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Time varying pass-through: Will the yen depreciation help Japan hit the inflation target? [*1]

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Abstract

The Bank of Japan officials, with their 2% inflation target, have come to stress importance of raising the public's inflation expectations. That is, they wish to somehow shift the intercept term of the Japanese Phillips Curve upwards. How this can be achieved, however, is not very clear. This paper argues that the recent depreciation of the Japanese yen, coupled with persistently high prices of imported raw materials, could provide a powerful mechanism through which the Japanese public's inflation expectations could be changed relatively swiftly. The argument proceeds in three steps. First, evidence suggests that household inflation expectations are greatly influenced by prices of the goods and services that they purchase more frequently. Second, exchange rates and import prices tend to have disproportionately large impacts on those prices. Third, those impacts are on the rise; that is, pass-through to those prices has risen sharply in recent years. The last point will be demonstrated via time series econometric approaches.

Key words: exchange rate, import prices, pass-through, expected inflation, TVP-VAR.

JEL classification：F41，E31

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I. Introduction

This paper re-examines the issue of pass-through of the exchange rate and imported input prices to the Japanese CPI. It is motivated by the recent policy changes at the Bank of Japan. On January 22, 2013, the Bank adopted a new inflation targeting scheme and set the target CPI (total, excluding fresh food) inflation rate of 2%. The current regime under Governor Kuroda has pushed the idea further. The Bank now aims at hitting the 2% target within two years. Moreover, it would continue the massive "Quantitative and Qualitative Easing" until inflation is recognized to have stabilized around 2%. At the time of this writing, the latest figure for CPI inflation has risen to about 1.3%, up from around -0.2% before the Abe administration took over. Despite the improvement, it is still unclear if the Bank would be able to hit the target, in time for its self-imposed deadline.

In light of those developments, the Bank officials have come to stress importance of raising the public's inflation expectations through policy measures and discourses. In other words, somehow shifting the intercept term of the Japanese Phillips Curve upwards has become an important policy agenda. For example, recent speeches by Governor Kuroda, such as the one on December 25, 2013 at Keidanren, emphasize the roles of inflation expectations. If the public indeed comes to expect 2% inflation, the Bank should be able to achieve the 2% actual inflation, at zero GDP gap, or, without overheating the economy. How policy makers could influence inflation expectations, however, has not been made not very clear (beyond, say, by the use of strong words and by appearing to hold onto a "firm commitment").

Since the dissolution of the parliament by the then-prime minister Noda, the Japanese Yen has depreciated against the US Dollar rapidly, from about 78 JPY/USD in early October 2012 to about 103 JPY/USD in May 2013. It continues to be weak under the current Bank of Japan regime. Also, prices of some of the imported inputs, such as wheat, have gone up considerably, in recent years. This paper such movements would provide a powerful mechanism through which the Japanese public's inflation expectations could be shifted swiftly. My argument consists of the following three

steps.

(1) Past research has found that household inflation expectations are greatly influenced by prices of the goods and services that they purchase more frequently. Japanese experiences have been consistent with such a view.

(2) Exchange rates and import prices tend to have disproportionately large impacts on prices of those frequently-purchased items. Examples include (often-cited) gasoline and processed foods.

(3) In the literature, however, some authors have claimed that the rate of exchange rate pass-through to import prices as well as to domestic prices has declined in the past two decades. If this is the case, the depreciation may not be of much help, after all. This paper finds, however, that, in the most recent years, the magnitude of pass-through to prices of regularly purchased items has risen sharply in recent years. This point will be demonstrated via time series econometric approaches, such as the time-varying parameter VARs.

The rest of the paper is organized as follows. Section II discusses the background of the current paper. Section III overviews the nature of the data on CPI classified by frequency of purchases. In Section IV, I estimate a VAR model with the aggregate CPI. I estimate the same model for various sub-periods and find that pass-through has come back lately. In section V, I repeat essentially the same exercise, incorporating prices of items that the consumers buy with higher frequencies, in place of the aggregate CPI. In section VI, I estimate a time-varying parameter VAR model to confirm the tendency toward a pass-through revival. Section VII concludes.

II. Background

Monetary policy at the zero bound

When an economy is stuck at the zero lower bound of the interest rate, inflation expectation plays a key role in an attempt to get out of the liquidity trap. However, at the zero bound, when the central bank has no (apparently) reliable tool to stimulate the private economy directly, it is less than clear how it could work on the private sector's

inflation expectation. It seems that it can only rely on policy announcements (such as strong words of commitment to a future course of policies), whose consequences are up to how households and firms interpret them.

The exchange rate might provide a much-needed tool for the central bank to work on the private inflation expectation. Suppose that, even at the zero bound, the central bank can influence the exchange rate via, for example, quantitative easing: the mechanism behind such an effect is theoretically unclear, but there is some empirical evidence that supports its existence. For example, Hosono, Yoshikawa and Isobe (2013) estimate GARCH models for daily exchange rate changes for Japan. They include dummy variables that represent important announcement dates for the Bank of Japan's unconventional monetary policies. They find some cases in which the policy announcements have significant effects on the exchange rate. Also, in relation to the current round of monetary easing, Fukuda (2014) shows that investors, most notably foreign investors, reacted to recent series of expansionary policy announcements.

Thus, the exchange rate could provide us a useful channel through which the central bank could influence both realized and expected inflation. A prerequisite is that domestic prices react to such movements in the exchange rate. I will now turn to that issue in the next sub-section.

Has exchange rate pass-through declined?

The issue of exchange rate pass-through has captured much attention from researchers in recent years. On the theory side, it has been known that policy implications could change substantially depending on the degree of exchange rate pass-through[1]. Here, I shall limit my review to empirical work. Campa and Goldberg (2005) have stimulated interests in the empirical analysis of exchange rate pass-through. Studies that belong to this strand of literature typically use a single equation approach, with domestic prices (or export or import prices) as the dependent variable, and the exchange rate as well as

[1]Refer to the contrast in the results between Obstfeld and Rogoff (1995), who develop an open economy New Keynesian model under the assumption of a perfect exchange rate pass-through, and Betts and Devereux (2000), who build a similar model but assume zero short-run pass-through.

other possible determinants of those prices on the right hand side. In the US, Marazzi, Sheets, Vigfusson, Faust, Gagnon, Marquez, Martin, Reeve and Rogers (2005) report that the pass-through rate to import prices (i.e., by what percentage import prices increase in reaction to a percentage depreciation in the nominal exchange rate) has come down from around 0.5 during the 1980s to about 0.2. In contrast, Hellerstein, Daly and Marsh (2006) argue that the reduction has been far more modest, coming down from around 0.56 to around 0.51.

Some authors have investigated the Japanese data. On the export side, Parsons and Sato (2008) who utilize a very detailed data set on Japanese export prices. Also on the export side, Yoshida (2010) utilizes Japanese export price data at the local port level: he finds that there is a fair amount of heterogeneity across the ports with respect to responses of export prices to the exchange rate, even when the goods are disaggregated down to the HS-9 level. On the import side, Otani, Shiratsuka, and Shirota (2003) analyze historical evolution of the pass-through rate to import price indices. Otani, Shiratsuka, and Shirota (2006) re-examine the issue by constructing an import price index which excludes influences of crude oil and all the other primary products.

Another important strand of literature employs the vector-autoregression (hereafter VAR) approach. This methodology enables us to take into account a possible bilateral dependence between those price variables and the exchange rate. Ito and Sato (2008) apply this approach to Asian countries. They include not just the final goods prices but a set of variables that would come “in the middle” to “relay” the effects of the exchange rate all the way down to domestic consumer prices. Specifically, import prices and producer prices are included, in addition to CPI. As expected, they find that, generally speaking, the effects of the exchange rate tend to be weakened as we go down the distribution chain, from import prices to producer prices, and then to consumer prices.

Shioji, Vu and Takeuchi (2007) examine the historical evolution of the pass-through rate to import prices in Japan. The entire sample period is divided between the pre- and the post-1990 periods. They find a sizable reduction in the pass-through rate between the two periods, on the import side (they find no clear difference on the export side).

Shioji and Uchino (2009, 2010) confirm robustness of this finding by, for example, controlling for the effects of oil prices. A problem with this VAR sub-sample analysis approach is that it is not possible to know at which point in time a structural change started and how fast it proceeded. To overcome this shortcoming, Shioji and Uchino (2011) employ the TVP-VAR approach[2], which allows the model structure to change over time (this methodology will be discussed in more detail later). Shioji (2012) also utilizes this approach and studies historical evolution of the pass-through rate, not only to export and import prices but also to domestic prices. The issue of pass-through to Japanese domestic prices has also been studied by Shioji and Uchino (2009) using a standard VAR approach, estimated on two sub-samples. In his most recent study, Shioji (2014) finds evidence of a "pass-through revival". That is, it appears that, in most recent years, the effect of the exchange rate on domestic prices have regained its strength. This paper will further investigate this point.

Inflation expectations and informational rigidities

In the standard Dynamic General Equilibrium model in which agents form rational expectations under full information, if the central bank commits to a higher inflation for the future, that would automatically raise people's inflation expectations. But such a view is at odds with recent evidence from micro data. Coibion and Gorodnichenk (2010, 2012) utilize survey data to test validity of the full information rational expectations model. Their tests favor models with informational rigidities, such as the sticky information model (Mankiw and Reis (2002)) and the model of rational inattention (Sims (2003)). Hori and Kawagoe (2013) and Ueno (2014) examine Japanese data from the *Monthly Consumer Confidence Survey* and also refute the full information rational expectations model. In view of such evidence, policies could be more effective in changing expectations when they can change what is in people's ("processed") information set[3].

[2]To the author's knowledge, a time-varying parameter estimation method has been applied to the issue of exchange rate pass-through first by Sekine (2006).

[3] When information is updated only infrequently, and if different types of information flow out of different sources at varying frequencies, it seems natural to expect that people would place larger

Evidence from a recent Opinion Survey (Bank of Japan)

In September 2013, the Bank of Japan conducted a supplementary survey of their regular *Opinion Survey* (this data set will be discussed in more detail in the next section). The respondents were asked to provide the basis of their answers about their own inflation expectation. The survey asked them to choose up to three reasons out of 11 choices (with ranking). As for the expected inflation for the next one year, the most frequently chosen answer was the movement of prices of frequently purchased items such as food (62.9%), followed closely by gasoline prices (62.4%)[4]. The Japanese government classifies gasoline as a frequently purchased item (more on this in the next section), so the overall role of those items seems to be quite dominant. The third most popular reasons were prices associated with expenditures that are made at regular frequencies (such as rents and public utilities, 36.4%), followed by the media (29.1%), and only 5.6% cited the Bank of Japan's monetary policy. This result confirms the conventional wisdom that people's inflation expectations are largely driven by prices of items that they purchase frequently, and thus gives justification to this paper's focus on such prices. Before we move on to the empirical part, however, the next section overviews the relationship between those prices and the Japanese households' inflation expectations (as they appear in survey data).

III. Data on Expected Inflation and CPI by purchase frequencies

This section overviews the relationship between the Japanese data on expected inflation, which is the focus of the current policy discussions, and the CPI by purchase frequencies, which will be the primary subject of empirical investigation of this paper. It is known that inflation expectation of the Japanese households, as it appears in the

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weights to information flows that are updated more frequently (and, thus, more fresh) when forming their forecasts. In the next version, I intend to demonstrate this point with a simple model.

[4] Gasoline prices were chosen as the number 1 reason by as much as 38.4%. Prices of food etc. were the top answer for 22.9% of the respondents.

survey data, is significantly biased upwards and is also far more volatile than the reported CPI inflation. In Figure 1, the average of inflation expectation by the respondents to the *Opinion Survey* (Bank of Japan) is plotted, together with their perception of the current inflation rate. The data is for the years 2004-2013. The measured CPI inflation in Japan has been fluctuating around 0% during this period, never exceeding 3% even at the peak of the natural resources inflation in 2008. But the average of expected inflation of the survey respondents always remained positive, easily exceeding 2% for much of the period and was around 9% in 2008. The figure also shows that expected inflation has been closely associated with the households' perceived inflation.

It is sometimes argued that households' perception about the current state of inflation as well as formation of their expectation is influenced by prices of items that they purchase more frequently, and thus observe more regularly. Nissay Institute (2013) points out similarity between the perceived / expected inflation and inflation rate of items that households purchase frequently. Their claim is based on the data on *CPI based on annual purchase frequency classes* (Statistics Bureau). In Figure 1, I present two inflation series computed from this statistics. "Frequent" refers to items purchased over 9 times a year on the average. "Infrequent" is less than 9 times a year. Evidently, inflation rate for frequently purchased items is much closer to the inflation perception and expectation, both in terms of their levels and volatility.

There are reasons to suspect that inflation rate of frequently purchased items is more heavily influenced by the exchange rate and prices of imported inputs. Those items include processed food, gasoline, electricity, fresh food, medical payment, train tickets, telephone fees, and newspapers. Among them, we can expect the first three to be sensitive to external shocks. On the other hand, much of less frequently purchased items are consumer durables, clothes, personal services, and rents.

Figure 2 plots CPI of frequently purchased items and the Import Price Index simultaneously. Both are in the log 12 months differences. We can see that they are highly correlated in recent years, especially since around 2007. Interestingly, between the late 1980s and the most recent period, the correlation is less than remarkable. That

is, we see a sign that pass-through to prices of this type of items has come back lately.

IV. Evidence from the aggregate CPI

This section revisits Shioji (2014)'s finding that pass-through has made a significant come-back in recent years, using the aggregate CPI data. In the next section, we will see what happens when disaggregated data is used instead.

Data and model specifications

Throughout the paper, in the regular VAR analysis, the same model will be estimated for the following three different (but overlapping) samples:

Sample period 1: February 1970 - December 1989

Sample period 2: January 1990 - December 2005

Sample period 3: January 2000 – June 2013.

By comparing periods 1 and 2, we would be able to confirm the much-discussed tendency of a decline in pass-through. By contrasting 2 and 3 (although the two samples have substantial overlaps), we should be able to examine if there was a reversal of such trend.

Following the idea of Ito and Sato (2008), my VAR model will incorporate various "intermediate" variables which are expected to "relay" the effects of changes in the exchange rate and prices of imported inputs to the consumer prices. Concretely, I estimate VARs with the following six variables:

PIM_OIL_CON: Import Price Index, Contract Currency Basis, Group: Petroleum, Coal and Natural Gas, Bank of Japan[5]

[5] The Import Price Index data is published both on the yen-basis and on the contract currency basis. The former data is available since 1970 but the latter becomes available only since 1975. I extend the series back to 1971 using the yen-based series, assuming that all the contract currency applicable to this group was US dollars during this period, and using the JPY-USD exchange rate series available from FRED. As the FRED series was not available for the year 1970, I extended my estimated series back to 1970 assuming that, during this year, the exchange rate was always 1 USD = 360 JPY. Note that, as the maximum lag length used in the analysis is 12, the data in 1970 does not enter on the left hand side of the VARs.

EX_ER2: Nominal Effective Exchange Rate, Bank of Japan (I take its inverse so that its increase signifies a depreciation of the yen)

PIM: Import Price Index, Yen Basis, All Commodities, Bank of Japan

CGPI_INT: Corporate Goods Price Index by Stage of Demand and Use, Intermediate Materials, Bank of Japan

CGPI_CONS: Corporate Goods Price Index by Stage of Demand and Use, Final Goods / Consumer Goods, Bank of Japan

CPI: Consumer Price Index, All Items, Statistics Bureau of Japan

Throughout the paper, all the series are monthly. I take the logarithms of all the variables and then take first differences, for all the variables that appear in the VARs in this paper. The lag structure is set as

(1, 2, 3, 6, 12),

throughout the paper (except in section VI, where I estimate a TVP-VAR). I include long lags to capture possible delays in the transmission of external shocks to the domestic economy. Throughout the paper (except again in section VI), I include two dummies for consumption tax (one for its introduction in April 1989 and the other for the tax hike in April 1997) whenever applicable, as well as the constant term. As the CPI series is not seasonally adjusted, I first tried including the seasonal dummies. However, the results were hardly changed. For this reason, in the estimation presented here, I exclude those dummies to save the degrees of freedom. Structural identification is achieved by assuming a short-run recursive structure (i.e., via the Cholesky decomposition), assuming that the causal relationship runs in the order of appearance in the above list (i.e., PIM_OIL_CON is supposed to be the “most exogenous”).

The first variable, PIM_OIL_CON is included to capture an external shock to the Japanese prices. PIM, CGPI_INT and CGPI_CONS are meant to capture transmission channels of two types of external shocks, namely an oil price shock (defined as a shock to PIM_OIL_CON) and an exchange rate shock (a shock to EX_ER2), to CPI.

Results

The estimated impulse responses are relegated to an appendix which is available upon

request, as the number of figures is enormous. To summarize the vast results quickly, I find some evidence that the rate of pass-through of an oil price shock to CPI has come up between periods 2 and 3. The effects of an exchange rate shock on PIM, CGPI_INT, CGPI_CONS and CPI, which had diminished considerably between periods 1 and 2, have regained their magnitudes between 2 and 3.

V. Pass-through to "visible" prices

Pass-through to prices of frequently purchased items

In this sub-section, I estimate a VAR model which basically replaces the aggregate CPI in the previous estimation with CPI of frequently purchased items. More concretely, the following six variables are included:

PIM_OIL_CON: same as in section IV

EX_ER2: same as in section IV

PIM: same as in section IV

CGPI_INT: same as in section IV

CGPI_NON: Corporate Goods Price Index by Stage of Demand and Use, Final Goods / Consumer Goods / Non-durable Goods, Bank of Japan

CPI_OVER9: CPI based on annual purchase frequency classes, Frequently Purchased Items (over 9 times a year on average), Statistics Bureau of Japan

The first sample period starts from February 1976, as the data on CPI_OVER 9 was available from 1975. Other than that, all the specifications are the same as in the first model.

Figure 3 presents responses of CPI_OVER9 to both an oil price shock and an exchange rate shock for the three sample periods. Responses in period 1 are large but unfortunately not significant. There are clear differences between period 2 responses and the results for period 3. For both types of shocks, the responses turn from insignificant to significant. Comparing the period 3 responses with those of the aggregate CPI in the same period (shown in the appendix which is available upon request), it can be seen that those for CPI_OVER9 are much larger in size. This

confirms the prior expectation that prices of frequently purchased items are more sensitive to external shocks (at least in recent years).

As CPI_OVER9 contains many items that are believed to be unresponsive to external shocks, I will now go into studying determinants of prices of items that seem most closely related to such shocks. They are: gasoline, electricity, and processed food.

Determinants of gasoline prices

Gasoline is one of the most frequently purchased items in the CPI statistics (over 15 times a year on the average) and is obviously closely related to imported inputs. It also has a special feature that, due to a characteristic of the Japanese gasoline tax system, at a higher level of gasoline cost, the pass-through rate of imported oil to consumer prices automatically becomes higher (Shioji and Uchino 2011). Here I estimate VARs with the following set of variables:

EX_ER2: same as in section III

PIM_OIL: same as PIM_OIL_CON that appeared in section III but on Yen Basis

CGPI_GAS: CGPI, Gasoline, Bank of Japan

CPI_GAS: CPI, Gasoline, Statistics Bureau of Japan

The first sample period starts from February 1971 as in the first model we saw in section III. Dummy variables for changes in the gasoline tax rate are included wherever applicable.

Figure 4A compares impulse responses of the last three variables to an exchange rate shock. It is evident that pass-through is very strong in period 1 but then goes down considerably in period 2 (responses of both CGPI_GAS and CPI_GAS turn insignificant). In period 3, pass-through is revived.

Figure 4B contrasts responses of the same three variables to a PIM_OIL shock across the three periods. The responses are always significant (at least at some time horizons) and the pattern of changes over time is less clear. We could still argue that domestic prices become more responsive, at least in the short run, in period 3 (especially if we normalize those responses by that of PIM_OIL itself).

Determinants of electricity prices

Prices of electricity sold to consumers are still heavily regulated even today. But due to progresses in deregulation (however slow it has been), we might find increasing sensitivity to external factors in recent periods. Here, I use the following three variables:

EX_ER2: same as in section III

PIM_ELEC: Import Prices of Inputs to Fossil-Fuel Power Generation: this is a weighted average of Import Prices of Crude Oil, Steam Coal and Natural Gas[6,7,8], all from Import Price Index, Bank of Japan

CPI_ELEC: CPI, Electricity, Statistics Bureau of Japan

Figure 5A depicts responses of PIM_ELEC and CPI_ELEC to an exchange rate shock. The responses of PIM_ELEC are always significant, though its size is diminished considerably between period 1 and 2. As for CPI_ELEC, the response turns from persistently significant to insignificant in period 2, and, in period 3, it becomes significant at some medium-term time horizons. Figure 5B reports their responses to a PIM_ELEC shock. Again, the response turns large (but insignificant) in period 1 to near-zero in period 2, and then, in period 3, it becomes at least partly significant (though small in size).

Determinants of processed food

[6] Weights between the three are based primarily on annual data on the sources of generated power (*White Paper on Energy*, Agency for Natural Resources and Energy). The data is kilowatt-based (not based on values). Some fractions of steam coal used in Japan are domestically produced: this was especially the case in the earlier part of the sample. I estimated the share of steam coal domestically produced using a ton-based data and subtracted it from its total use for power generation. This data was available only up to 2006; I assumed that, afterwards, the share (which was quite small by then) remained the same.

[7] Import Price data for Natural Gas and Steam Coal are available only since 1980. I assumed that, between 1970 and 1979, their prices moved in parallel with Crude Oil. As usage of Steam Coal for power generation was not common back then, this is unlikely to cause problems for coal. Natural gas could be more problematic, especially during the last few years of the 1970s.

[8] The data for the sources of power generation was available only up to 2011 at the time of this writing. For years 2012 and 2013, I assumed the shares stayed the same as in 2011. This could be a problem as we can expect the relative importance of various sources of power has shifted substantially during the post nuclear accident period.

Finally I turn to processed food. It should be noted that not all the processed food is classified as frequently purchased items. For example, ten-don, gyu-don, pizzas and donuts (all consumed at home) are purchased about once a year on average, according to the 2010-based CPI. On the other hand, items such as an-pan, shoku-pan and curry-pan are classified as most frequently purchased. Due to lack of appropriate data, I use data for all the processed food items. I use the following set of variables:

EX_ER2: same as in section III

PIM_FOOD: Import Price Index, Yen Basis, Group: Foodstuffs and Feedstuffs, Bank of Japan

CGPI_FOOD: CGPI, Group: Food, beverages, tobacco and food stuffs, Bank of Japan

CPI_FOOD2: CPI, weighted average of Food Products and Tobacco (the relative weights are taken from the 2010-based CPI[9], Statistics Bureau of Japan

Figure 6A report responses of the last three variables to an exchange rate shock. Unfortunately, most of the responses are insignificant, with the exception of CGPI_FOOD in period 1. But in Figure 6B, in which their responses to an imported food price shock (a shock to PIM_FOOD) are shown, we see clear evidence that pass-through was very strong in period 1, then turns insignificant in period 2, and finally comes back up in period 3. Hence, recent increases in prices of imported food (most notably wheat) could have an impact on the rate of price increases of items that people regularly observe, such as bread.

VI. Evidence from a TVP-VAR

In this section, I present estimation results from a time-varying parameter VAR (TVP-VAR) model, to confirm the tendency toward a “pass-through revival” which was found in section IV. This approach is also useful in knowing the timing of the changes in the rate of pass-through, including if the change occurred gradually over

[9] This is likely to result in under-estimation of influences of tobacco in earlier years.

time or if it was an abrupt one.

Methodology

The methodology employed here is a version of TVP-VAR utilized by Primiceri (2005) and Nakajima (2011), among others. In contrast to the more traditional TVP-VAR used by Shioji (2012) (among many others), this method allows the variance covariance matrix of the error terms to be time varying. Here I briefly explain the basic idea behind this "TVP-VAR with Stochastic Volatility (SV)" employed in this paper.

As an example, consider the following VAR model, with just two variables and one lag. Denote those variables as x_t and y_t, where t stands for a period. The reduced form model is:

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} b_{11t} & b_{12t} \\ b_{21t} & b_{22t} \end{pmatrix} \cdot \begin{pmatrix} x_{t-1} \\ y_{t-1} \end{pmatrix} + \begin{pmatrix} b_{1t} \\ b_{2t} \end{pmatrix} + \begin{pmatrix} u_{xt} \\ u_{yt} \end{pmatrix}. \quad (1)$$

Note that, unlike in the traditional VAR model, all the coefficients have the time subscript t. Thus the coefficients in the model, namely b_{ijt} (i=1 or 2, j=1 or 2), b_{it} (i=1 or 2) are potentially time-varying parameters. Both the traditional TVP-VAR as well as this paper's TVP-VAR with SV share this feature. The latter departs from the former in that it assumes that the variance covariance matrix of the error terms, u_{xt} and u_{yt}, is potentially time varying:

$$\Sigma_t \equiv Var_t \begin{pmatrix} u_{xt} \\ u_{yt} \end{pmatrix} = \begin{pmatrix} \sigma_{uxt}^2 & \sigma_{uxyt} \\ \sigma_{uxyt} & \sigma_{uyt}^2 \end{pmatrix}. \quad (2)$$

Note that the above variance covariance matrix Σ_t is accompanied by the time subscript t. Also note that, as in the traditional, fixed coefficient VAR, the two error terms are allowed to be correlated with each other. It is often assumed that, behind this reduced form model, there is a structural model, in which the two error terms in the reduced form model are determined by two mutually orthogonal structural shocks in the structural model. Identification is achieved through assuming the following kind of short-run causal ordering:

$$\begin{pmatrix} 1 & 0 \\ a_{21t} & 1 \end{pmatrix} \begin{pmatrix} u_{xt} \\ u_{yt} \end{pmatrix} = \begin{pmatrix} \sigma_{xt} & 0 \\ 0 & \sigma_{yt} \end{pmatrix} \cdot \begin{pmatrix} e_{xt} \\ e_{yt} \end{pmatrix} \quad (3)$$

and $$Var\begin{pmatrix} e_{xt} \\ e_{yt} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}. \quad (4)$$

In the above structural model, stochastic variations in the economy are caused by two types of structural shocks, namely e_{xt} and e_{yt}. Note that the coefficients of the contemporaneous relationship, a_{21t} being the only one in the two variable case of equation (3), are allowed to change over time. Also, the standard errors of the structural shocks, namely σ_{xt} and σ_{yt}, are allowed to be time varying. Those two assumptions in turn imply that, in the analysis that follows, the contemporaneous impulse response of each variable to each type of structural shocks can vary over time, unlike with the traditional method.

Time variations in the parameters

In the estimation, following Primiceri (2005) and Nakajima (2012), I assume that all the coefficients, namely all the *b*'s and the *a*'s, as well as the logs of the shock variances (namely $h_{xt} \equiv \ln(\sigma_{xt}^2)$ and $h_{yt} \equiv \ln(\sigma_{yt}^2)$ in the above example) follow random walks:

$$\beta_{t+1} = \beta_t + u_{\beta t}, \quad a_{t+1} = a_t + u_{at}, \quad h_{t+1} = h_t + u_{ht} \quad (5)$$

where β_t is a vector that stacks all the lagged coefficients of the VAR (namely the *b*'s in the above example), a_t is a vector of contemporaneous coefficients (the *a*'s), h_t is a vector of the logs of the shock variances. Also, denote the vector of all the structural shocks (the *e*'s in the above example) by ε_t. Then I assume normality:

$$\begin{pmatrix} \varepsilon_t \\ u_{\beta t} \\ u_{at} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right). \quad (6)$$

The Σ's in turn are drawn from distributions specified by the researcher, and I shall come back to this issue later.

Data and model specification

Data is monthly and spans the period from January 1975 (the first month for which the

oil price data is available) to December 2012. I include the following four variables.

- Oil Prices (Import Price Index of Japan: Oil, Coal and Natural Gas, denominated in contracting currencies units, Bank of Japan)
- Exchange Rate (yen-dollar rate, nominal, monthly averages, Bank of Japan)
- Import Prices (Import Price Index of Japan, Overall, in JPY, Bank of Japan)
- Aggregate CPI (Consumer Price Index, Total, Base year = 2010, Laspeyres Index, Ministry of Internal Affairs and Communications)[10]

I take logarithms of all the series, multiply them by 100, and then take first differences. An important limitation with the TVP-VAR approach has to do with the curse of dimensionality. As the model becomes large, the researcher would quickly face a limitation of the PC's computing ability. For this reason, in this model, the number of variables is limited to 4, and the number of lags is just 3.

Priors

A crucial step for estimating the TVP-VAR is to specify hyperparameters for the priors, that is, distributions from which the Σ's in equation (6) are drawn. All the Σ's are assumed to be orthogonal matrices. For the *i*th orthogonal elements of Σ_β and Σ_h, I specify:

$\Sigma_{\beta,i}$ ~ Inverse Wishert (100, 10^{-4}),

and $\Sigma_{h,i}$ ~ Inverse Gamma (2, 10^{-10})

The estimation results turn out to be most sensitive to the specification of Σ_a, namely how much time variation is allowed for the *a*'s, the contemporaneous coefficients. I employ the following specification:

$\Sigma_{a,i}$ ~ Inverse Gamma, with median = 0.0025 and the 95th percentile = 0.01.

The corresponding distribution parameters are easily calculated.

Finally, on the implementation of the MCMC estimation, after discarding 500 burn-in samples, I sampled over 5,000 trails.

[10] I take out the effects of changes in the consumption tax rates, which happened twice during the sample period, and then seasonally adjust the data using the X-12 method.

Results

Figures 7A and 7B report impulse responses of Import Prices and CPI to an Oil Price shock, evaluated at four different points in time, namely January 1985, January 1995, January 2005 and December 2012. Although the estimations are carried out with differenced series, I report cumulative impulses in all the cases that follow: consequently, those lines in the figures can be interpreted as responses of the variables in their *levels*. The three lines in each panel are median impulse responses (red lines with circles) and the 14^{th} and the 86^{th} percentiles (black dashed lines).

Figure 7A indicates that Japanese import prices used to react very strongly to oil prices (in 1985) but the influence had diminished considerably, in 1995 and 2005. However, there has been a revival of this effect in recent years, and, in 2012, the magnitude of the response is almost as large as in 1985. In Figure 7B, we find a similar re-emergence of oil pass-through for the Japanese CPI, though the sizes of the impulse responses are naturally smaller than in Figure 7A.

Figure 7C and 7D report impulse responses of the same two variables to an Exchange Rate shock, evaluated at the same four points in time. In Figure 7C, we do not find much change in the response of import prices to the exchange rate. Figure 7D suggests that the influence of the exchange rate on CPI was never strong since 1985, and it even turns slightly negative in 2005, but there has been a notable surge of the exchange rate pass-through: the impulse response turns positive and significant in 2012.

Quantitative implications

I found that the exchange rate itself depreciates by about 3.631 logarithmic points in response to the Exchange Rate shock. On the other hand, as we have seen, CPI increases by about 0.165 logarithmic points. In October 2012, the yen-dollar rate stood at around 78. By April 19 of the following year, it was very close to 100. This is a depreciation of about 0.25 log points. My estimation indicates that this would contribute to an increase in the aggregated CPI of 0.0114 log points. Thus, the yen depreciation alone would not be powerful enough to bring Japan all the way to hit the

declared inflation target of two percent. But it would carry us almost half way there[11].

VII. Conclusions

When the economy is at the zero lower bound of the interest rate, changing the course of expected inflation is arguably more important than controlling the actual inflation. In this paper, I have argued that, assuming that expected inflation is driven, in part, by what consumers regularly observe, namely prices of items that they purchase frequently, the exchange rate could provide a more reliable mechanism through which the central bank could influence people's inflation expectation, at least in Japan. This fact is especially important in today's Japan, as there is ample evidence to suggest that pass-through of the exchange rate and imported input prices to domestic prices has regained its importance in recent years.

An important task for future research is to investigate the cause of the pass-through revival. Shioji and Uchino (2011) argue that changing structure of production costs in Japan can go a long way toward explaining this. Whether this is a reasonable hypothesis or not needs to be examined further in an extended sample. Another, more challenging, future research topic is to establish the connection between observed inflation and inflation expectation, both theoretically and empirically. Such a research would shed light not only on policy effects at the zero bound but also on the subject of expectation formation in general.

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[11] Note, however, that those are predicted effects on the *level* of CPI, while the target is defined with respect to the CPI *inflation*. According to the estimates, the depreciation would boost the CPI inflation rate by the above rate in the first year. However, from the second year onward, the boost would have to come from elsewhere.

(2013)

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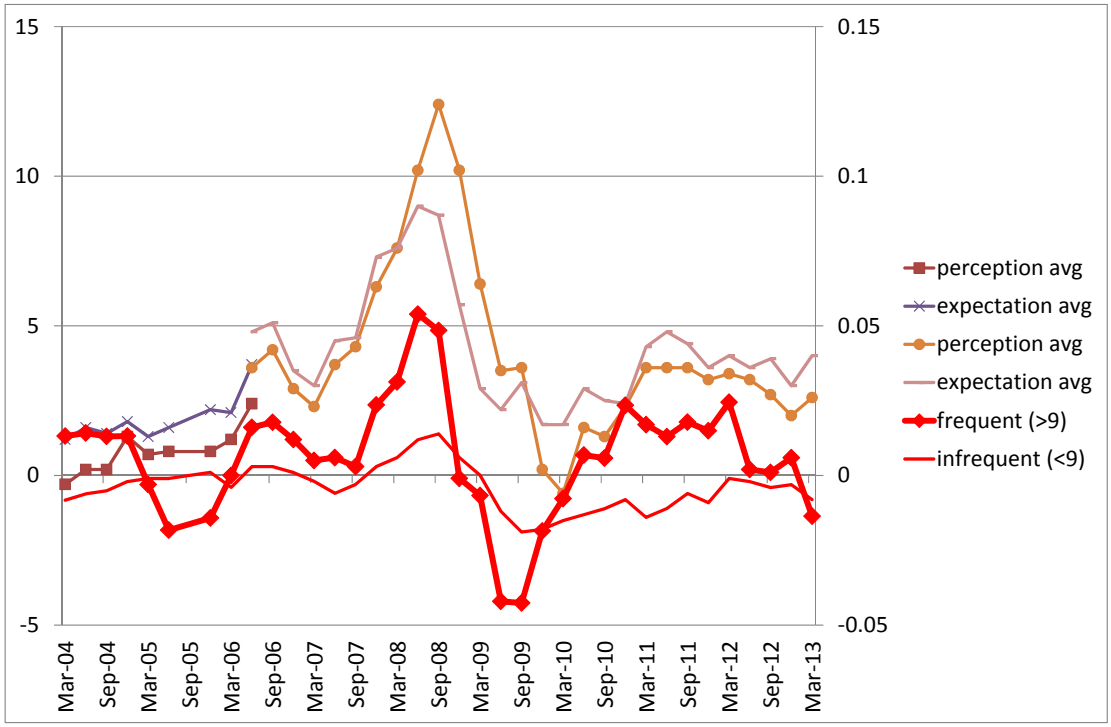
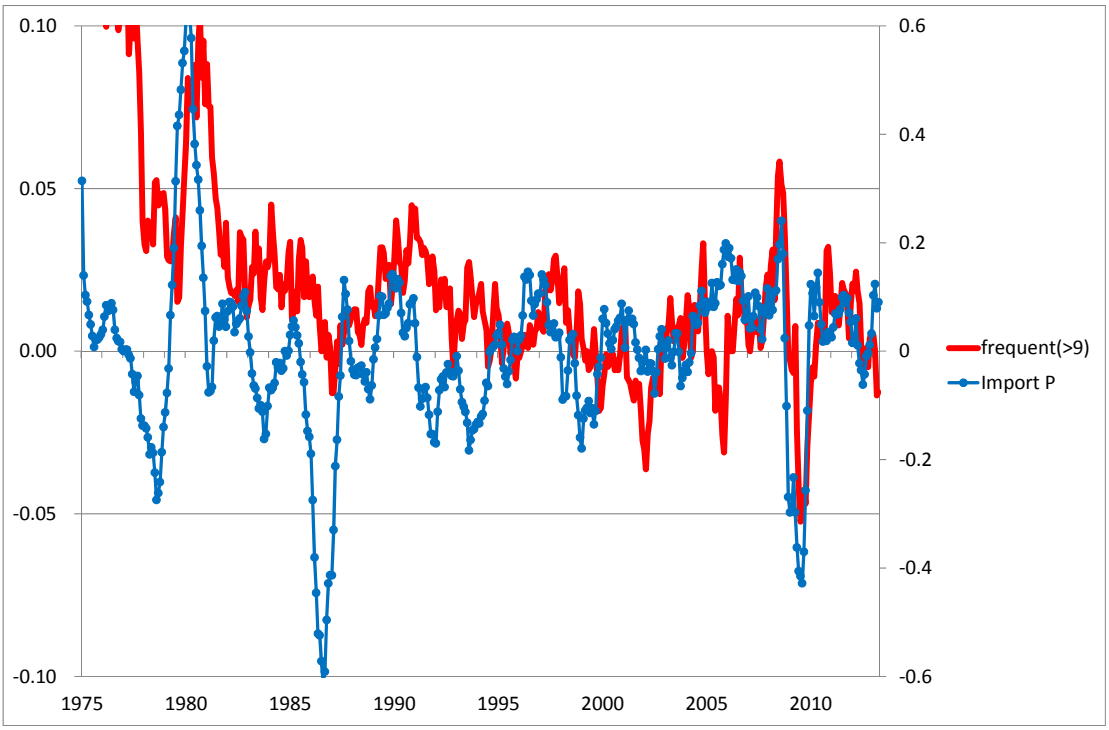
Figure 1: CPI by purchase frequencies, perceived inflation, and inflation expectations (rate of change from the year before)



Inflation perception and expectation data is taken from the Opinion Survey (Bank of Japan). Note the discontinuity of the series in 2006.

The red lines are for the CPI based on annual purchase frequency classes (Statistics Bureau). “Frequent” refers to items purchased over 9 times a year. “Infrequent” is less than 9 times a year.

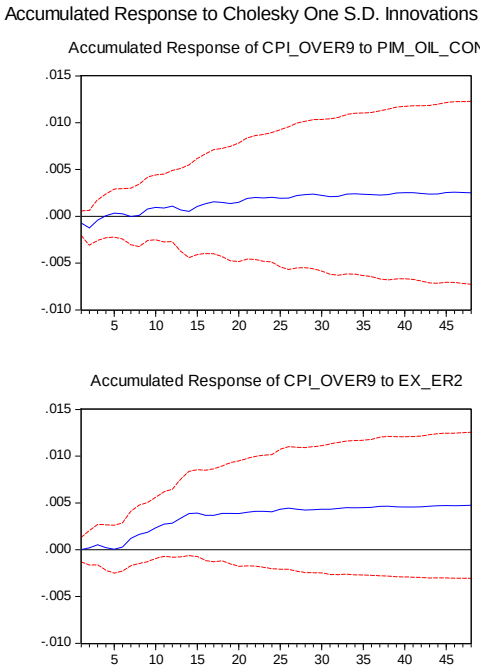
Figure 2: CPI of frequently purchased items and the Import Price Index
(log differences from the year before)



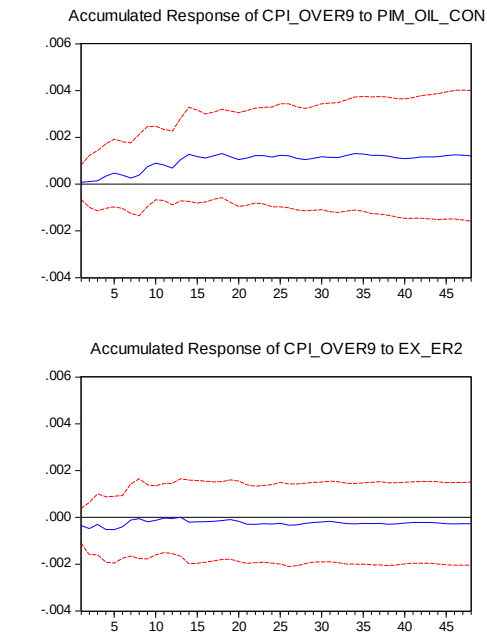
The red line is from the CPI based on annual purchase frequency classes (Statistics Bureau). “Frequent” refers to items purchased over 9 times a year.
The blue line is for the Import Price Index (all items, Bank of Japan).

Figure 3: Impulse responses of CPI_OVER9

Sample period 1: 02/1976-12/1989



Sample period 2: 01/1990-12/2005



Sample period 3: 01/2000-06/2013

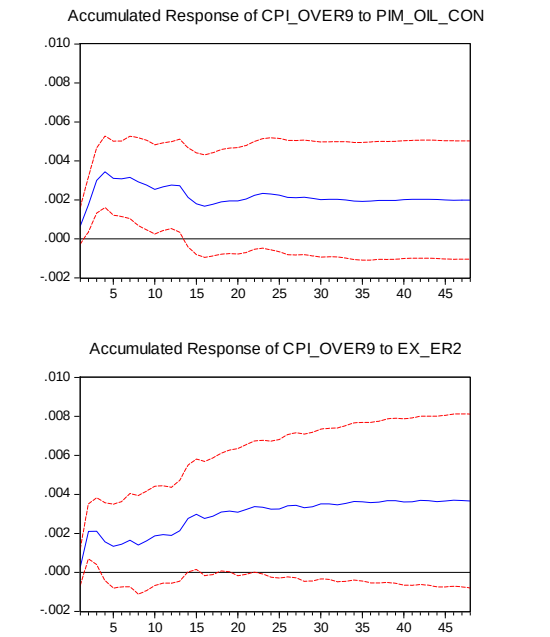


Figure 4A: Impulse responses of Gasoline Price to an Exchange Rate shock

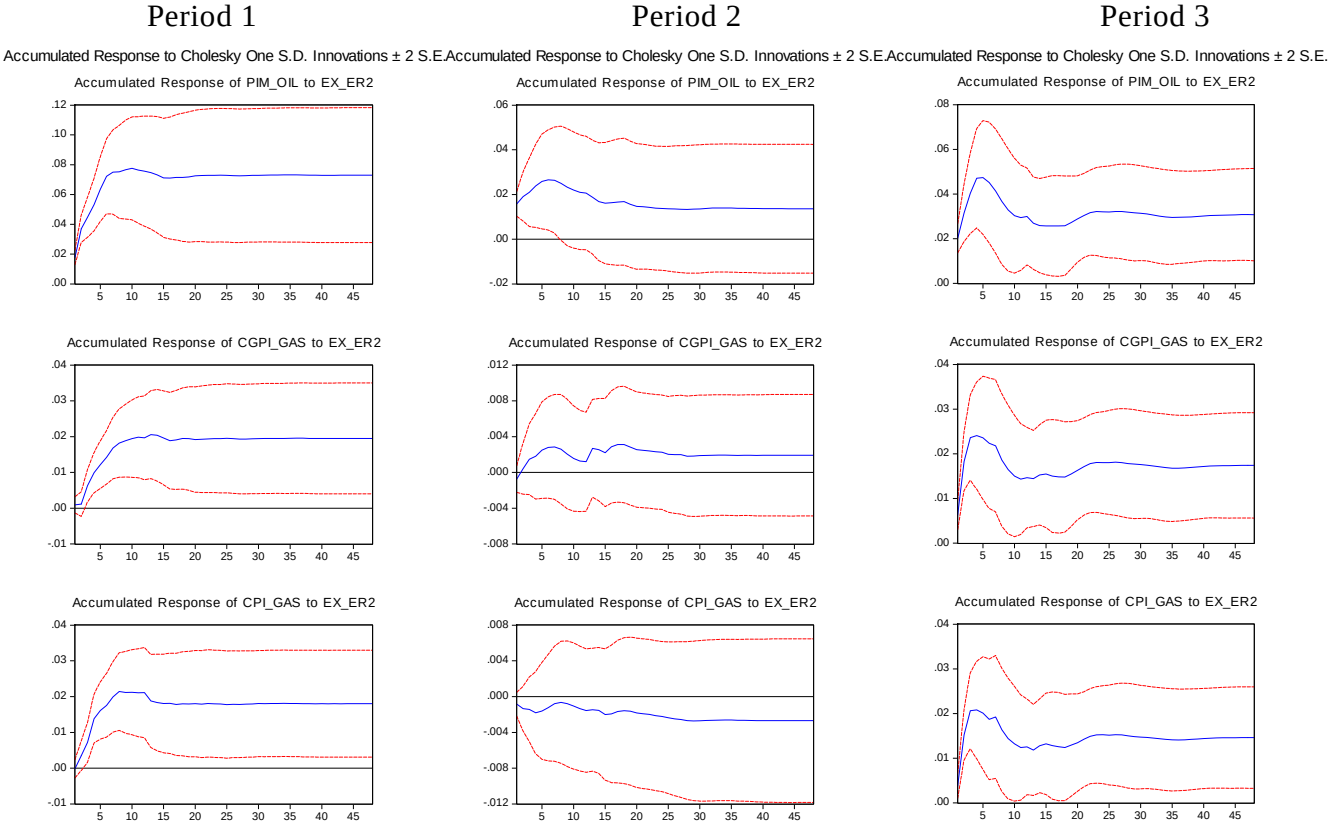


Figure 4B: Impulse responses of Gasoline Price to an Oil Price shock

Period 1 Period 2 Period 3

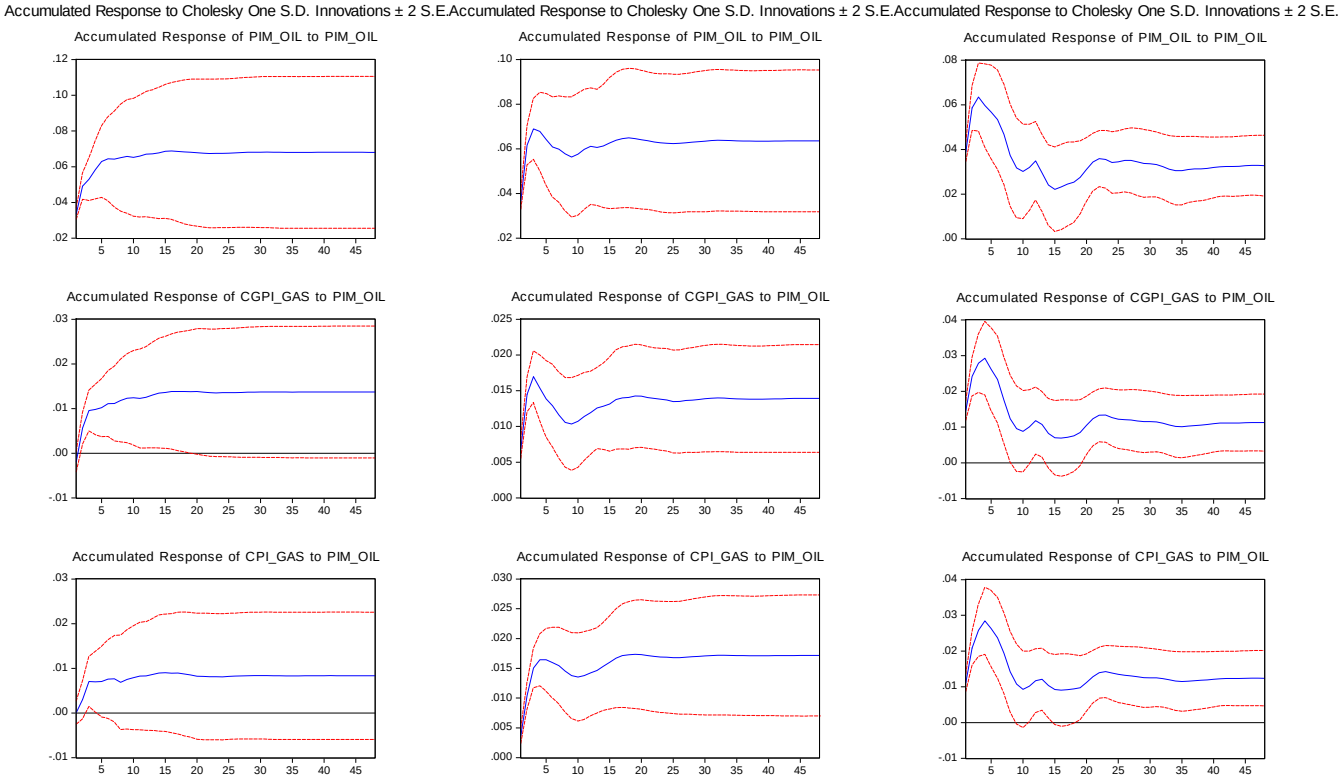


Figure 5A: Impulse responses of Electricity Price to an Exchange Rate shock

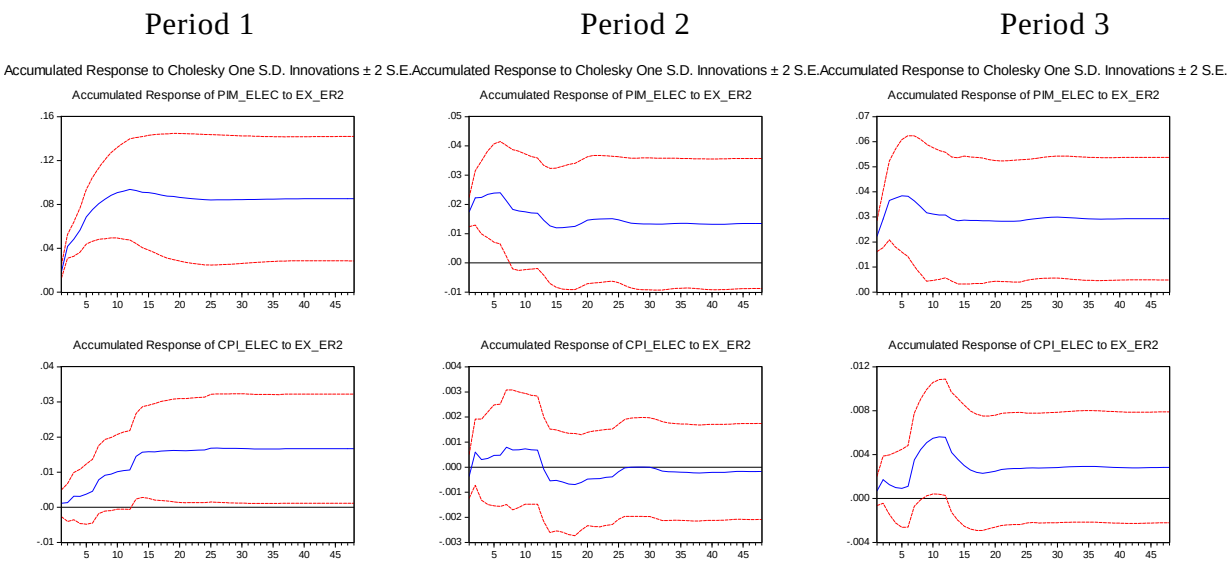


Figure 5B: Impulse responses of Electricity Price to an Imported Input Price shock

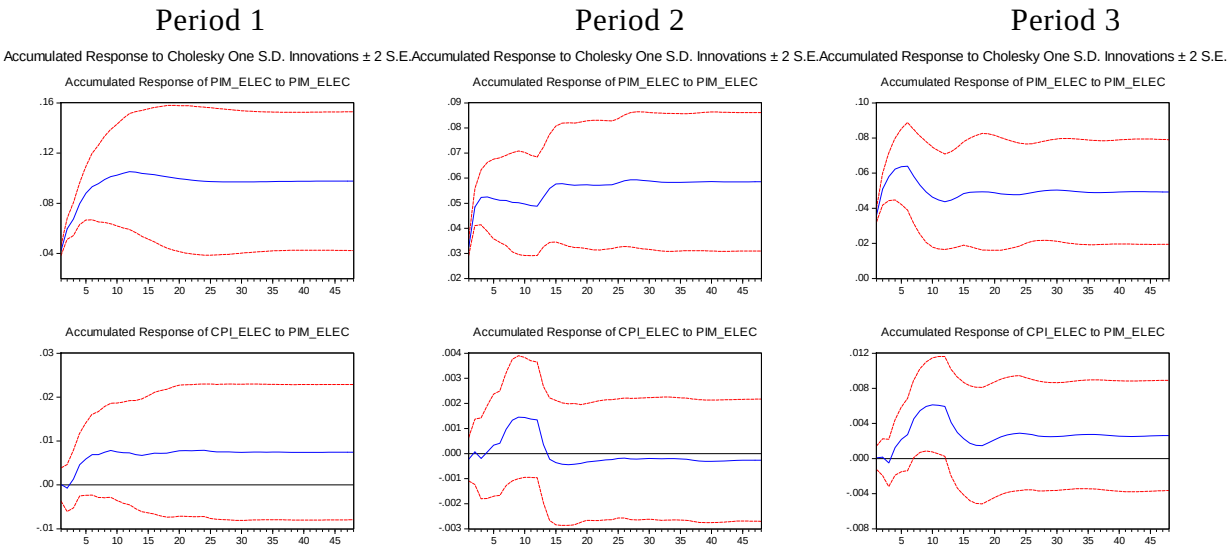
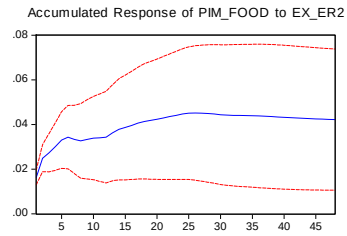
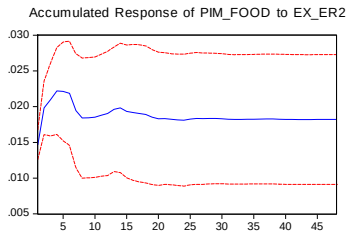


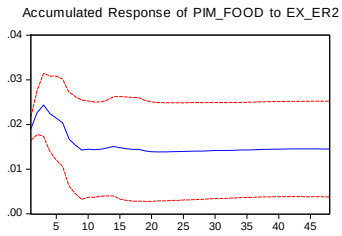
Figure 6A: Impulse responses of Food Price to an Exchange Rate shock

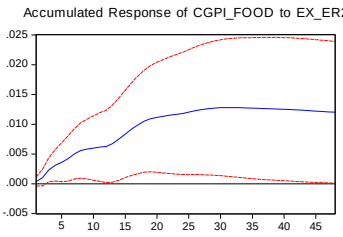
Period 1 | Period 2 | Period 3

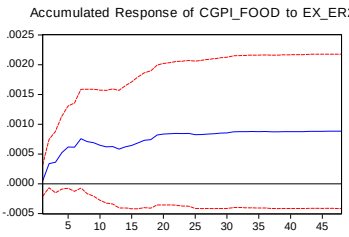
Accumulated Response to Cholesky One S.D. Innovations ± 2 S.E.

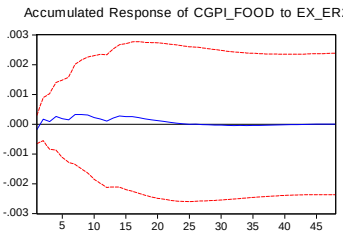


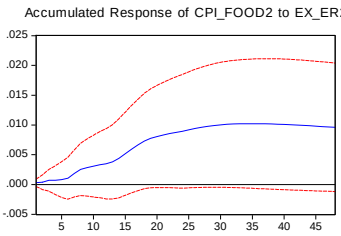


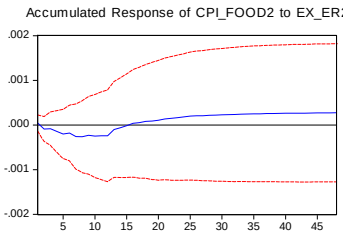












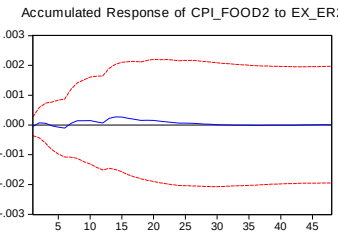


Figure 6B: Impulse responses of Food Price to an Imported Food Price shock

Period 1 Period 2 Period 3

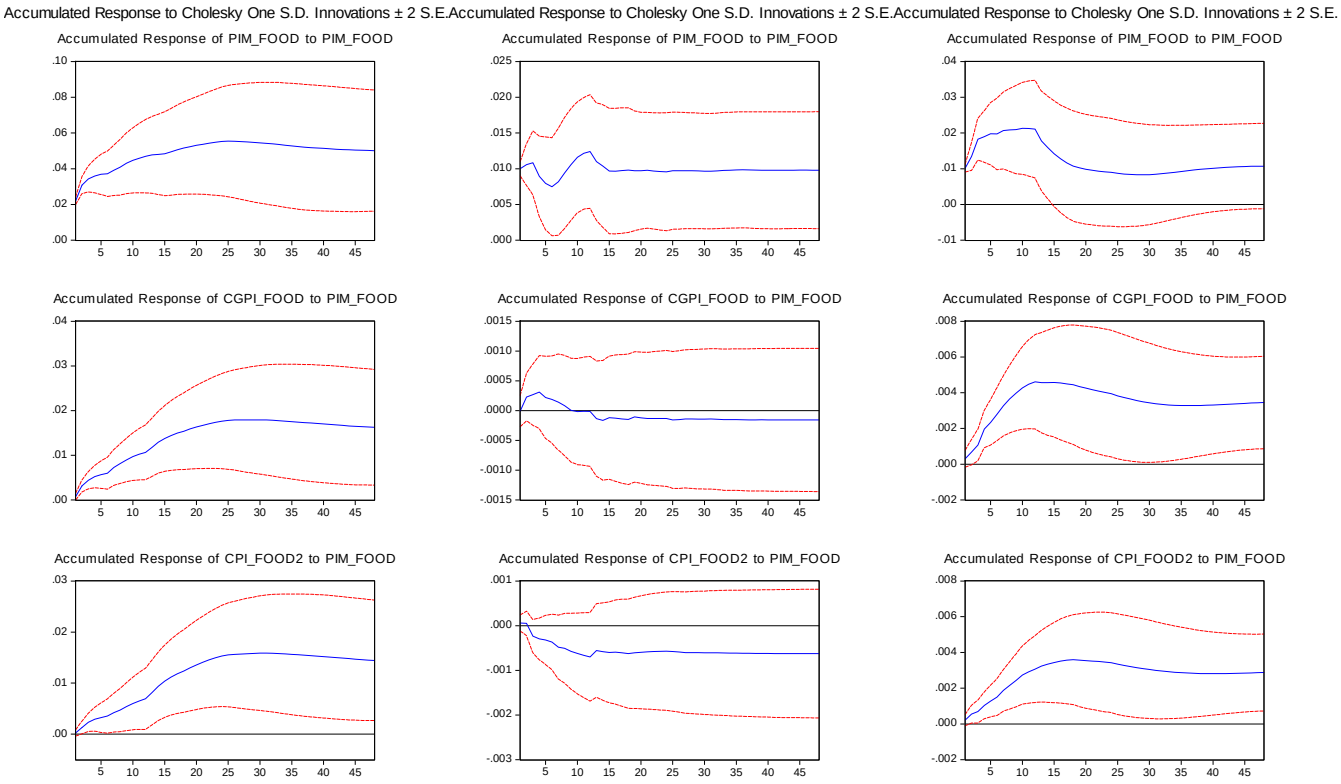


Figure 7A TVP-VAR: Impulse responses of Import Prices to an Oil Price shock

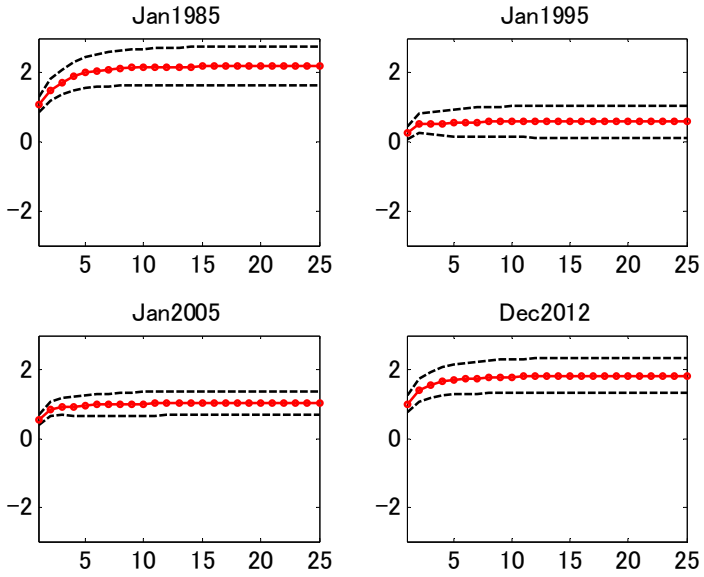


Figure 7B TVP-VAR: Impulse responses of CPI to an Oil Price shock

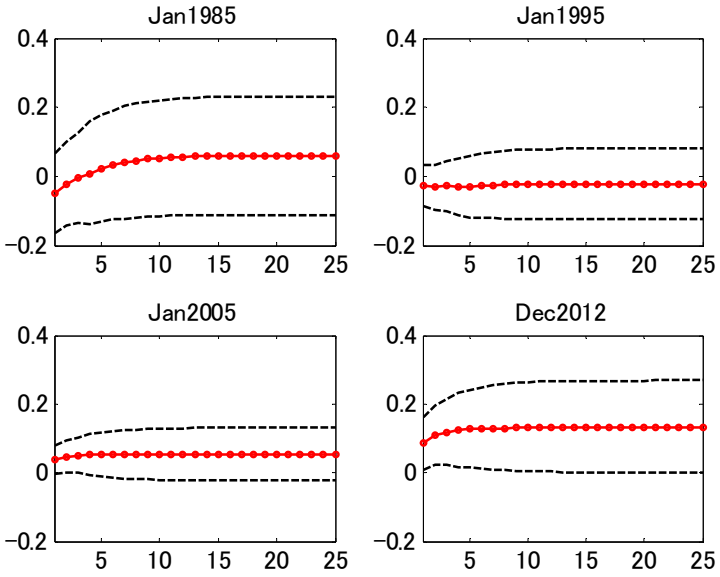


Figure 7C TVP-VAR: Impulse responses of Import Prices to an Exchange Rate shock

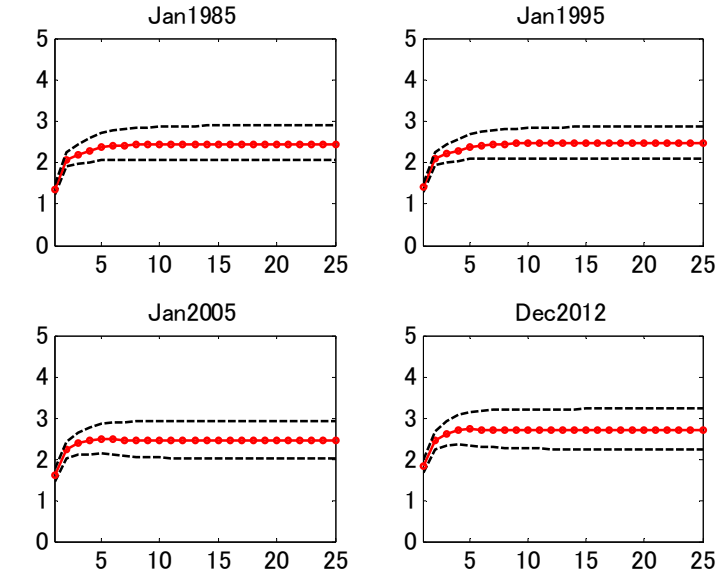


Figure 7D TVP-VAR: Impulse responses of CPI to an Exchange Rate shock