

There are two possible explanations to the above finding: either that Japan went through a structural change whose timing happened to coincide with the Lehman crisis, or that there is an inherent non-linearity in the relationship between external shocks and production. That is, output reacts differently to large shocks than to small shocks. The second half of the paper pursues the latter possibility. We utilize detailed data on automobile production, sales, and inventories that are available by company and by types of cars. We use a Quantile Regression approach to find that auto producers tend to undertake disproportionately more aggressive inventory adjustment against a larger negative shock to sales. At the end of the paper, we offer some insights on why such a non-linearity is observed.

I Introduction

The Japanese economy exhibited the worst performance among major industrialized nations during the Lehman crisis period, i.e., from the fall of 2008 to the spring of 2009. This paper asks why the US-originated crisis had such a large impact on its output. The poor performance was surprising because the Japanese financial system remained largely stable, unlike its counterparts in the US and Europe. On the surface, the cause of the output decline seems clear: it was hit by a massive contraction in external demand for its products. But this fact does not explain why Japanese output had to go down disproportionately more than those of the markets for its exports. We shall investigate this puzzle by focusing on the automobile industry, the country's most important exporting sector.

It is often argued that Japan is very "export dependent" and this makes it susceptible to external demand changes. In particular, during the sustained (though modest) boom between January 2002 and February 2008, the share of exports to GDP became 1.6 times larger than before. It might be that, just prior to the crisis, Japan had become so dependent on external demand that it was susceptible to even a small decline in exports. In the first half of this paper, we investigate these claims using time series data. We start this part by estimating a regular VAR (vector autoregression) model which includes both external variables (oil prices, exchange rates, and variables representing the strength of external demands) and Japanese exports and output. We find that external variables are indeed important determinants for Japanese exports and output. Next, we utilize the time varying parameter VAR method to see if there was an important structural change in this relationship during the pre-crisis boom. We find no such changes. We also ask the following question. Take the estimated relationship that existed prior to the crisis, and feed in the massive negative external shocks that occurred during the crisis period: would the model successfully predict the sharp declines in export and output that we observed during the crisis period? The answer turns out to be negative. We also redo the same set of exercises, focusing on automobile exports to one particular market, namely the US. Messages that come out of this analysis are essentially the same.

We can think of two possible explanations to the above finding. The first is that Japan went through a structural change whose timing happened to coincide with the Lehman crisis. But such a coincidence does not seem likely. The second explanation, which we are more sympathetic with, is that there is an inherent non-linearity in the relationship between

external shocks and exports and production. That is, output reacts differently to small shocks than to large shocks. Such a non-linearity is hidden in normal times and is revealed only when the economy is actually hit by a large shock. The second half of the paper pursues this possibility.

As the Lehman crisis was a one-time event, it is not likely that a time series analysis would adequately characterize the nature of non-linearity (if any). This has motivated us to utilize a panel data on automobile production, sales, and inventories that are available by company and by types of cars. We estimate how automobile production in Japan responds to the inventory-sales ratio in the US and to other determinants. Using a quantile regression approach, we study if the coefficients vary depending on the business conditions. We find that the Japanese auto producers indeed tend to respond more strongly to accumulated inventories in the US in very bad times (that is, when output is declining fast), than in normal times.

The rest of the paper is organized as follows. In section 2, we review the performance of the Japanese economy and its automobile industry during the Lehman crisis period. We will also explain why we choose to focus on the automobile industry. In section 3, we first study how the Japanese macro economy has reacted to external shocks, by estimating a regular VAR model. We then estimate a time varying parameter VAR model which allows the effects of the external shocks to change over time. The objective is to study if the Japanese economy had really become so much "export dependent" during the pre-crisis export boom. Section 4 focuses on automobile exports from Japan to the US. We utilize the time varying parameter VAR to see if the decline in automobile demand in the US could adequately explain the sharp drop in automobile exports from Japan. Section 5 studies the panel data on Japanese automobile companies and car types to seek for evidence for non-linear behaviors. Section 6 contains a brief discussion on the direction for future research. Section 7 concludes.

2 The Japanese economy, its automobile industry and the "Great Trade Collapse"

Japanese macroeconomy and the Lehman crisis in retrospect

We start by reviewing the performance of the Japanese economy during the Lehman crisis period, and comparing it with those of some other countries. Figure 1 presents recent evolutions of real GDP for four countries, Germany, Japan, Korea and the US. The data is

quarterly and each series is normalized to be equal to 100 in the first quarter of the year 2007. The graph shows that the trough was by far the deepest for Japan. In terms of the growth rate, between the first quarter of 2007 and that of 2009, GDP of Japan declined by 8%. This compares with the US output loss of 3% and Germany's 4% decline. Korean GDP, in the meantime, gained by 1%. Figure 2 presents time series evolution of industrial production for the same set of countries. The data is monthly and all the series are normalized to take the value of 100 in January 2007. Basic patterns are the same. The graph also shows that the decline in Japanese industrial production was concentrated in a relatively short period of time. During a five month period between September 2008 and February 2009, it decreased by as much as 33%. On the other hand, during the same period, the US industrial production declined by just 5%. It is widely recognized that declines in export demand were behind this sharp decline in production. Figure 3 shows the evolution of total export values (in US dollars) for the same set of countries. The value for Japan decreased by 45% during the five months period mentioned above. The corresponding number for the US was 25%.

The figure also shows that other countries also experienced large declines in export values[1]. It seems safe to assert that this worldwide reduction in trade, known as the "Great Trade Collapse", was the direct cause of the Japanese slump. It appears that the same worldwide negative demand shock had a much greater "multiplier effect" on the Japanese economy. I will now review the growing literature on the Great Trade Collapse to look for a hint that might be useful for understanding what happened to Japan.

Literature on the "Great Trade Collapse": looking for a clue

According to figures presented by Eichengreen and O'Rourke (2009, 2010), between the fall of 2008 and the spring of 2009, worldwide trade volume shrank by about 20%. According to them, this speed of decline far exceeded what we saw at the onset of the Great Depression in the 1930s. They also emphasize the fact that it is larger than the rate of decline in worldwide industrial production, which is estimated to have been between 10 and

[1] From Figure 3, which depicts US dollar values of exports from the four countries, we get an impression that the export declines for Germany and Korea were of magnitudes similar to that for Japan. However, export volumes statistics, also from OECD, tells a slightly different story. During the five month period between September 2008 and February 2009, export volumes for Germany, Japan and Korea declined by 26%, 47%, and 16%, respectively. OECD does not provide trade volume statistics for the US. Instead, the US Census bureau reports real exports, which declined by 14% during the same time interval. This compares to a 39% decline for the Japanese real exports (Bank of Japan).

15%. Note that the Japanese numbers cited above are much greater than either of those world averages: studying the Japanese case carefully might provide us some important hints for understanding this global phenomenon.

Below, I follow Levchenko, Lewis and Tesar (2010) and list three major hypotheses proposed in the literature of international economics in efforts to explain the worldwide collapse in international trade.

(1) Credit crunch: The sudden reduction in trade may have been a consequence of a severe financial disintermediation. Evidence suggests that a contraction in the supply of trade credits, induced by a financial crisis, can lead to a massive decline in international trade (Amiti and Weinstein (2009), Ahn, Amiti and Weinstein (2011) and Chor and Manova (2010)).

(2) Vertical trade: Suppose that a good is produced in two stages. Stage 1 of the production is done in country A, stage 2 is located in country B, and the goods are consumed in country C. When there is a unit decline in consumer demand in C, that will cause not only a unit decline in exports from B to C, but will also induce a reduction in exports from A to B. Such an effect would be stronger as production becomes more fragmented across different parts of the world. This idea has been put forth most explicitly by Bems, Johnson and Yi (2010). Refer to Tanaka (2009) for evidence for Japan. This vertical structure of trade is also important for Japan in the following (slightly different) sense. Recent Japanese statistics shows that Asian economies, most notably China, have gained importance as destinations for Japanese exports. But they may not be the final destinations. Intermediate goods constitute a large share of exports to Asia, and much of them are assembled and then shipped to the US and Europe. This means that Japanese exports may not be as insulated from demand fluctuations in the US and Europe as one might suspect from the statistics. This point has been stressed by Fukao and Yuan (2009) and Wakasugi (2009).

(3) Demand volatility in international trade: Compared with domestic transactions, exports and imports inherently involve greater shares of goods whose demand tend to be more volatile. Most notably, capital goods and consumer durables make up greater shares in international trade, while services tend to be traded less intensively internationally. This makes trade more sensitive to worldwide economic downturns. This point is likely to be important for understanding the Japanese experience during the Lehman crisis. Its exports are even more intensive in capital goods and consumer durables than the world

average. Bank of Japan (2009) emphasizes differences in industrial structure between the US and Japan as a cause of the differing performance between the two during the crisis period.

This paper is motivated by our suspicion that none of the above three provides an adequate explanation for the Japanese experience. In this paper, we focus on the automobile industry because we believe it gives us an ideal ground for questioning adequacy of those three ideas for reasons we discuss below. As we will see later, it is a major exporting sector for Japan. The industry also experienced collapses of both exports and production that were far greater than the national averages. If we can successfully argue that the above ideas are inadequate for this industry, it should give us a good reason to look for an alternative explanation for the overall Japanese experience.

Let us start with the above hypotheses (1) and (2). Concerning hypothesis (1), namely the credit crunch hypothesis, note that the Japanese automobile manufacturers are large and well known companies that are more credit worthy than a typical Japanese firm, and tend to be cash rich. They are least likely to be victims of the financial market turmoil (and, as explained above, financial instability was not as big a problem in Japan as in the US and Europe to begin with). Although it is true that the Japanese corporate bonds market went through a brief period of paralysis, according to Uchino (2011), firms that could not roll over their debts in this market could successfully borrow from commercial banks. The credit crunch hypothesis does not seem to explain why the Japanese automobile manufacturers had to go through such tough times. On hypothesis (2) about the vertical trade structure, note that this paper avoids complications that might arise from this issue, by design. This is because this study deals specifically with production and exports of finished automobiles, and excludes trade in auto parts from the scope of the analysis.

This leaves hypothesis (3), which emphasizes the inherent volatility in demand for consumer durables and investment goods. To study the relevance of this idea, it helps to focus on a single sector in which goods are more or less homogeneous in terms of their durability: we do not need to be concerned with changing composition of goods with differing degrees of durability. Also, as we focus on finished goods, we can safely assume that most of the goods exported to a certain region will be consumed there[2]. This gives us a

[2] In contrast, in the case of the electronics industry, another important exporting sector for Japan, much of the goods exported from Japan are intermediate goods. This means that there are discrepancies between the region to which they are shipped to and the region of final consumption. For example, it is not easy to estimate what fraction of TV parts exported to Malaysia for assembly end up in the hands of

chance to construct a good measure of demand which is specific to a region or a country. That is the reason why, in section 4, we will focus on automobile exports to the US. We shall construct a measure of the US demand for automobiles. We will see that the demand indeed declined substantially during the period of the financial crises. We will argue, however, that the export contraction during this period was so sharp and so deep that it could not be adequately explained by the movement of the demand alone. Hence, demand volatility offers only a partial account of the output and exports behaviors. Section 5 will study behaviors of the Japanese automobile manufacturers to fill the gap.

The Japanese automobile industry during the Lehman crisis

The automobile industry is one of the most important sectors of production in Japan. Its weight in the 2005-based index of industrial production was 10.42%. Its share in total export value was 17.05% in year 2007. The industry is also quite export oriented: 56.48% of automobiles produced in Japan were exported in 2007 (Japan Automobile Manufacturers Association, the data is based on the number of units of automobiles, not their values).

Figure 4 presents evolution of the index of industrial production for Japan (the same data as in Figure 2 but is for a longer time period) together with that of the automobile industry. They are both normalized to equal 100 in January 2007. Apparently, the Lehman crisis had a large impact on the automobile manufacturers. During the five month period between September 2008 and February 2009, automobile production decreased by 58%. Figure 5 plots total real exports of Japan (Bank of Japan) along with its real exports of automobiles[3]. Again, they are normalized to be equal to 100 in January 2007. During the same five month period mentioned above, automobile exports decreased by a staggering 72%.

As already mentioned, section 4 of this paper will pay a particular attention to a single destination for automobiles exported from Japan, namely the US. It is the largest market for those products. Also, detailed information is published by the US government and private companies concerning the demand side conditions within the US market. Figure 6 depicts evolution of automobile sales within the US. It is in the units of automobiles, i.e., the number of automobiles sold[4]. Once again, it is normalized to equal 100 in January 2007.

US consumers. This problem becomes more serious when different stages of production are fragmented across different countries of the world.

[3] Export value of automobiles in Japanese yen is taken from the Ministry of Finance Trade Statistics. Then the series is deflated by the export price index of transportation equipment (Bank of Japan).

[4] The data is taken from the Bureau of Economic Analysis, which derives much of the original data from *Ward's Automotive Reports*. US sales is computed as the sum of "domestic autos", "domestic light

US automobile sales start to decline from the middle of year 2007. The descent accelerates during the Lehman crisis period. In February 2009, it stood at about 56% of the January 2007 level. The same figure shows Japanese automobile export to the US, also in the units of automobiles[5]. It is notable that Japanese exports exhibit a very sharp decline, which is concentrated in several months after the Lehman crisis. In February 2009, it was only 33% of the January 2007 level.

In summary, the reduction in Japanese exports may have been a reaction to worsening of the economic conditions of the destination market, but the export decline was much faster and far deeper, and this puzzling feature seems to call for an explanation.

Role of the exchange rate

Another noticeable development during the period in question is the appreciation of the Japanese yen. The monthly average exchange rate went up from 1 US dollar = 109.24 yen in August 2008 to 96.89 yen in November, and then to 91.21 yen in December. This could cause prices of Japanese exports to rise in the US and contribute to a demand contraction. However, recent studies have established that the exchange rate pass-through is incomplete in the short run, which means that there will be a lag for the above effect to take place. This point is re-confirmed in the analysis below. It is hence questionable if the exchange rate movement played much role in the abrupt fall in exports between the fall of 2008 and the spring of 2009. We will nevertheless include the exchange rate as an explanatory variable in the analysis that follows, to control for any effect it might have had on both exports and production.

3 External shocks and Production in Japan: evidence from aggregate data

Evidence from a regular VAR

In this section, we use aggregate (in the sense that variables involved here are not specific to the US market) data to estimate influences of external shocks on Japan. We study how the Japanese automobile exports and production, as well as aggregate industrial production, respond to external shocks such as oil prices, the exchange rates and foreign demand

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trucks", "heavy trucks", "foreign autos", and "foreign light trucks" (all seasonally adjusted) from the data set. Note that, in the Bureau's terminology, "autos" refer to passenger cars and exclude "trucks", while "trucks" in their definition include minivans and SUVs.

[5] The data is taken from the Japanese Automobile Manufacturer's Association.

expansions. We start with a regular VAR estimation which does not consider a possibility of a structural change. It uses monthly data and involves the following six variables.

(1) Oil prices: US dollar price per barrel, in logarithm. It is taken from the International Financial Statistics, International Monetary Fund, "World Petroleum: Average Crude Price".

(2) Exchange rate: Nominal effective exchange rate (Bank of Japan), in logarithm. Its increase implies an appreciation of the Japanese yen.

(3) US total imports: Nominal values in US dollars (Direction of Trade Statistics, International Monetary Fund), seasonally adjusted by X12-ARIMA, in logarithm. This variable is included to measure effects of the US aggregate demand for imported goods.

(4) EU total imports: Nominal values (same source as (3)), also in US dollars, seasonally adjusted by X12-ARIMA, in logarithm[6]. This variable represents the EU aggregate demand for imported goods in general.

(5) Automobile exports from Japan to the World: The yen value (from Trade Statistics, Ministry of Finance) is deflated by the export price index for automobiles (Bank of Japan). It is seasonally adjusted by X12-ARIMA, and is in logarithm.

(6) Automobile production in Japan: Taken from the Indices of Industrial Production Statistics (Ministry of Economy, International Trade, and Industry). In logarithm, and seasonally adjusted.

(7) Industrial production in Japan: The same source and the treatment as (6). This variable is included partly to control for the effects of domestic business cycles.

All the variables are in their levels (i.e., we do not take differences). The number of lags is set to six. The sample period is from July 1980 to August 2008. The US and EU import data were available from January 1980 only. We end the sample just before the Lehman crisis to obtain the average pre-crisis picture of the Japanese economy. The reduced form residuals are orthogonalized by Cholesky decomposition, that is, we assume a short run recursive structure, with oil prices being "most exogenous".

Figure 7 reports estimated impulse responses. To save space, we report only the responses of the three domestic variables, namely automobile exports, automobile production and industrial production, to four types of external shocks, i.e., oil prices, the exchange rate, US total imports and EU total imports. In each panel, the shaded areas are the 95% confidence

[6] We compute the sum of imports of the EU 15 countries, and then subtract their imports from trade partners within the region.

intervals.

The first panel shows responses of the three domestic variables to oil prices. They are all insignificantly different from zero. We suspect this is a reflection of two opposing effects of oil prices cancelling each other out. On the one hand, an increase in oil prices raises costs of production as well as gasoline prices, thus hurting exports and output. On the other hand, by the year 2008, both Middle East and Russia had emerged as major destinations for exported Japanese automobiles (Shioji and Uchino (2011)). A boom in the oil market could stimulate demands from those regions. Also, fuel efficient Japanese automobiles may benefit from higher gasoline prices to the extent that consumers around the world switch from larger cars to those cars.

In the second panel, an exchange rate appreciation increases real automobile exports in the short run. This is a counter-intuitive result but it keeps re-emerging from the Japanese data. This "J curve in quantities" effect (note that the original J curve effect was supposed to be about nominal export values measured in the exporter's currency, in this case the Japanese yen, and not about volumes) might be explained by an anticipation effect: as consumers in the US expect the dollar prices of Japanese automobiles to rise in the future, they rush to buy them now. We do not find this argument to be particularly realistic, but it is at least a theoretical possibility. After a few periods, the impulse response turns negative. A currency appreciation also has effects of reducing both automobile and industrial productions, which set in gradually.

In the third and the fourth panels, an increase in either US or EU imports increases automobile exports from Japan, as expected. This effect spills over to both automobile and industrial productions.

In the fifth panel, an increase in automobile exports from Japan to the US increases automobile production in Japan, as expected. This also has a positive effect on industrial production, reflecting the importance of this industry in Japan. In the sixth panel, an increase in automobile production also raises industrial production, and also increases automobile exports from the next period onwards. In the seventh panel, an increase in industrial production, which represents a domestic boom, expands automobile exports and stimulates auto production with some lags.

Table 1 summarizes results of variance decomposition. It is generally consistent with the idea that external shocks are important for Japan. In particular, if we are willing to include the shocks to automobile exports as a part of external shocks, those external shocks, taken

together, explain 43.3% and 28.0% of forecast error variations in automobile production and industrial production, respectively, at the 24 months horizon.

Evidence from a time varying parameter VAR

The above exercise with the regular VAR reveals the average feature of the Japanese economy during the pre-crisis era. However, as stated in the introduction, many claim that Japan became excessively export dependent during the long boom which started in January 2002 and lasted till February 2008. It is of interest to see if such a structural change could be found in our data. Also, according to this view, the hypothesized export dependent structure was the main reason why the Japanese economy reacted so strongly to the Lehman crisis. If that is the case, we should not observe a large structural change after the onset of the crisis: the model estimated by the data prior to the crisis should do a good job in predicting Japan's reaction to the external demand contraction.

To investigate this issue, we estimate a time varying parameter VAR, hereafter TVP-VAR, which allows the coefficients of the reduced form VAR model (including the constant terms) to vary over time, which involves use of the Kalman filter (Kim and Nelson (1999)). It should be noted that, with this method, the variance covariance matrix of the error terms is assumed to remain constant over time, which implies that the impact response of each variable to each of the identified shocks stays the same over time[7].

We estimate a TVP-VAR model with the same set of variables, extending the sample to the end of the Lehman crisis period[8]. We needed to reduce the number of lags to four due to a limitation of the computational capacity. The first seven panels of Figure 8-1, 8-2 and 8-3 present impulse responses, estimated at each point in time, of automobile exports, automobile production, and industrial production, respectively. Each panel in the figures corresponds to each type of shocks. We present impulse responses estimated at 5 years intervals between January 1985 and January 2005. Those are in solid lines (with no markers) in different colors. Impulse responses in October 2008, i.e., at the onset of the

[7] In contrast, a more recent version of TVP-VARs allows the variance covariance matrix to vary over time. Refer to Primiceri (2005) and Nakajima (2011). A shortcoming of this new methodology is that it is time consuming, and that it has difficulties dealing with a large model (i.e., models with long lags and/or many variables).

[8] We opted for *not* using the Kalman smoothing to update estimates at each point in time in the past using the most current set of information. Hence, an estimated impulse response at a point in time does not use information that became available after that date: it represents the best effort estimate based on the information that was available up to that point.

crisis are represented by lines with the “+”s. Impulse responses during the severest period of the crisis, namely those for December 2008 and January, February and March of 2009, are shown by lines with circles (“o”s) in different colors. Finally, impulse responses for June 2009, at the end of the crisis period, are in lines with “*”s.

Note the general tendency for the solid lines (for the pre-crisis period) and the line with “+”s (for the onset of the crisis) to be clustered closely. This means that there was no noticeable structural change in the relationship between the Japanese economy and the external shocks prior to the Lehman crisis. This contradicts the view that, during the run up to the crisis, the Japanese economy had become very export dependent. In contrast, lines with circles (for the crisis period) tend to move away from the pre-crisis clusters, in directions that amplify the effects of the external shocks. This implies that the strong reaction to the external demand contraction was largely unexpected: the TVP-VAR model tries to explain this by saying that there were sudden structural changes. At the end of the crisis period, in many of the panels, impulse responses (with “*”s) go back to the “normal” positions. This indicates that the “structural” change that emerges from this estimation was largely a temporary phenomenon.

Based on these estimates, we can ask the following question. Take the model that was estimated using the information that was available just before the crisis. Imagine that, at that point in time, we knew that there was going to be a massive contraction in external demand in the subsequent period. Could we have anticipated the sharp declines in Japanese exports and production? The last panels of Figure 8-1, 8-2, and 8-3 answer this question. In those panels, we fix the parameters of the model at values that were estimated in August 2008. Then we make forecasts for September 2008 for the last three domestic variables, namely automobile exports, automobile production and industrial production, by plugging in the actual values of the first four external variables, namely oil prices, the exchange rate, US total imports and EU total imports, for that month. Once this is done, we move on to October 2008, again using the observed values for the external variables but using the predicted values for September for the domestic variables. We continue this exercise till July 2009.

In each of the eighth panels of Figure 8-1, 8-2 and 8-3, dashed lines represent out of sample forecasts thus formed, while lines with circles show the actual evolutions of those domestic variables. If the export dependency of the Japanese economy, that had been developed prior to the crisis, was the main reason for the collapse, we should observe the former line

closely tracking the latter line. In reality, we see a large discrepancy: despite that we are feeding in actual values of the external variables, the model predicts only minor declines in the domestic variables. We find it difficult to support the "we knew it was going to happen" kind of attitude on the export and production collapses.

4 US demand contraction and Japanese automobile exports

In this section, we shall focus on Japanese exports of automobiles to the US[9]. We ask, to what extent, the collapse of the exports can be justified as a normal reaction to the large demand contraction for automobiles in the US.

Data

There are two main data sources for the Japanese automobile exports by destination. The first one is the Ministry of Finance's Trade Statistics, which publishes the nominal (in the Japanese Yen) values as well as quantities by destination country. A drawback is that the data set goes back only to 1987, on the web. The second one is published by the Japanese Automobile Manufacturers Association. It is in the units of automobiles and thus cannot capture changes in the values of automobiles. On the other hand, the data is available since 1975 and by types of automobiles such as small cars vs. regular-sized cars[10]. We have decided to utilize the second data set. Figure 9-1 plots historical evolution of automobile exports from Japan to the US for small cars, regular-sized cars, and the total[11]. The export collapse during the Lehman crisis period is apparent, especially in total and for regular-sized cars. We also note that small cars and regular-sized cars behave quite differently, and thus it might be worthwhile studying the two separately.

We next construct an indicator for the US demand for automobiles. The Bureau of Economic Analysis publishes a quarterly series "Final sales of motor vehicles to domestic purchasers" as a part of the NIPA account. This is a quantity index (i.e., it is a real variable) and is seasonally adjusted. We found that, at high frequencies, its movement is closely

[9] The Japanese version of this paper (Shioji and Uchino (2011) also examines determinants of exports to EU, Middle East, and Russia.

[10] They also provide data by manufacturers, a feature that we will take advantage of in the next section.

[11] The original series exhibit peculiar seasonal patterns, mainly due to natures of the voluntary export quantity restraint that was in place between April 1983 and March 1994. We split the sample between the pre-1990 and the post-1990 periods and seasonally adjusted the two sub-samples separately with the X-12 ARIMA, and then connected them. We also eliminate some apparent outliers.

correlated with the Bureau's monthly series "Motor vehicle unit retail sales (total, seasonally adjusted)". We hence decided to construct a monthly series of US real purchases of automobiles, by interpolating the former quarterly series using the latter monthly series[12]. The resulting estimates are shown in Figure 9-2. We note the large decline in automobile demand: between January 2007 and January 2009, it decreases by almost 39%. This re-confirms the well-known property that demand for durable goods tends to be volatile. However, we can also see that the decline is more gradual than that of automobile exports from Japan. It also starts early, from the beginning of 2008.

The above variable is our main indicator of the US automobile demand. However, we have noticed that the US demand for automobiles might fluctuate for different causes between domestic cars and imports from Japan. For that reason, we decided to add two more variables, which capture different aspects of the US financial crisis. The first one is "CP spread", which is the difference between the three months CP rate and the three months treasury bill rate[13]. This is meant to capture general degrees of distress in the US financial market. The second is "auto loan spread" which is defined as the difference between the interest rate charged on auto loans and the US treasury bond rate[14]. This variable captures the degree of distress that is specific to the auto loan market. The CP spread is plotted in Figure 9-3, while the auto loan spread is shown in Figure 9-4. A main difference between the two is that, while the CP spread starts to rise during the subprime crisis that precedes the Lehman crisis, the auto loan market remains calm. Also, the peak of the latter comes two to three months later than the former, which might indicate a time lag for the financial crisis to spill over to this market.

Evidence from a regular VAR

We first estimate a regular VAR model with the following six variables: (1) CP spread, (2)

[12] We assume that the ratio of the value in each month to the quarterly average is the same between the two series.

[13] The data source is FRED, the Federal Reserve Bank of St. Louis web site. For the CP rate, we take "3-Month Commercial Paper Rate" (CP3M) until August 1997. After the termination of the series, we take "3-Month AA Financial Commercial Paper Rate" (CPFR3M) since September 1997. As of August 1997, the discrepancy between the two series was very small. For the treasury bill rate, we use "3-Month Treasury Bill: Secondary Market Rate" (TB3MS).

[14] For the auto loan rate, we take "New car average finance rate at auto finance companies, not seasonally adjusted" from the web site of the Federal Reserve Board. The same source provides information on "Weighted-average maturity of new car loans at auto finance companies, not seasonally adjusted": according to this, the average maturity fluctuates around five years. We thus use "5-Year Treasury Constant Maturity Rate" (GS5) from FRED and take the difference.

auto loan spread, (3) the yen-dollar exchange rate, (4) US total imports, (5) US real purchases of automobiles, and (6) automobile export from Japan to the US (total). The number of lags is six. The sample period is from July 1980 to August 2008, just before the Lehman crisis. Figure 10 reports impulse responses of (5) and (6) to all the identified shocks.

In the first two panels, we see that, while the US automobile demand responds negatively to spread increases in both the CP and the auto loan markets, as expected, Japanese exports do not respond significantly. If anything, the point estimates are mostly positive. This could reflect a switch in consumer demand. It is possible that, as the financial conditions worsen and it becomes more difficult to finance a large amount of automobile purchases, US consumers would turn to smaller cars, which tend to benefit Japanese manufacturers.

In the third panel, as the Japanese yen depreciates, Japanese exports tend to increase in the medium to long runs, as expected. However, here again, we observe the "J curve in quantities" effect. While its precise cause is unknown, the general picture does support the view that it takes time for the exchange rate to exert substantial effects on volumes of trade.

In the fourth panel, US total imports, which are supposed to represent the strength of aggregate demand in the US, have a positive effect on Japanese exports but it is insignificant. On the other hand, in the fifth panel, US real purchases of automobiles have the expected positive effect on the same variable and it is significant. It may be that it is sufficient to include the latter variable to control for movements in the US demand for automobiles.

Table 3 summarizes the variance decomposition results for Japanese exports. The exchange rate and, to a lesser extent, US real purchases turn out to be important, while the two spread variables are less important.

We have also tried including exports of regular-sized cars or small cars in place of the total number of exported cars in the above VAR estimation. Figure 11 presents only impulse responses to the two spread shocks from those two estimations. Note that, for regular-sized cars, at least the point estimates of the response to an auto loan spread shock turns negative (though insignificant). However, for small cars, both of the impulse responses turn marginally significantly positive. This finding renders more support to the above view that those counter-intuitive responses reflect a substitution between large and small cars under financial distress[15].

[15] We also tried adding the Korean won – Japanese yen rate to the analysis. We found that an

Evidence from a time varying parameter VAR

We estimate a TVP-VAR model with the same set of six variables as in Figure 10. The methodology is the same as in the previous section and the number of lags is again reduced to four. Figure 12 presents evolution of impulse responses of automobile exports from Japan to the first five identified shocks. As in the previous section, impulse responses from the pre-crisis period are all very close to each other: there is little evidence of a structural change. Then, after the crisis hits, those responses start to move away, in directions that tend to strengthen the impacts of external (i.e., US) shocks. For example, impulse responses to the spreads suddenly turn negative. Impulse responses to the exchange rate turns positive soon after the shock and the effect become stronger. The influence of US real purchases becomes much stronger.

In the sixth panel, we again ask if the model estimated in August 2008 is capable of predicting the collapse of Japanese exports, if we are informed that there will be a financial crisis (increases in the spreads), an appreciation of the Japanese yen and a decline in the US demand in subsequent months. The result is again negative. The predicted path for Japanese exports is downward sloping but it fails to capture a major portion of the export collapse.

To summarize our findings in this section, although it is true that demand for durable goods (automobiles in this case) tends to be volatile, and that Japanese automobile companies were hit by a large decline in foreign demand during the Lehman crisis, it was not enough to account for the massive collapse in exports. Something (which was difficult to anticipate before the crisis) must have happened that magnified the influences of the fall in demand. In the next section, we shall investigate what was behind the "multiplier".

5 Panel data quantile regression analysis of inventory adjustment by Japanese manufacturers

In the previous two sections, the TVP-VAR results have pointed to presence of large "structural changes" in the relationship between external variables and Japanese exports and production. There are two ways to interpret this result. First is that there was indeed a shift in the structure, whose timing happened to coincide with the period of the Lehman

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appreciation of the yen against the won has a large negative impact on Japanese exports of small cars, but not on those of regular-sized cars. We thank Toshitaka Sekine for suggesting this analysis.

crisis. We find such a coincidence unlikely. Such an interpretation also seems incompatible with the fact that most of the estimated impulse responses "came back" to the original position after the crisis. The second interpretation is that there is an inherent non-linearity in the relationship, in the sense that the Japanese economy tend to react to very large external shocks differently from regular, smaller shocks: such a non-linearity is revealed only when it is hit by a sufficiently large shock. This section pursues the second interpretation.

Inventory adjustment during the "Great Trade Collapse"

We shall pay a particular attention to the role played by inventory adjustment by Japanese automobile manufacturers during the export collapse. In section 2, we referred to three major ideas on the "Great Trade Collapse" which have been proposed in the literature of international economics, and we called them hypotheses (1), (2) and (3). In macroeconomics, Alessandria, Kaboski and Midrigan (2010) put forth another idea, which could be called hypothesis (4). They develop a theoretical model in which inventory adjustment tends to enhance volatility in production[16]. Their simulation shows that, under a reasonable assumption that importers have to pay a larger fixed cost for placing an order than domestic dealers, the size of an order tends to be larger for international transactions than for transactions within a country. This means that exports tend to be more volatile than domestic production. They thus hypothesize that inventory adjustments played an important role during the "Great Trade Collapse". For Japan, Sugo et. al. (2009) argue that a sudden build-up of automobile inventories in the US for caused the Japanese manufacturers to cut their levels of inventories drastically, thus contributing to collapses in both exports and production. Figure 13 plots historical evolution of inventory-sales ratio in the US[17]. The data source is the Bureau of Economic Analysis. We observe a sharp rise in the middle of the year 2008 and a quick decline subsequently.

[16] In the macroeconomic literature on inventories (see Hornstein (1997) for a survey of earlier work), the production smoothing hypothesis (Fair (1989), for example) and the (S,s) model (e.g., Khan and Thomas (2007)) have long been in a competition to become the basic framework. Inventories tend to stabilize output in the former model (however, Ramey and West (1999) introduces stock out avoidance motive into this kind of model to show that output could react more strongly to a demand shock than sales). In the latter type of models, sellers face a fixed cost of placing an order. This motivates them to place a new order in a lump sum amount only when the level of inventories is reduced below a threshold. This contributes to increase volatility in output.

[17] The data is for "domestic autos", namely for passenger cars (not including "light trucks") produced in the US, Canada or Mexico.

In this section, we follow Sugo et. al. (2009) and hypothesize that an aggressive inventory adjustment was behind the sharp fall in both exports and production. We searched through the data base of Japan's *Nikkei* Newspaper and found reports that Toyota was resorting to a shutdown of all the factories as a means of output adjustment, and that this was a drastic measure rarely taken by the company (January 18 and 30, 2009). Our interpretation is the following: those manufacturers possess several means to adjust their output, and some are more effective in cutting output but involves higher fixed costs of implementation. Only when hit by a large enough shock and after their inventories build up to a certain level, they resort to drastic measures such as a temporary shutdown of factories. This would yield a strong non-linearity in the reaction of output to inventories.

Data set

Our aim here is to study if Japanese manufacturers' reactions to inventories are different when they are hit by a large shock than when they are hit by a small shock. As the Lehman crisis was a one-time event, it would be difficult to test this hypothesis using time series data. For this reason, we construct a panel data that consists of different companies and different types of automobiles, with information on production, sales and inventories.

We combine Japanese and the US sources of information. For production and sales within Japan, we retrieve data from the Japan Automobile Manufacturers Association web site. The data is monthly and is available by company and for two types of automobiles, namely regular-sized cars and small cars. Both production and sales data are in the units of automobiles. We extract information for the five major producers, namely Toyota, Honda, Nissan, Mazda and Mitsubishi.

Our US data source is the *Automotive News* Data Center on the web. They provide monthly data on inventory levels (again in the units of automobiles) as well as inventory-sales ratios. From those two, we can compute the number of units sold. The information is available by company, and, in many cases, by brands. They also provide information on whether the automobiles are domestically produced or imported[18]. Unfortunately, for Toyota and Nissan, they provide numbers that are aggregated across brands.

We aggregate the US brand-level data into two groups, namely regular-sized cars and small cars, to form a correspondence between the US data and the Japanese data. Refer to Table 3

[18] For example, they provide inventory levels of domestically produced Mitsubishi Galant as well as that of imported Lancer. Note that there may be instances in which "imported" Japanese automobiles may not come from Japanese factories but from elsewhere in the world.

for details of this aggregation.

Methodology

Our dependent variable is the rate of change in production (in Japan) from the previous month. For the right hand side variables, we employ changes in sales within Japan from the previous month (divided by production in the previous month), changes in sales within the US from the previous month (also divided by production in the previous month), and the inventory-sales ratio in the US[19]. We also include monthly dummies.

Our methodology for estimation is a quantile regression. It allows the coefficients to change depending on the level of the dependent variable. This permits us to study if the reaction of production in Japan to inventories in the US is different when the producers are hit by a large shock (i.e., when the growth rate of production is very low) than in normal times.

Sample period is from August 2007 to May 2010. The choice of the starting month is dictated by the US data availability.

Estimation results

Table 4 summarizes the result. In the table, "US_Sales" is sales within the US, "Domestic_Sales" is sales within Japan, and "Inventory" means the inventory-sales ratio within the US. As expected, the coefficient on "Domestic_Sales" is positive and very significant. But "US_Sales" turns out to be insignificant. Most notably, the coefficient on "Inventory" is significantly negative for lower quantiles (i.e., when the value of the dependent variable is relatively low) and, as we move up the quantiles, it increases steadily and turns insignificant for higher quantiles. This relationship is also summarized in Figure 14. Our estimation thus supports the view that the Japanese producers tend to undertake more drastic inventory adjustment when they are hit by large (and negative) shocks.

6 Conclusions

This paper has studied the collapse of the Japanese exports and production during the Lehman crisis period, with a special focus on the automobile industry. We have shown that, although the decline in external demand for Japanese automobiles was massive, this fact alone does not explain why there was a fall in exports that was even more drastic. We

[19] A corresponding data was not available for Japan.

interpret this evidence as suggesting non-linearity in the producers' responses to inventory accumulation. We have used a panel data quantile regression approach and found a support for this idea. In our future work, we intend to build a theoretical model that can give rise to such non-linear behaviors.

References

Ahn, JaeBin, Mary Amiti and David E. Weinstein (2011) "Trade Finance and the Great Trade Collapse" *American Economic Review* 101(3) 298-302.

Alessandria, George, Joseph P. Kaboski and Virgiliu Midrigan (2010) "The Great Trade Collapse of 2008-2009: an Inventory Adjustment?" *IMF Economic Review* 58, 254–294..

Amiti, Mary, and David E. Weinstein (2009) "Exports and Financial Shocks," NBER Working Paper No. 15556.

Baldwin, Richard eds. (2009) *The Great Trade Collapse: Causes, Consequences and Prospects*, VoxEU,org Publication, Centre for Economic Policy Research.

Bems, Rudolfs, Robert C. Johnson, and Kei-Mu Yi (2010) "The Role of Vertical Linkages in the Propagation of the Global Downturn of 2008", IMF Conference in Paris, January 28-29.

Chor, Davin and Kalina Manova (2010) "Off the Cliff and Back? Credit Conditions and International Trade during the Global Financial Crisis," NBER Working Paper No. 16174.

Eichengreen, Barry and Kevin H. O'Rourke (2009) "Tale of Two Depressions", VoxEU.

Eichengreen,Barry and Kevin H. O'Rourke (2010) "Tale of Two Depressions: What do the New Data Tell Us?", VoxEU.

Fair, Ray C. (1989) "The Production-smoothing Model is Alive and Well", *Journal of Monetary Economics* 24(3), 353-370.

Fukao, Kyoji and Tangjun Yuan (2009) "Why is Japan So Heavily Affected by the Global Economic Crisis? An Analysis Based on the Asian International Input-Output Tables" Hi-Stat Vox, No. 8.

Hornstein, Andreas (1997) "Inventory Investment and the Business Cycle," Federal Reserve Bank of Richmond *Economic Quarterly*, vol. 84 (Spring), 49–71.

Kim, Chang-Jin, and Charles R. Nelson. 1999. *State-Space Models with Regime-Switching: Classical and Gibbs-Sampling Approaches with Applications*. MIT Press.

Khan, Aubhik and Julia Thomas (2007) “Inventories and the business cycle: An equilibrium analysis of (S,s) policies.” *American Economic Review*, 97(4), 1165-88.

Levchenko, Andrei, Logan Lewis and Linda Tesar (2010) “The collapse of international trade during the 2008-2009 crisis: in search of smoking guns.” NBER Working Paper Series 16006.

Nakajima, Jouchi (2011) “Time-varying parameter VAR model with stochastic volatility: An overview of methodology and empirical applications” *Monetary and Economic Studies*, 29, 107-142.

Primiceri, Giorgio E. (2005) “Time Varying Structural Vector Autoregressions and Monetary Policy” *Review of Economic Studies* 72(3), 821–852.

Tanaka, Kiyoyasu (2009) “Trade Collapse and International Supply Chains: Japanese Evidence”, chapter 22 of Baldwin (2009).

Wakasugi, Ryuhei (2009) “Why was Japan’s Trade Hit So Much Harder?” chapter 23 of Baldwin (2009).

(Writings in Japanese)

Bank of Japan (2009) *Monthly Report of Recent Economic and Financial Developments*, February, in Japanese.

Shioji, Etsuro and Taisuke Uchino (2011) “External Shocks and the Japanese Business Fluctuations: an Empirical Analysis of the “Great Trade Collapse” of the Japanese Automobile Industry” in Japanese, Bank of Japan Working Paper Series No.11-J-1.

Sugo, Tomohiro, Yoshitaka Ichinose and Kazushige Kamiyama (2009), “On Recent Variations in Inventories: Their Characteristics in the Current Phase and Implications for Future Business Conditions” in Japanese, *Bank of Japan Review* 09-J-2.

Uchino, Taisuke (2011) “Bank Dependency and Financing Constraints on Equipment Investment for Listed Firms in Japan” in Japanese, mimeo (Ph.D. thesis, Chapter 2).

Table 1: Variance decomposition results, the VAR model for total exports (in percentages)

(1) Response variable = Total auto exports from Japan

	Oil prices	Exchange rate	US total imports	EU total imports	Auto exports from Japan	Auto production in Japan	Industrial production in Japan
Contemporaneous	0.1	9.8	0.1	0.4	89.5	0.0	0.0
12 months ahead	0.4	11.6	4.4	1.0	76.4	4.2	2.0
24 months ahead	1.3	18.9	8.4	2.7	56.3	2.3	10.0

(2) Response variable = Auto production in Japan

	Oil prices	Exchange rate	US total imports	EU total imports	Auto exports from Japan	Auto production in Japan	Industrial production in Japan
Contemporaneous	0.0	2.5	0.1	2.0	12.1	83.2	0.0
12 months ahead	0.4	3.3	1.1	6.9	24.9	52.0	11.3
24 months ahead	0.5	4.1	1.7	11.8	25.2	33.9	22.7

(3) Response variable = Industrial production in Japan

	Oil prices	Exchange rate	US total imports	EU total imports	Auto exports from Japan	Auto production in Japan	Industrial production in Japan
Contemporaneous	0.0	2.6	0.2	3.3	8.1	26.9	58.9
12 months ahead	0.3	0.5	0.4	5.1	13.7	9.2	67.7
24 months ahead	2.4	1.2	4.5	6.2	13.7	9.7	62..3

Table 2: Variance decomposition for auto exports from Japan to US (in percentages)

	CP spread	Auto loan spread	Exchange rate	US total imports	US car purchase	Auto exports to US
Contemporaneous	0.0	0.0	2.5	0.1	0.1	97.2
12 months ahead	2.0	2.1	8.8	0.8	2.9	83.4
24 months ahead	1.8	2.2	30.9	1.5	5.6	58.1

Table 3: Construction of the panel data set: correspondence between car-types (used in the estimation) and brands (in the original *Automotive News* data set)

Manufacturer	Type	Brands etc.
Toyota	Regular-sized	Lexus car, Lexus truck
	Small	Toyota car, Toyota truck
Honda	Regular-sized	Acura car, Acura truck
	Small	American Honda car, American Honda truck
Nissan	Regular-sized	Infiniti car, Infiniti truck
	Small	Nissan N.A. car, Nissan N.A. truck
Mazda	Regular-sized	Mazda3, Mazda6, CX-7, CX-9, Tribute
	Small	MX-5/Miata, RX-8, Mazda8
Mitsubishi	Regular-sized	Eclipse, Eclipse-Spyder, Galant, Endeaver, Raider
	Small	Lancer, Outlander

Table 4: Panel data quantile regression results: LHS = Automobile production in Japan, by manufacturer and car-type (rate of change from the previous month)

	Quantile=0.1			Quantile=0.2			Quantile=0.3			Quantile=0.4			Quantile=0.5		
	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.
US_Sales	0.0085		0.0140	-0.0008		0.0104	-0.0002		0.0132	0.0177		0.0124	-0.0038		0.0153
Domestic_Sales	0.4991	***	0.0925	0.4870	***	0.0826	0.4092	***	0.0684	0.4240	***	0.0647	0.3770	***	0.0813
Inventory	-0.0020	***	0.0006	-0.0018	***	0.0004	-0.0012	***	0.0003	-0.0009	***	0.0003	-0.0007	**	0.0003
Month2	0.1342	**	0.0603	0.1724	***	0.0481	0.1154	***	0.0376	0.1558	***	0.0365	0.1159	***	0.0427
Month3	0.3397	***	0.0574	0.2143	***	0.0496	0.1074	***	0.0389	0.0998	***	0.0381	0.0793	*	0.0447
Month4	0.2612	***	0.0712	0.1401	**	0.0552	0.0063		0.0439	0.0353		0.0407	0.0105		0.0494
Month5	0.3721	***	0.0577	0.2949	***	0.0465	0.1410	***	0.0366	0.1429	***	0.0356	0.0885	**	0.0418
Month6	0.5384	***	0.0703	0.4049	***	0.0495	0.2869	***	0.0408	0.2833	***	0.0395	0.2237	***	0.0461
Month7	0.4217	***	0.0674	0.2866	***	0.0515	0.1987	***	0.0401	0.2255	***	0.0389	0.1675	***	0.0459
Month8	0.1533	**	0.0706	0.0593		0.0542	-0.1034	**	0.0410	-0.1096	***	0.0404	-0.1754	***	0.0471
Month9	0.4897	***	0.0594	0.4001	***	0.0461	0.3258	***	0.0381	0.3475	***	0.0377	0.3281	***	0.0444
Month10	0.3824	***	0.0565	0.3082	***	0.0460	0.1464	***	0.0379	0.1536	***	0.0367	0.0910	**	0.0430
Month11	0.3124	***	0.0615	0.2462	***	0.0467	0.1040	***	0.0363	0.1213	***	0.0350	0.0806	*	0.0411
Month12	0.3091	***	0.0575	0.2094	***	0.0463	0.0383		0.0362	0.0402		0.0351	-0.0122		0.0416
const.	-0.3483	***	0.0490	-0.2164	***	0.0377	-0.0819	***	0.0318	-0.0903	***	0.0318	-0.0320		0.0382
N. of Obs.	324			324			324			324			324		
Pseudo_Rsquared	0.401			0.3867			0.3778			0.3739			0.3699		

	Quantile=0.6			Quantile=0.7			Quantile=0.8			Quantile=0.9		
	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.	coef.	p>|z|	std.err.
US_Sales	-0.0050		0.0077	-0.0025		0.0131	0.0003		0.0168	0.0073		0.0264
Domestic_Sales	0.3542	***	0.0575	0.4749	***	0.0981	0.5360	***	0.1203	0.5734	***	0.2083
Inventory	-0.0005	**	0.0002	-0.0001		0.0004	0.0002		0.0005	0.0002		0.0008
Month2	0.1256	***	0.0297	0.1257	***	0.0485	0.1592	***	0.0582	0.1931	*	0.1005
Month3	0.1240	***	0.0309	0.1272	**	0.0508	0.1714	***	0.0611	0.3086	***	0.0947
Month4	0.0312		0.0340	0.0653		0.0545	0.1363	**	0.0654	0.1327		0.0974
Month5	0.0908	***	0.0292	0.0841	*	0.0479	0.1520	***	0.0573	0.4299	***	0.0962
Month6	0.2248	***	0.0327	0.1847	***	0.0548	0.2112	***	0.0668	0.2459	**	0.1034
Month7	0.1531	***	0.0323	0.1300	**	0.0536	0.1519	**	0.0650	0.1948	*	0.1003
Month8	-0.1921	***	0.0332	-0.1215	**	0.0551	-0.1122	*	0.0654	-0.0260		0.1026
Month9	0.3719	***	0.0314	0.3438	***	0.0524	0.3722	***	0.0665	0.3567	***	0.1237
Month10	0.0974	***	0.0300	0.1028	**	0.0496	0.1104	*	0.0593	0.1150		0.0978
Month11	0.0810	***	0.0287	0.0549		0.0473	0.0773		0.0552	0.0594		0.1000
Month12	-0.0039		0.0288	-0.0173		0.0475	-0.0130		0.0549	-0.0306		0.0898
const.	-0.0243		0.0271	-0.0177		0.0458	-0.0144		0.0587	0.0366		0.1031
N. of Obs.	324			324			324			324		
Pseudo_Rsquared	0.369			0.3621			0.3553			0.325		

(note 1) "US_Sales": Sales within the US (change from the previous month, divided by the number produced in the previous month), "Domestic_Sales": Sales within Japan (change from the previous month, divided by the number produced in the previous month), "Inventory": Inventory-sales ratio within the US (inventories divided by sales per day), "MonthXX": monthly dummies.

(note 2) "***", "**", and "*" indicate 1%, 5% and 10% level significance, respectively.

Figure 1: GDP since 2007 (2007QI=100, data source = OECD)

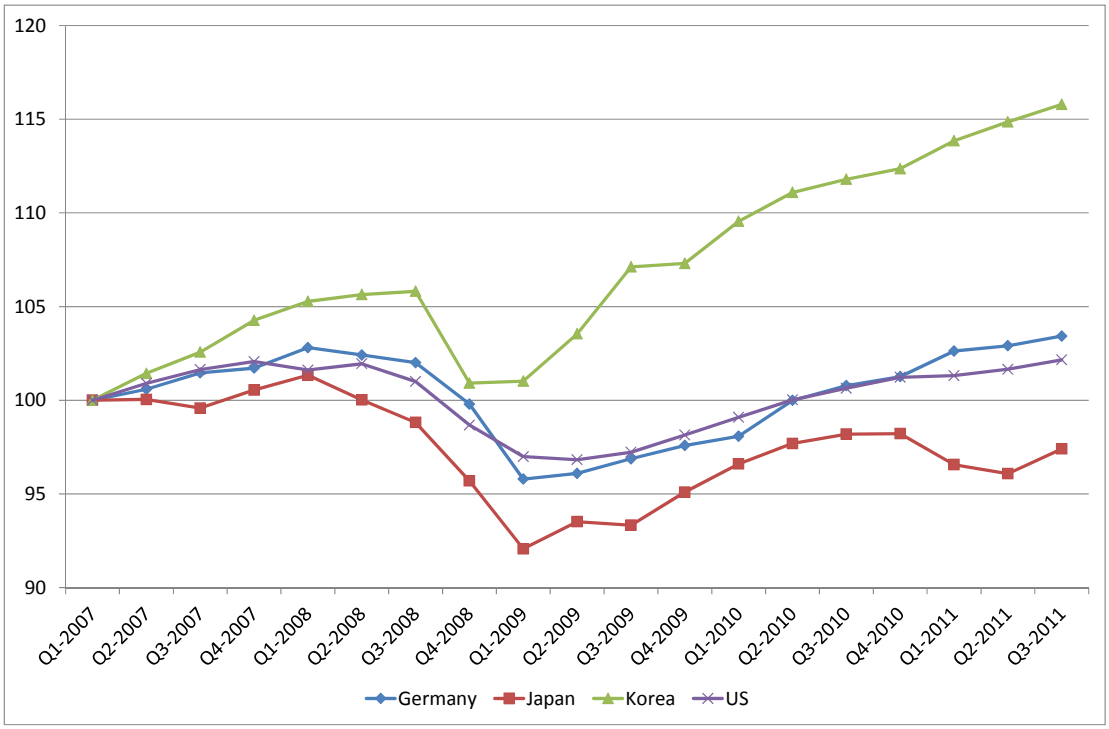


Figure 2: Industrial Production since 2007 (January 2007 = 100)

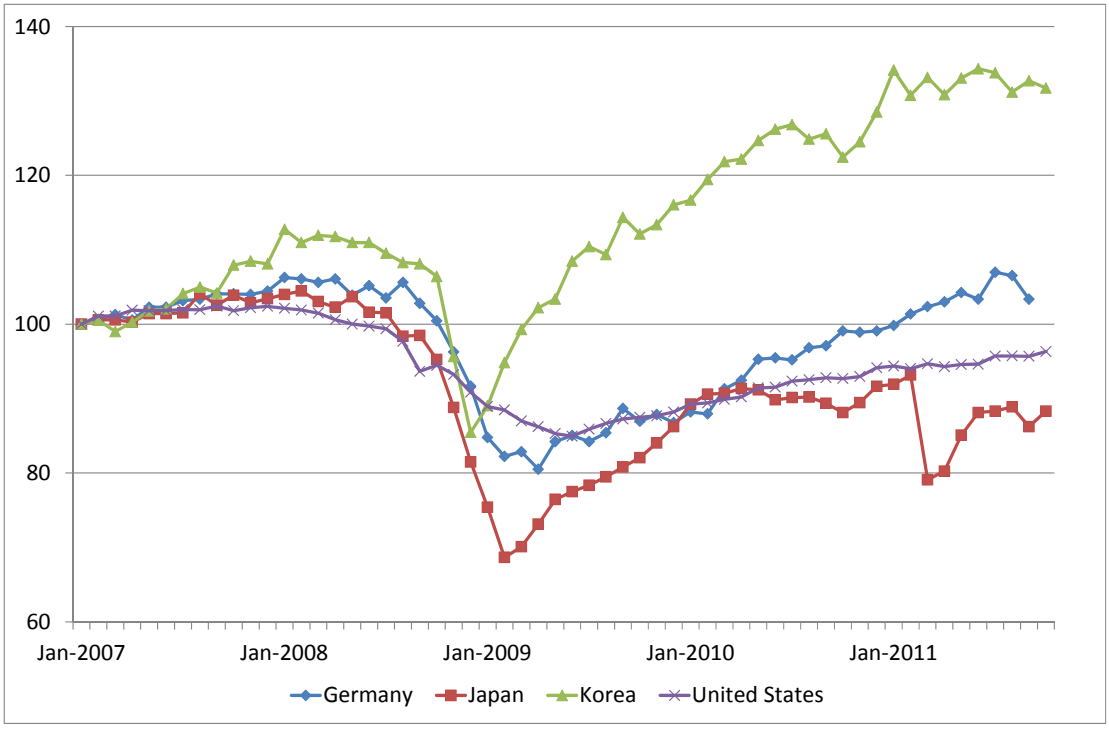


Figure 3: Export values (in US Dollars) since 2007 (January 2007=100)

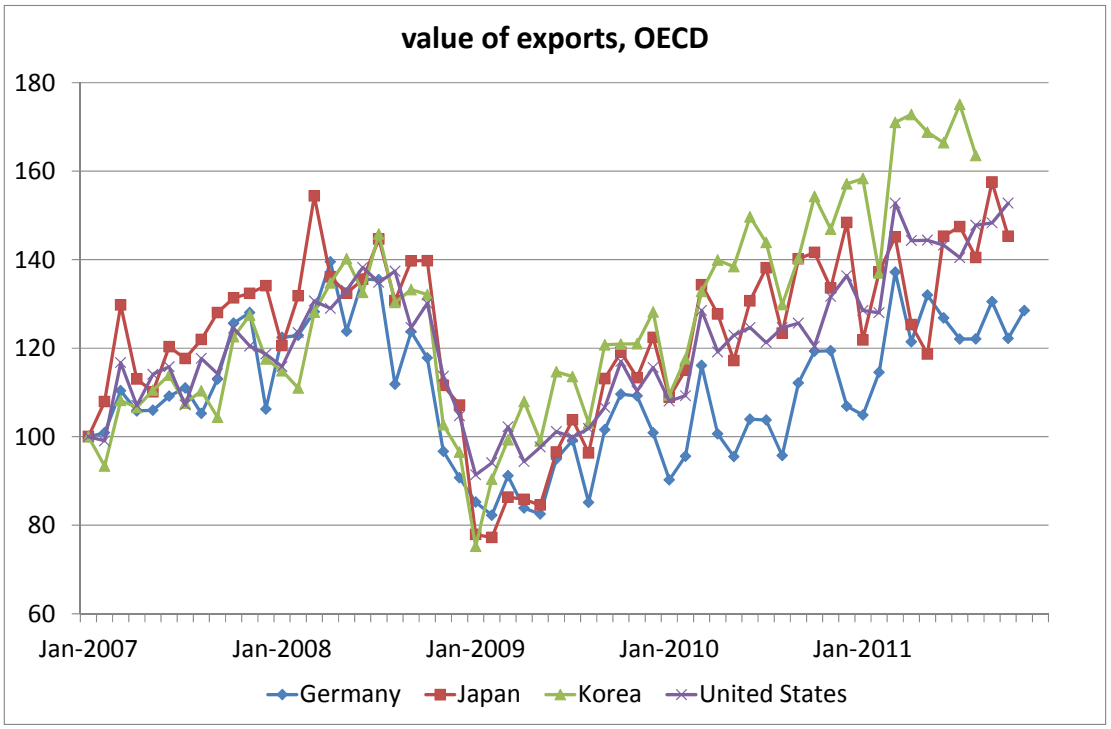


Figure 4: Industrial Production in Japan, total vs. automobiles (January 2007=100)

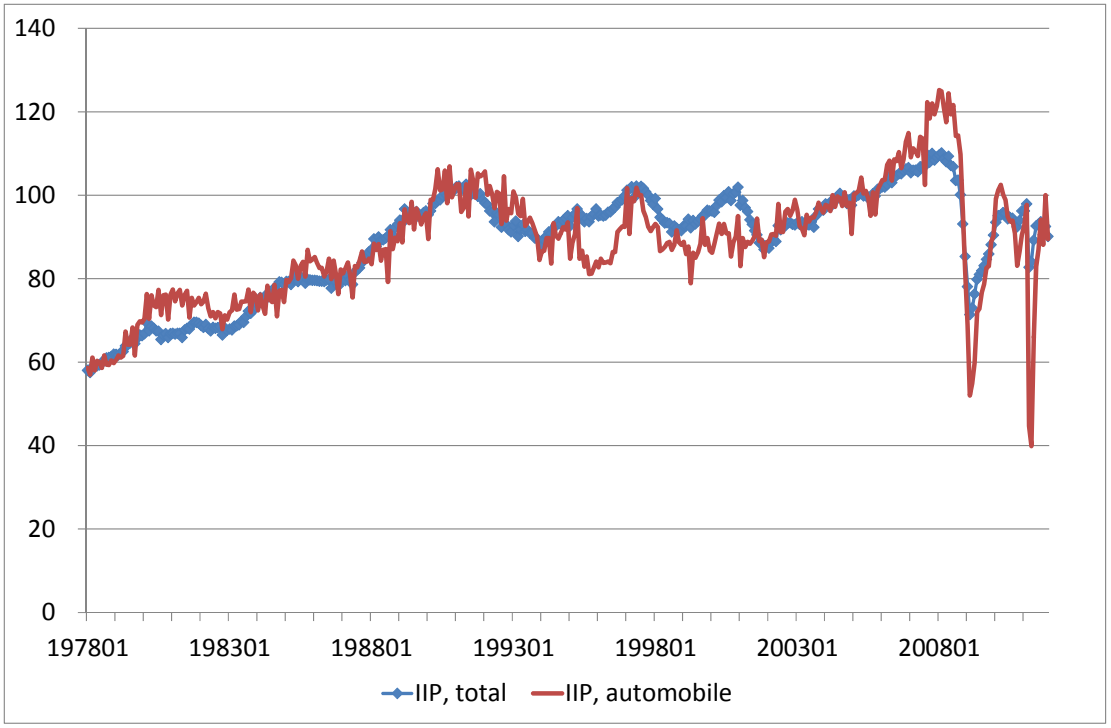


Figure 5: Real exports from Japan, total vs. automobile

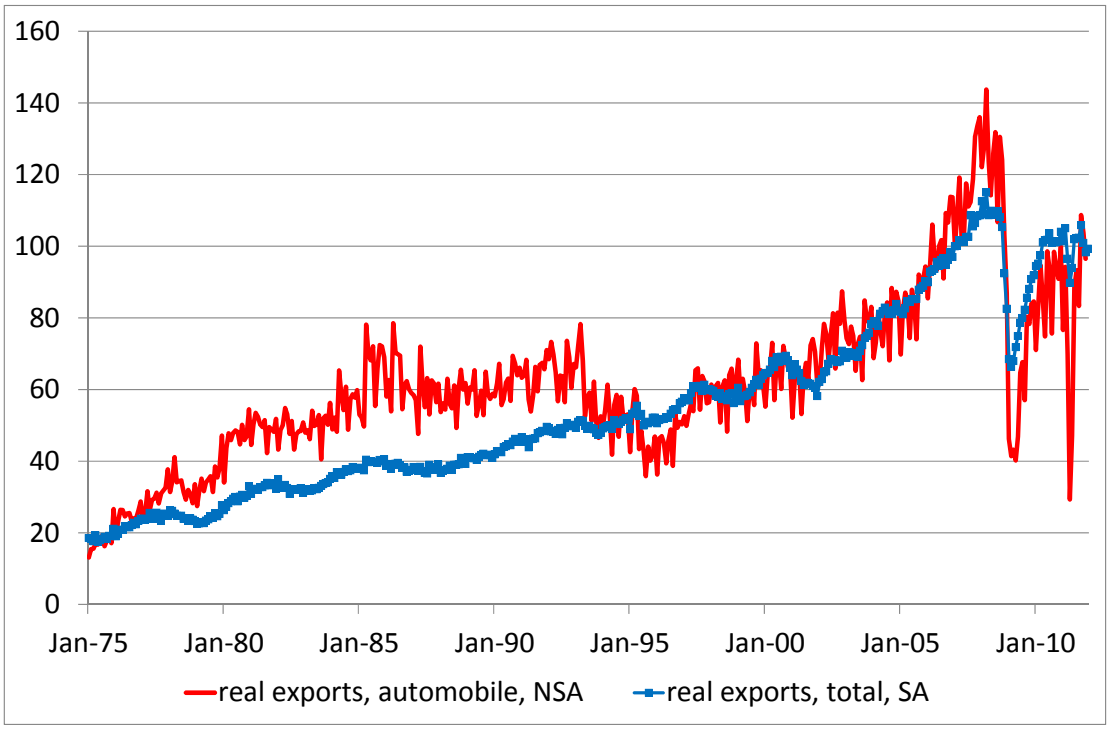


Figure 6: US automobile sales vs Japanese automobile exports to US (January 2007=100)

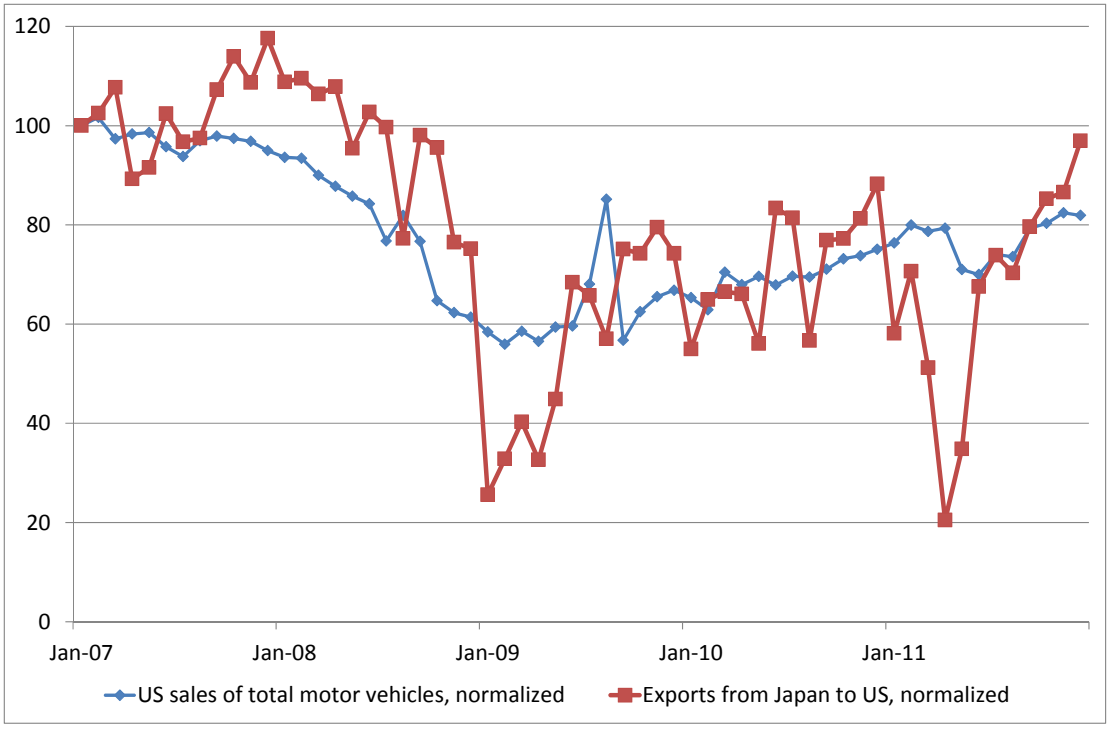
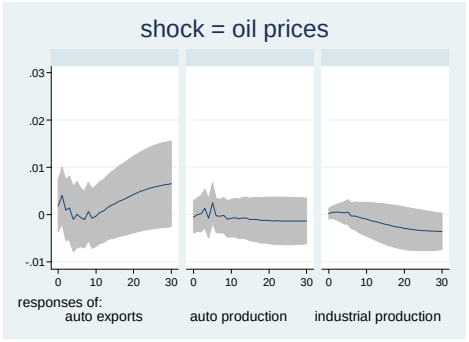
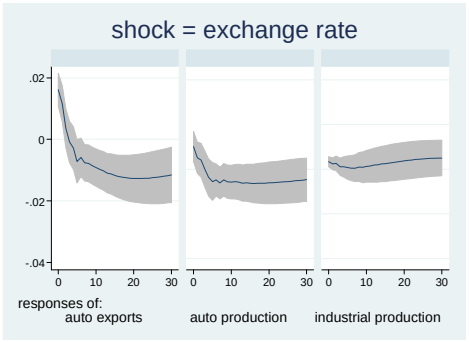
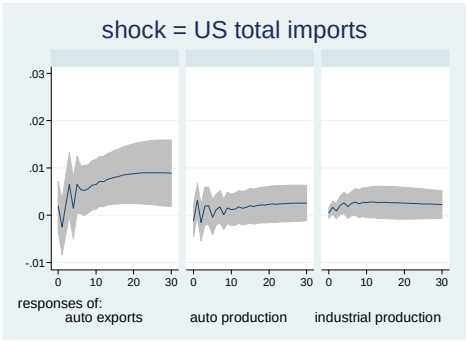
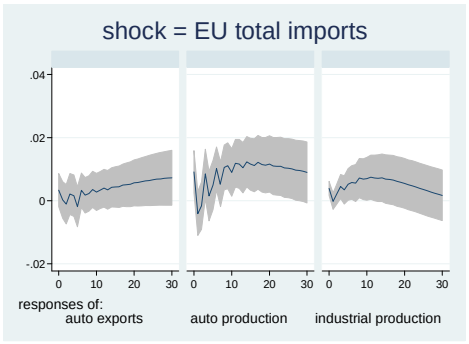


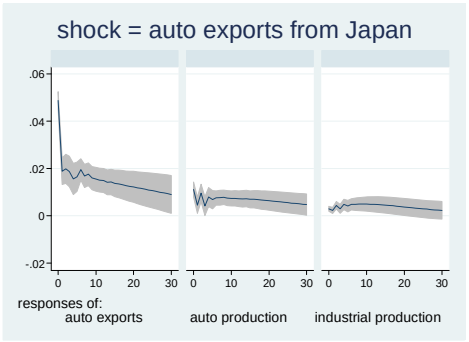
Figure 7: Impulse responses, VAR model for total automobile exports from Japan

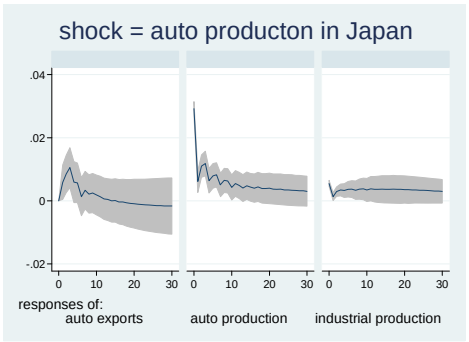


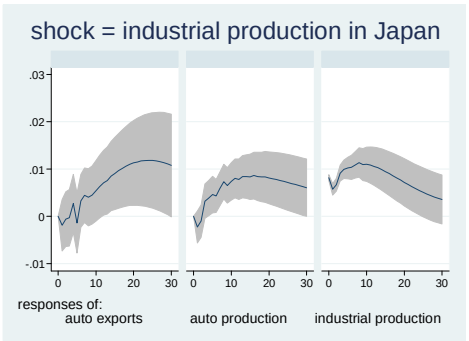








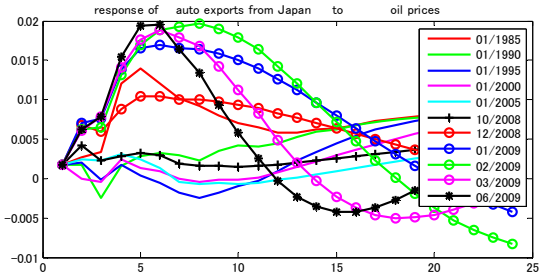


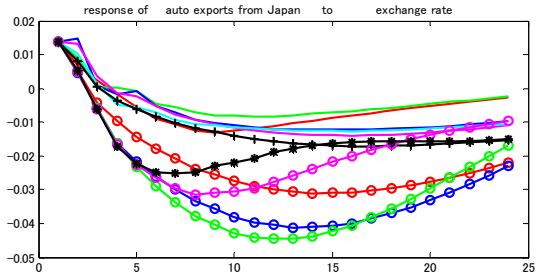


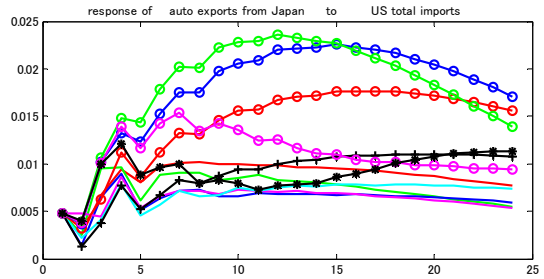
Note: Shaded areas are the 95% confidence intervals.

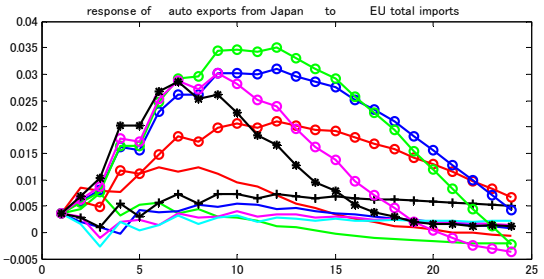
Figure 8: Impulse responses, TVP-VAR model for total automobile exports from Japan

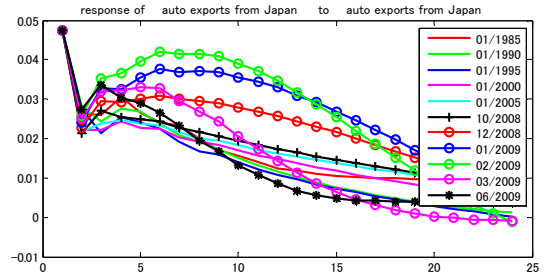
(1) Response variable = total automobile exports from Japan

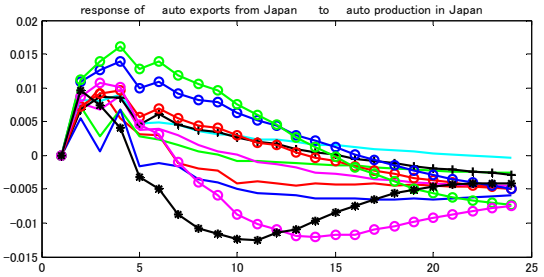


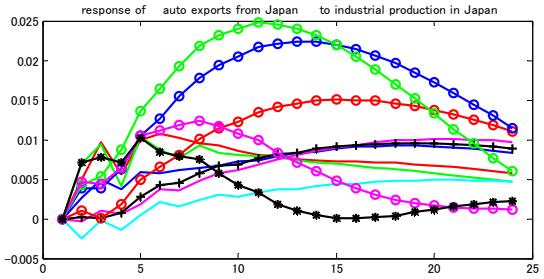


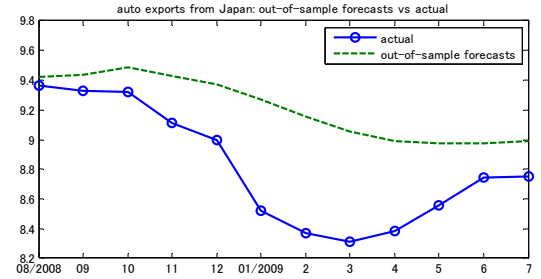




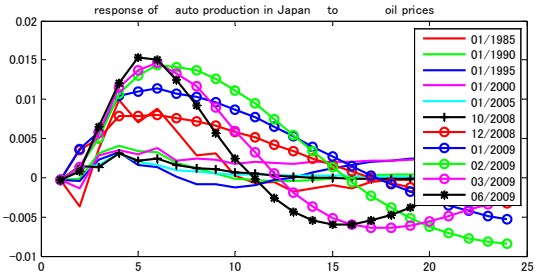


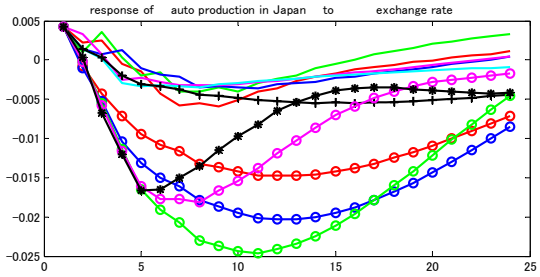


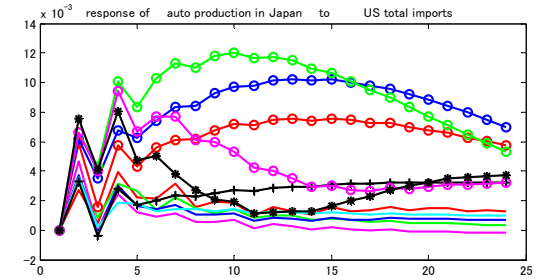


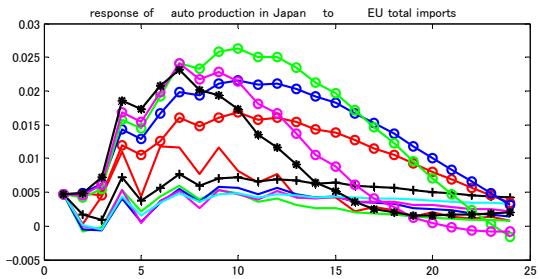


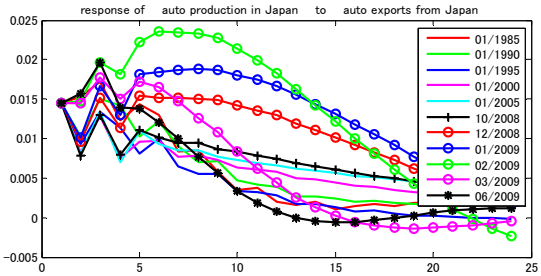
(2) Response variable = automobile production in Japan

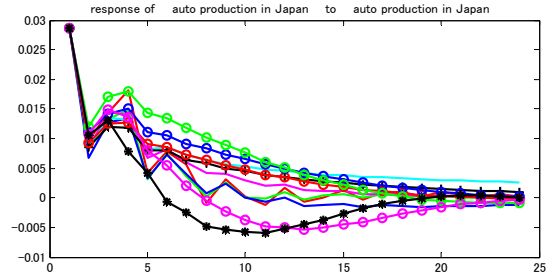


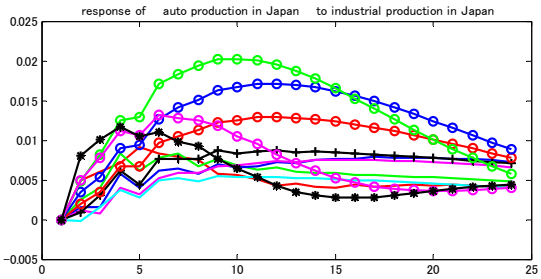


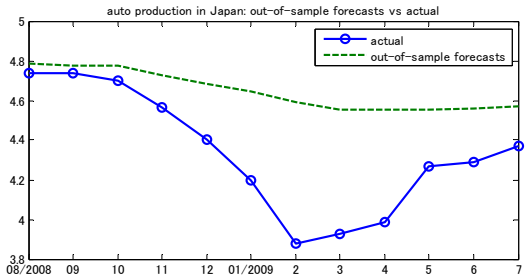




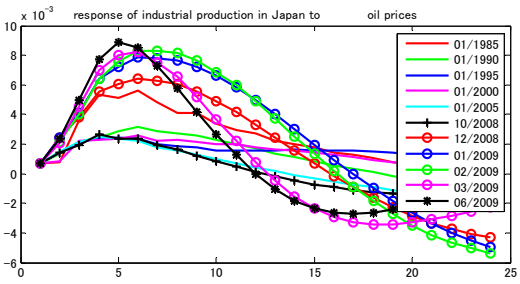


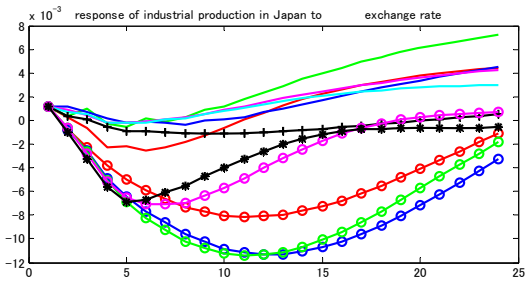


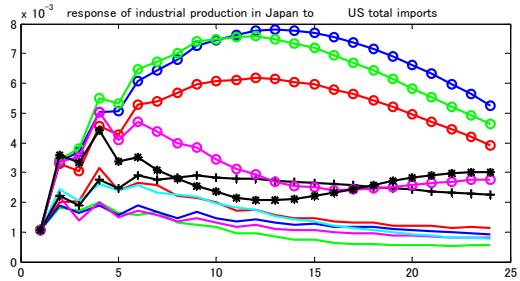


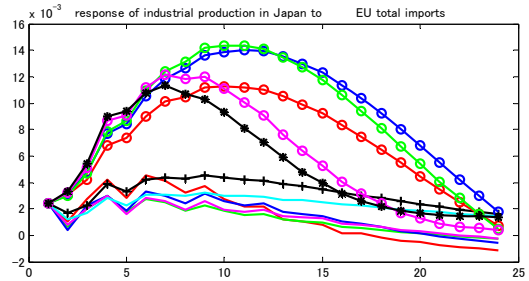


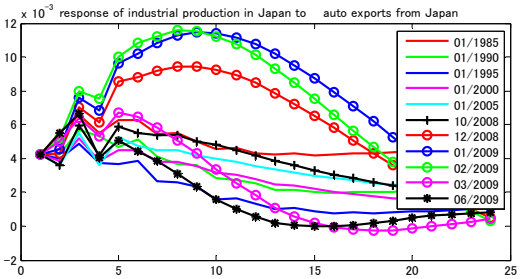
(3) Response variable = industrial production in Japan

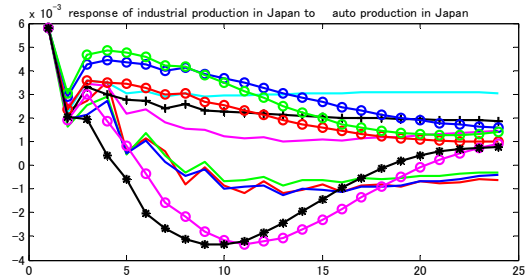


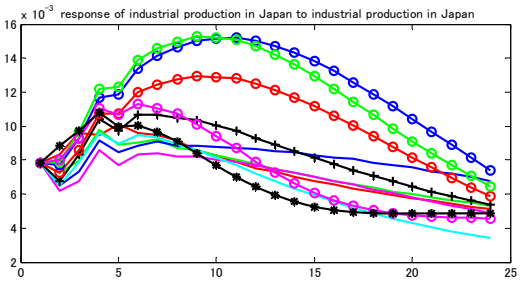












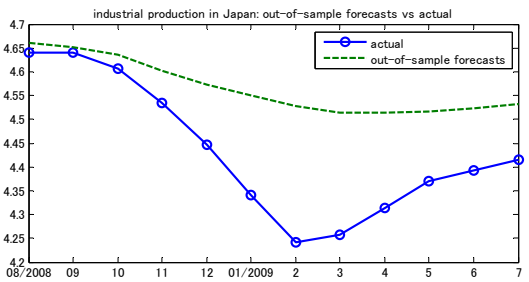
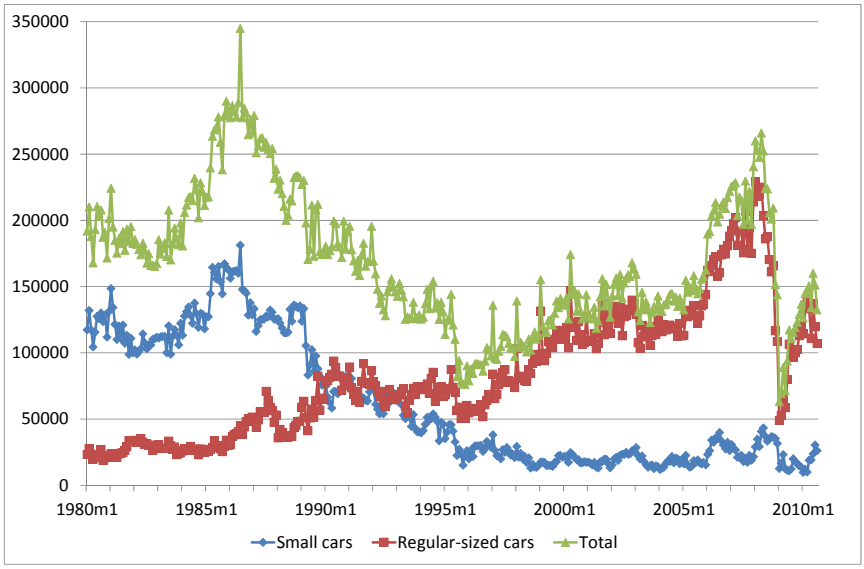
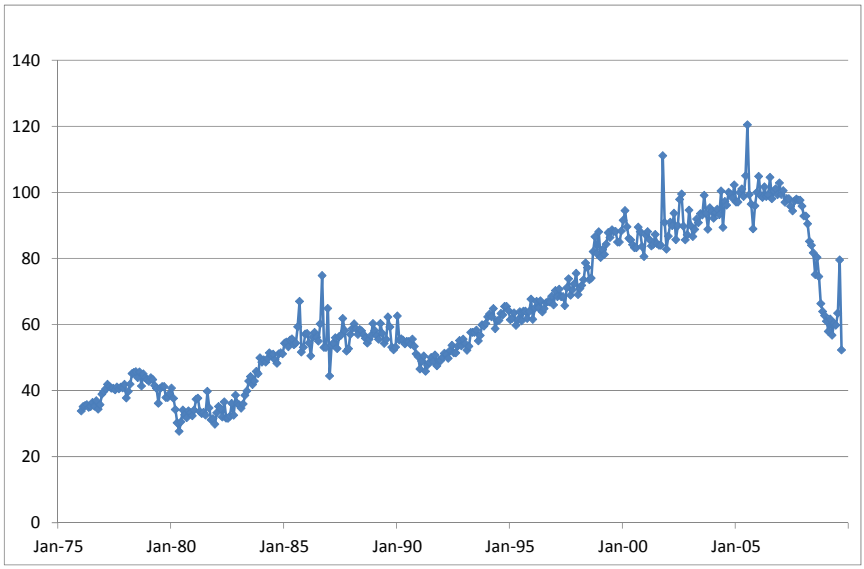


Figure 9: Variables used for the estimation of the (TVP-)VAR model for automobile exports to US

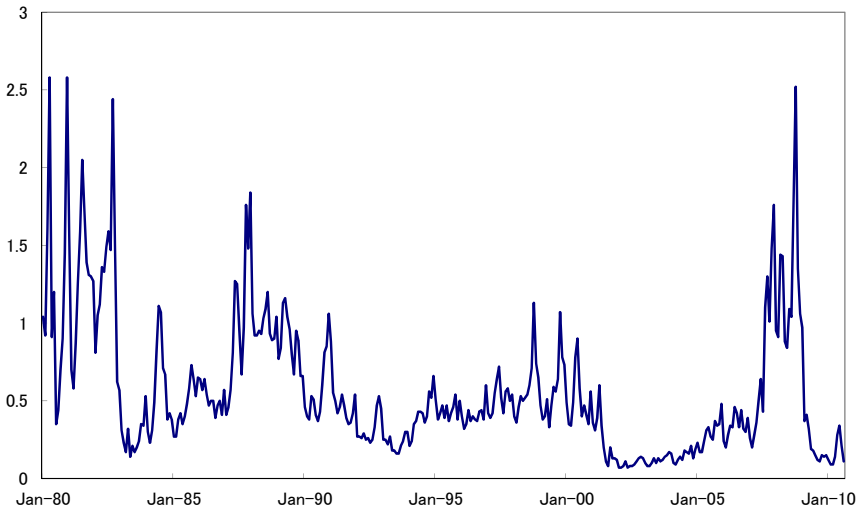
(1) Automobile exports from Japan to US (in units of automobiles)



(2) US real purchases of automobiles, monthly estimate



(3) US CP spread



(4) US auto loan spread

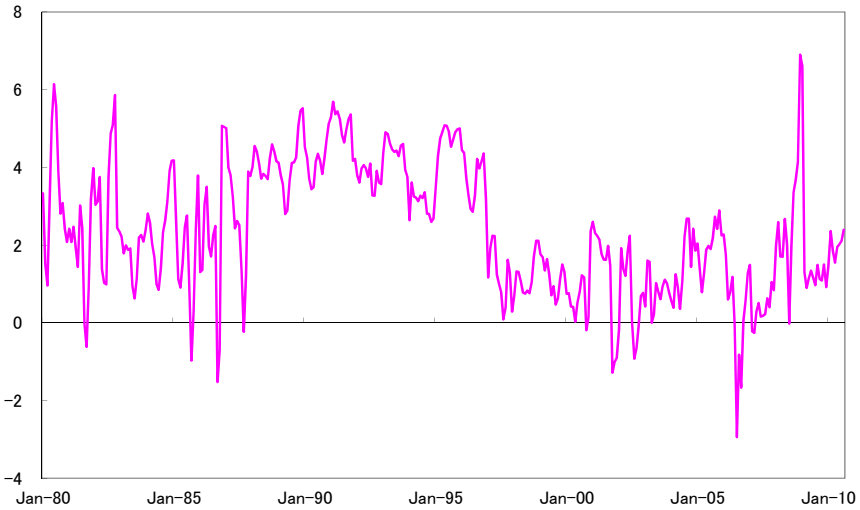


Figure 10: Impulse responses, VAR model for automobile exports from Japan to the US

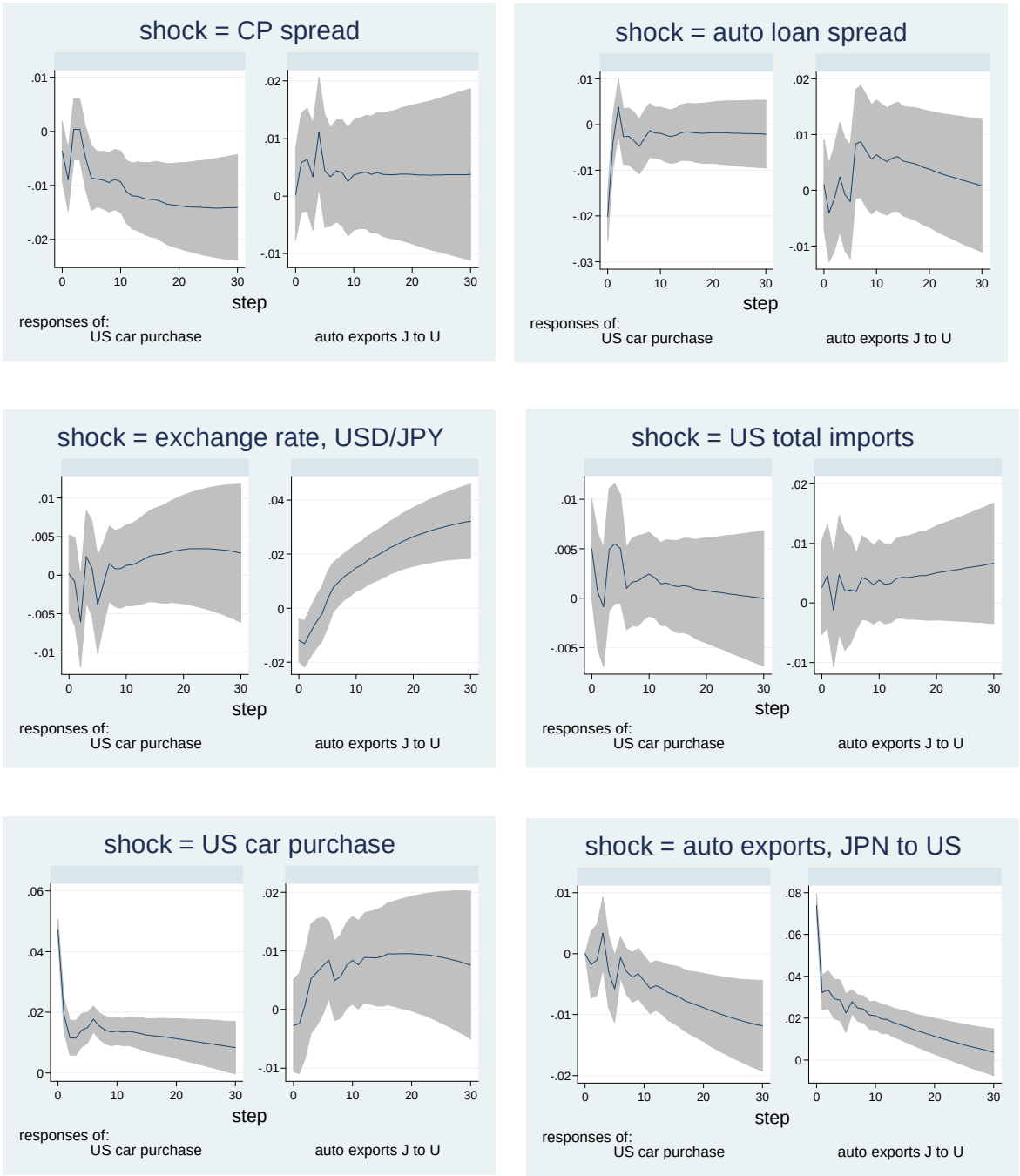
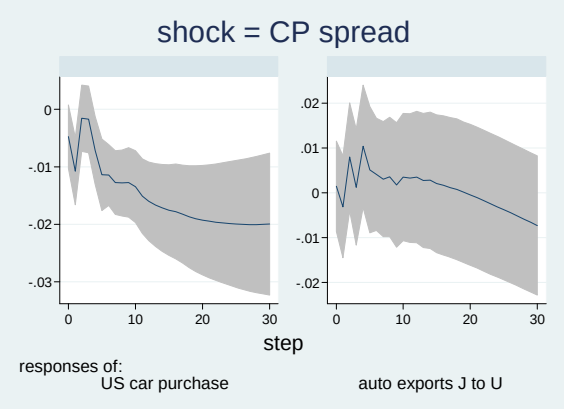
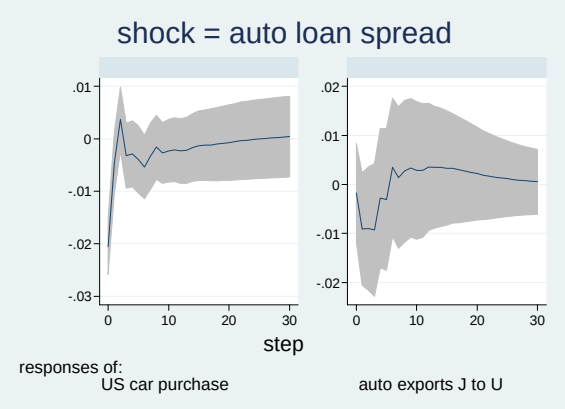


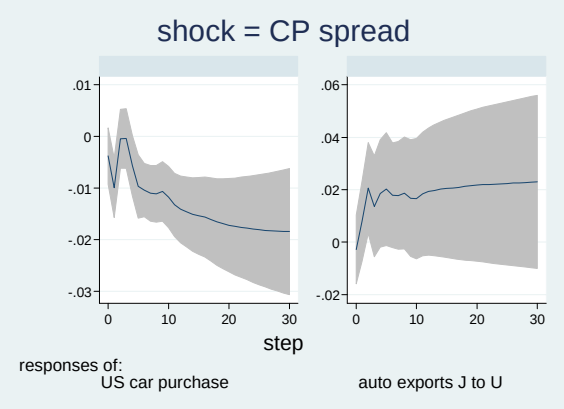
Figure 11: Impulse responses of exports of regular-sized vs. small automobiles from Japan to the US, to US financial shocks

(1) Regular-sized cars





(2) Small cars



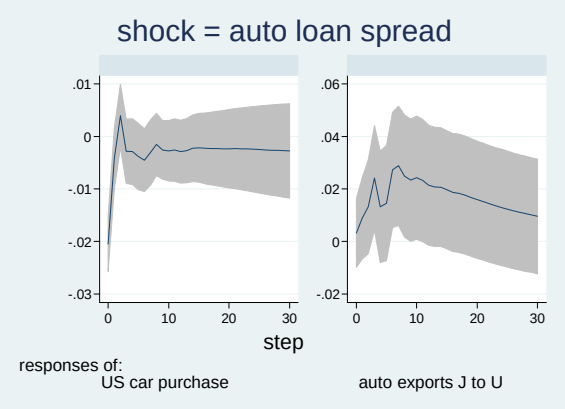
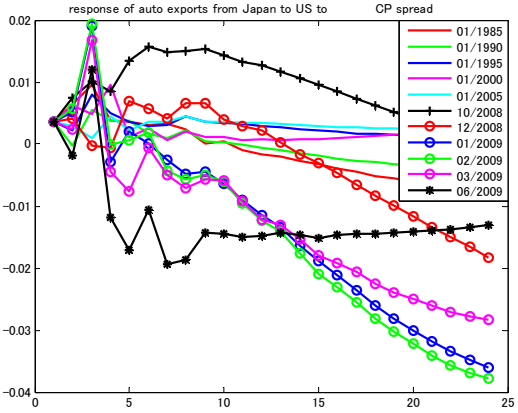
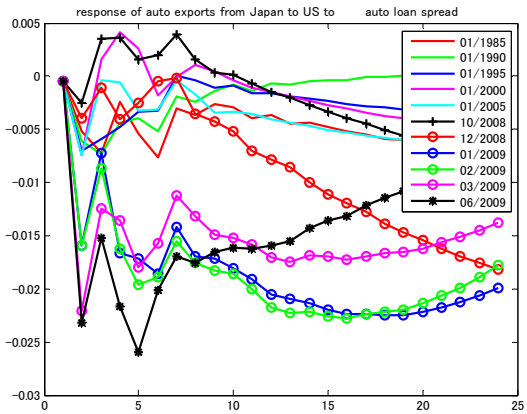
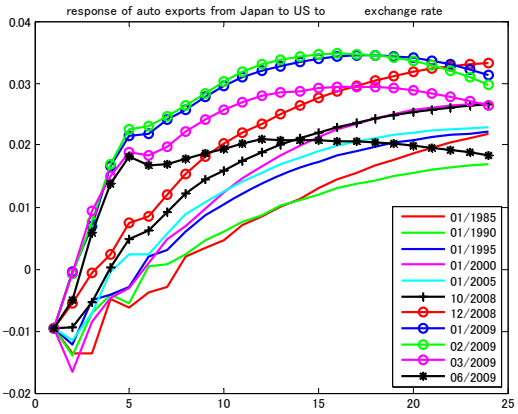


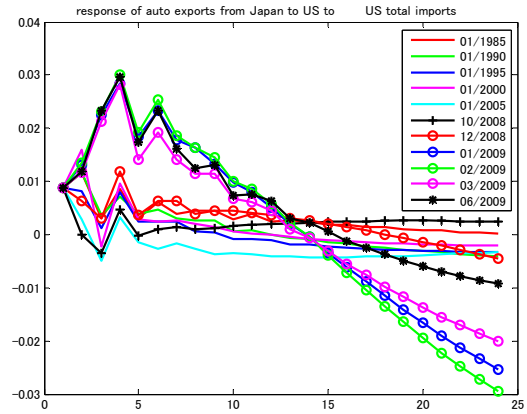
Figure 12: Impulse responses, TVP-VAR model for automobile exports from Japan to the US

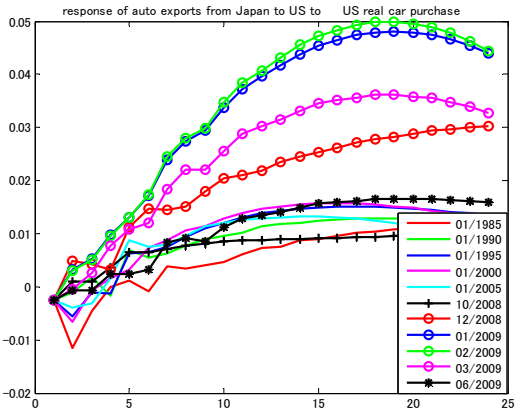
Response variable = automobile exports from Japan to the US











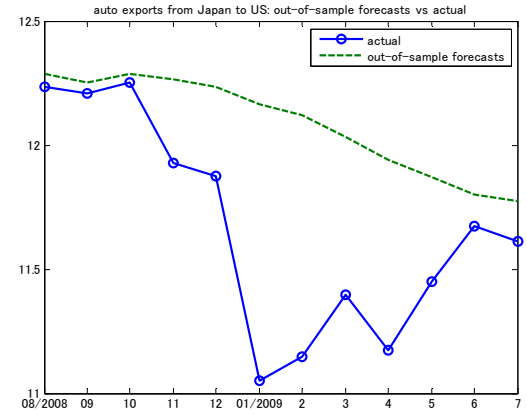


Figure 13: Evolution of automobile inventory-sales ratio in the US (unit: days)

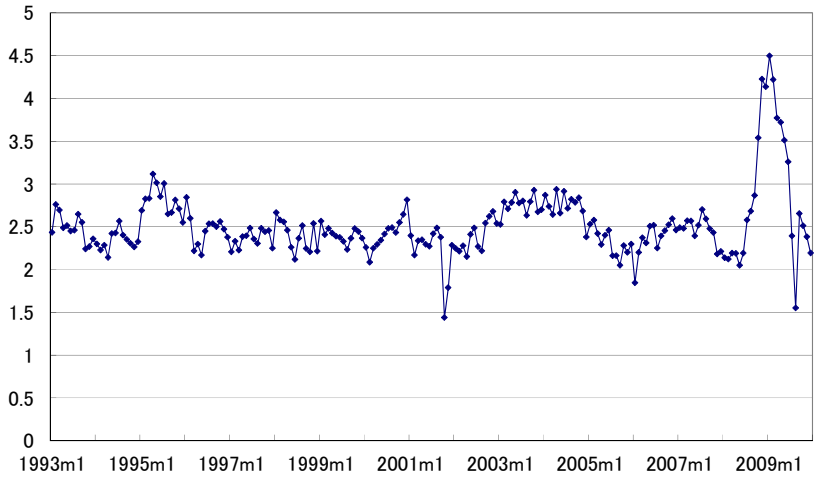
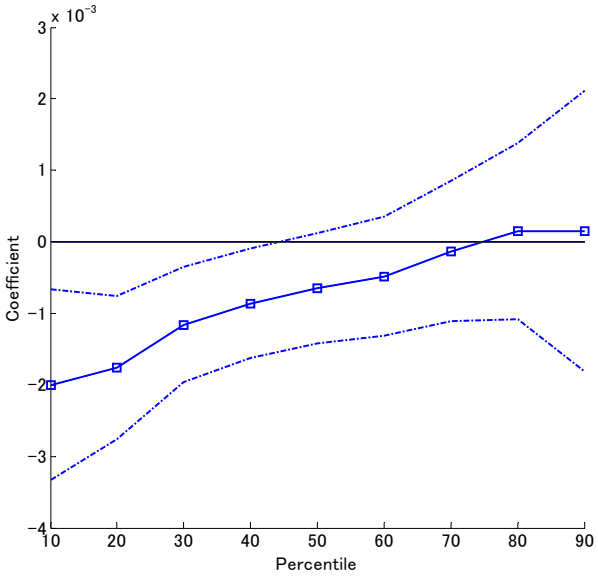


Figure 14: Estimated coefficient on inventory-sales ratio by quantile and the 95% confidence intervals (dashed lines)



(note) Confidence intervals are derived by the bootstrap method.