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A Pass-Through Revival

Etsuro Shioji

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UTokyo Price Project
702 Faculty of Economics, The University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel: +81-3-5841-5595
E-mail: watlab@e.u-tokyo.ac.jp
http://www.price.e.u-tokyo.ac.jp/english/

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A pass-through revival[*1]

Etsuro Shioji[*2]

Abstract

It has been argued that pass-through of the exchange rate and import prices to domestic prices has declined in recent years. This paper argues that it has come back strong, at least in Japan, in the most recent years. To make this point, I estimate a time-varying parameter-volatility VAR model for the Japanese exchange rates and prices. This method allows me to estimate responses of domestic prices to the exchange rate and import prices at different points in time. I find that the response was fairly strong in the early 1980s but, since then, had gone down considerably. Since the early 2000s, however, pass-through starts to show a sign of life again. This implies that the exchange rate may have regained the status of an important policy transmission mechanism to domestic prices. At the end of the paper, I look for a possible cause of this pass-through revival by studying the evolution of the Japanese Input-Output structure.

Key words: exchange rate, pass-through, time-varying parameter VAR with stochastic volatility, import prices, domestic prices

JEL classification：F41， E31

[*1] Much of the author’s knowledge reflected in this paper has been developed through a series of joint research with Taisuke Uchino (Daito Bunka University). I am also indebted to Jouchi Nakajima (Bank of Japan) for his enlightening comments about the statistical methodology and matlab coding. Needless to say, all the remaining errors are my own responsibility.
[*2]Department of Economics, Hitotsubashi University: shioji [at] econ.hit-u.ac.jp.

I. Introduction

This paper re-examines the effects of the exchange rate and import prices on Japanese domestic prices. In recent literature, it has been claimed that the extent of pass-through has declined substantially. My goal is to re-examine this claim by studying the most updated data from Japan, using an approach that allows for flexible forms of structural changes.

The empirical approach employed in this paper is the time-varying parameter VAR method (TVP-VAR for short). I have pursued this line of research elsewhere using the Japanese data (Shioji and Uchino (2011), Shioji (2012)). However, those past studies have employed the traditional TVP-VAR which allows only the reduced form VAR coefficients to vary over time, which is conceptually unappealing. In contrast, this paper employs a method which also allows the variance-covariance matrix of the error terms to fluctuate across time. This effectively means allowing contemporaneous (i.e., within a month) relationship between the variables to evolve over time. This method enables me to draw impulse responses evaluated at different points in time. By comparing the impulse responses of domestic prices to the exchange rate and the import price shocks, it is possible to examine if the extent of pass-through has truly declined, as many authors have claimed. I also update the sample period to April 2013.

I find that, in fact, there has been a notable "revival" of exchange rate pass-through in recent years in Japan. If policy makers, especially those who are concerned with domestic inflation, have shifted their attention away from the exchange rate and import prices, because of the reports of declining pass-through, they might wish to reconsider their positions.

The rest of the paper is organized as follows. Section 2 discusses the background of the current paper and the economic significance of the pass-through issue. Section 3 overviews the Japanese data on the exchange rate, import prices and domestic prices. Section 4 specifies the VAR model estimated in this paper. Section 5 reports the estimation results. Section 6 concludes.

II. Background

Theoretical importance of pass-through

The extent of exchange rate pass-through influences the way the domestic economy responds to fluctuations in the exchange rate. Suppose, for example, that the yen has just depreciated. On the import side, the effects on the Japanese economy will depend crucially on the degree at which this fall in the value of the yen will be reflected in prices of imported raw materials and imported intermediate goods, as well as those of domestic goods that are produced using those imported inputs (i.e., the rate of exchange rate pass-through). If this extent is small, there will be less inflationary pressure on the domestic economy. This means that Japanese households and firms will have to suffer less from higher prices of goods that they purchase (an exception is a Japanese firm that produces goods that are in direct competition with imported products; such a firm could gain if its rivals' prices went up more, not less). On the other hand, the volume of imports may not decrease as much as it would if the extent of pass-through were higher. On the export side, if exporting firms cannot pass through the impact of the weaker yen to prices of their exports, measured in the foreign currency unit (i.e., if the pass-through rate on the export side is low), their profit per unit of exported goods, measured in the Japanese yen, will increase. On the other hand, the extent of the increase in export volumes from Japan will be limited. This implies that we cannot expect much immediate increase in employment. That is, while a textbook argument assumes that a monetary expansion, through causing a currency depreciation, raises domestic prices and improves the trade account through promoting exports and discouraging imports, thus exerting a positive impact on output and employment, those effects will be weaker in a situation of limited exchange rate pass-through.

In open economy versions of the New Keynesian models, where nominal price rigidities play a central role, policy implications could change substantially depending on the degree of exchange rate pass-through. Obstfeld and Rogoff (1995), which pioneered this entire literature, develop a two country model under the assumption of a perfect exchange rate pass-through. They show that, in their model, a monetary easing of one country always improves welfare of the other country. That is, there is no *beggar thy neighbor* effect. On the other hand, Betts and Devereux (2000) develop a model in which exporting firms, in the short run, fix prices they charge in the destination market in the units of the buyers' currency. In other words, they assume zero exchange rate pass-through in the short run. They show that, in such a situation, a monetary expansion can be a *beggar thy neighbor* policy.[1]

Monetary policy at the zero bound and pass-through

Extent of pass-through could have a profound implication for recent debates on monetary policy in Japan and elsewhere. Japan was the first among major economies to fall into a zero interest rate "trap". Deflation has persisted despite that the Bank of Japan has kept the short term interest rate at near-zero. Once at the zero bound, it is not possible to lower the interest rate further to stimulate the economy to lift it out of the deflationary situation. Between 2001 and 2006, Japan experimented with the Quantitative Easing policy, under which the supply of monetary base was increased substantially, but it appears that much of the additional money stayed in the financial sector in the form of excess reserves. Currently, other major countries such as the US and the UK are experimenting with their own versions of Quantitative Easing, but the effects of the policies are largely unknown.

However, we are starting to see some evidence that this kind of policy may have influences on the exchange rate. For example, Hosono, Yoshikawa and Isobe (2013) study daily exchange rate data and find that unconventional monetary policies by both the US and Japan had statistically significant impacts on the value of their currencies

[1]Another reason why the issue of exchange rate pass-through has caught much attention in the literature of macroeconomic theory is that, depending on what one thinks is the main cause of the reduction in the pass-through rate over time reported by many observers, one might draw very different implications to macroeconomics. For example, Taylor (2000) argues that, in an environment of low inflation, firms become more hesitant to pass through changes in production costs to prices of goods that they supply. Gagnon and Ihrig (2004) advances this argument further, and point out a possibility that a regime shift in monetary policy, which resulted in a more anti-inflationary policy stance, might have resulted in the reduction in the pass-through rate.

(though they tend to be short lived). It is thus a possibility that the exchange rate could be used as one of the more reliable (relatively speaking!) policy transmission mechanisms at the zero bound. If this is confirmed, the next crucial question is if the effects of the policies could go beyond the exchange rate. If the rate of pass-through is low or insignificant, we have a reason to be skeptical. If, on the other hand, pass-through is back to life, as this paper will try to claim, the policies could have effects on the domestic economy through import prices[2].

Earlier this year, the Bank of Japan established a new inflation targeting scheme, and declared it would pursue the target CPI (all items, excluding fresh food) inflation of 2%; the much anticipated announcement came on January 22, 2013. As stated above, the unresolved question is how to achieve such a target at the zero bound. Since April, the Bank started to pursue an aggressive quantitative expansion: under the current plan, monetary base is to be increased to twice the amount of the level prior to the policy change (bank reserves are expected to increase sevenfold). In recent months, 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 mid May 2013. How much of this has to do with the policy change is unknown. In any case, if pass-through is strong enough, this massive depreciation will certainly help the Bank of Japan hit its newly established target. Thus, pass-through has become one of the most urgent research topics of today.

Empirical evidence on pass-through

On the side of the empirical analyses, Campa and Goldberg (2005), among others, have stimulated interests in the empirical analysis of exchange rate pass-through. Studies

[2]In fact, the surge of interest in the pass-through issue among US policy makers dates back to some time prior to the introduction of unconventional monetary policies. Even before the Lehman crisis, the Fed had started lowering its policy rate, since mid-2007. At that time, there was a concern that this might cause inflation within the US through a depreciation of the US dollars. This concern was in part based on the increase in the shares of both exports and imports in the US GDP. Frederic S. Mishkin, who was a Board Member of FRB at that time, countered this concern in his speech titled ”Exchange rate pass-through and monetary policy”, given on March 7 in 2008. He points out that the reduced pass-through rate would weaken the influence of exchange rate fluctuations on domestic prices.

that belong to this strand of literature typically take domestic prices (or export prices or import prices) as the dependent variable, and employ the exchange rate as well as other possible determinants of those prices, and estimate single equation models. 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. An example of a study which uses the Japanese data is Parsons and Sato (2008) who utilize a very detailed data set on Japanese export prices. Yoshida (2010) is a unique study which utilizes Japanese export price data at the local port level: he finds that there is a fair amount of heterogeneity across the ports in responses of export prices to the exchange rate, even when the goods are disaggregated down to the HS-9 level. Also, Otani, Shiratsuka, and Shirota (2003) analyze historical evolution of the pass-through rate to import price indices. In addition, Otani, Shiratsuka, and Shirota (2006) construct an import price index which excludes influences of crude oil and all the other primary products, and reexamine the reduction in the pass-through rate.

Another important empirical approach is estimation of vector-autoregressive models (hereafter VARs), which takes into account a possible bilateral dependence between those price variables and the exchange rate. The current paper also belongs to this second strand of the empirical literature. Within this literature, Ito and Sato (2008) apply the VAR methodology to Asian countries. Their study is an important predecessor to the current analysis, especially because they include in their VARs not just a single price indicator but a set of variables that would serve as transmission channels between the exchange rate and domestic prices (i.e., they put variables that come “in the middle” to “relay” the effects all the way down to domestic consumer prices). This approach will be followed in this paper. Specifically, in their VARs, three price variables, import prices, producer prices, and CPI are included. 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. When we split the entire sample period into half, the post-1990 period has seen a sizable reduction in the pass-through rate, compared to the pre-1990 period. On the other hand, there is no clear difference between the two sub-periods on the export side. Shioji and Uchino (2009, 2010) re-examine robustness of the earlier results by, for example, controlling for the effects of oil prices, but the results remain qualitatively the same. 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, Uchino and Shioji (2011) and Shioji (2012) employ the TVP-VAR approach[3], which allows the (reduced-form) VAR coefficients to change over time (refer to, for example, Kim and Nelson (1999) for details of this methodology). This enables us, for example, to analyze graphically how the pass-through rate from the exchange rate to import prices has evolved over time. The analysis is expected to reveal to us at which point in time the pass-through rate started to decline, and if this shift occurred abruptly within a short period of time or the change was gradual. Shioji (2012) 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.

III. Japanese price data

CPI vs CGPI

In this section, I give a brief overview of the Japanese price data and its comovement with the exchange rate and import prices. Among monthly time series, which I will

[3] 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).

utilize in this paper, the two representative sources for domestic price series are the *Consumer Price Index* (CPI) published by the Statistics Bureau and the *Corporate Goods Price Index* (CGPI, formerly known as the Wholesale Price Index or WPI) published by the Bank of Japan (hereafter BOJ). The latter measures transaction prices between firms and contains only goods and not services (there is a separate index called Corporate Services Price Index or CSPI, which is available since 1985). As stated earlier, the official target of BOJ is CPI (all items, less fresh food) inflation. In that sense, CPI is the more important one for the purpose of policy analysis. In this paper, however, I will focus on the other series, CGPI. (In a companion paper, Shioji (2013), I focus on CPI, not only at the aggregate level but also at more disaggregated levels.) A disadvantage of using CPI is that it is not very sensitive to external factors such as the exchange rate and import prices, and thus it is more difficult to detect significant changes in its responsiveness to those factors. This is primarily because of a large presence of services, such as housing rents and imputed rents, in the CPI statistics: services are given about 50% of the overall weights. Also, the presence of distribution margins tends to mask variations in prices of goods per se.

In contrast, CGPI is far more responsive to the external factors, as we shall see shortly. Its main problem, on the other hand, is multiple counting of the same material: for example, the same wood can first appear as a raw material, then as a part of an intermediate good, and finally as a smaller part of a final product. This structure tends to exaggerate sensitivity of domestic prices to imported raw materials.

Fortunately, BOJ publishes CGPI at different stages of production, namely raw materials, intermediate goods and final goods. The final goods are further divided between consumer goods and investment goods (the former is further divided into consumer durables and non-durables). In this paper, I will utilize the consumer goods CGPI, as this is (at least conceptually) closest to CPI, the official monetary policy target. In the following analysis, the intermediate goods CGPI will also play an important role as an intermediate transmission channel from the exchange rate and import prices to the final goods price.

Figure 1-1 contrasts historical evolution of CPI (all items, less fresh food, denoted simply “CPI” in the figure) with those of CGPI (total, denoted “CGPI”) as well as the consumption goods CGPI (“CGPI-CONS”). For the ease of comparison, I take logs and then take differences from 12 months ago for both series, though the statistical analysis in later sections uses first differenced series. Evidently, CGPI exhibits a higher degree of variability, especially at historically important moments when the Japanese economy was hit by large external shocks, such as the first and the second oil crises, the “reverse” oil shock in the mid 1980s, the energy price surge in the mid 2000s, and the Lehman crisis. CGPI-CONS, on the other hand, is somewhere between CPI and CGPI; it is highly correlated with the latter but the variability is smaller.

Exchange rate, import prices, and domestic prices

As an indicator of the exchange rate, in this paper, I shall use the Japanese yen - US dollars spot rate, which is the most popularized among various exchange rate measures. As prices of much of the Japanese imports are quoted in the US dollars, this seems to be a reasonable choice.

In the statistical analysis in later sections, I also include the Index of Import Prices, from BOJ. BOJ publishes two types of series, one denominated in contracted currency units and the other denominated in the Japanese yen. I use the latter. This variable serves two purposes. First, controlling for the effects of the exchange rate, this variable is expected to reflect variations in prices of imported goods, most notably imported inputs such as energy (oil, coal, gas, etc.) and raw materials (metal, wheat etc.), expressed in the units of the US dollars. Second, as fluctuations in the exchange rate are expected to influence prices of domestic products primarily through changes in prices of imported inputs, by incorporating the latter, it is expected to help us better capture the transmission of the exchange rate fluctuations to domestic prices.

As already mentioned, the intermediate goods CGPI will also be included in the analysis, in order to better capture the transmission of shocks to the exchange rate and import prices to final consumption goods prices.

Figure 1-2 plots the intermediate goods CGPI (denoted “CGPI-INT”), import prices (“PIM”) and the exchange rate (“EXR”). Again, I take logs of all three and take differences from the same month of the previous year. From the figure, one can observe a historically high correlation between EXR and PIM: at least partially because prices of much of the imports into Japan are quoted in the US dollars, exchange rate fluctuations are reflected in imported prices in the Japanese yen units relatively quickly. We can also see that CGPI-INT is highly correlated with PIM, which means that intermediate goods prices have played the role of a transmission mechanism from external factors to domestic prices. The variations in CGPI-INT are smaller than those of PIM, though. By comparing Figure 1-1 with 1-2, it is possible to see that CGPI-CONS has been strongly correlated with CGPI-INT, though the variability of the former is even smaller.

Changing correlations

Figures 1-1 and 1-2 also suggest that the comovements between external factors and domestic prices were more prominent in the first half of the sample. To check this impression, in Table 1, I compute correlations between those series that have appeared in Figures 1-1 and 1-2, (i) for the entire sample (January 1971 - April 2013, except for the correlations involving EXR, which starts in January 1974), (ii) the first half (the period ending December 1989) and (iii) the second half (the period starting January 1990). By comparing (ii) and (iii), it is evident that the correlations of domestic prices, namely CPI, CGPI, CGPI-CONS and CGPI-INT with external factors, namely PIM and EXR, have weakened in the second half of the sample, in some cases substantially. This diminished comovement underlies the declining pass-through from the exchange rate and import prices to domestic prices which have been reported by many previous authors (and will be reconfirmed by my analysis below).

IV. Empirical specification

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 SV (or Stochastic Volatility)" method employed in this paper.

As an example, consider the following VAR model with just two variables and one lag. Although the actual empirical model estimated later is going to be a more elaborate one, this simplified example would help the reader understand the basic idea behind the methodology. Denote the two 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 formerby assuming that the variance covariance matrix of the error terms, u_{xt} and u_{yt}, is also 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, in equation (2), the variance covariance matrix Σ_t also comes with 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 customary to assume 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. Typically, 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:

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

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:

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

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

I use monthly data throughout the paper, and the whole sample spans the period from January 1975 to April 2013. An important limitation with the TVP-VAR approach has to do with the curse of dimensionality. If the estimated model gets too large, the researcher might quickly face a limitation of the PC's computing capacity. For this reason, this paper tries to limit the number of variables included in the model to just 4. The following four variables, all of which have been overviewed in the previous section are included:

- Exchange rate, denoted **EXR**: the yen-dollar rate (nominal), the spot rate in the Tokyo market at 5PM, monthly averages, the data source is BOJ.
- Import prices, **PIM**: Import Price Index, All items, in JPY, base year = 2010, from *Corporate Goods Price Index*, BOJ.
- CGPI for intermediate goods, **CGPI-INT**: base year = 2010, Intermediate Materials, Index for Domestic Demand Products, from *Index by Stage of Demand and Use*, *Corporate Goods Price Index*, BOJ.
- CGPI for consumer goods, **CGPI-CONS**: base year = 2010, Final Goods / Consumer Goods, Index for Domestic Demand Products, from *Index by Stage of Demand and Use*, *Corporate Goods Price Index*, BOJ.

As stated earlier, after controlling for the effects of EXR, PIM reflects changes in the prices of imported goods in their contracted currencies. Also, PIM is expected to capture the transmission channel from EXR to the domestic prices. CGPI-INT is an index for domestic prices, and is also expected to capture a transmission mechanism from EXR and PIM to final consumer goods prices.

I take logarithms of all the series, multiply them by 100, and then take first differences. Within the VAR model, the variables are included in the order of appearance in the above list: that is, in the short-run causal ordering, EXR is assumed to be the "most exogenous", while PIM can be contemporaneously affected by EXR but not by either of the two CGPI variables, and so on. Basically, price variables in the "upstream" are allowed to affect those in the "downstream" within the month, but not vice versa. Due to the issue of "curse of dimensionality", the number of lags is kept relatively short at 3.

Priors

A crucial step for estimating the TVP-VAR is to specify "hyper-parameters" for the priors. Those are distributions from which the Σ's in equation (6) are drawn. They are important as they tend to determine the extent of time variations in the estimated parameters. All the Σ's are assumed to be orthogonal matrices. For the *i*th orthogonal element of Σ_h, namely the variances in the error terms for the process of (the log of) the shock variances, I specify:

$$\Sigma_{h,i} \sim \text{Inverse Gamma } (2, 10^{-10}).$$

Results are a little more sensitive to choices of the hyperparameters for the model coefficients. For that reason, I have tried several alternative specifications. First, the benchmark specification for the orthogonal elements of Σ_β, the variances of the error terms in the stochastic process for the reduced form coefficients, is

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

This amounts to allowing relatively small variations in the coefficients. I found that, under this specification, convergence of the estimation procedure is easier to obtain. As an alternative specification, I also tried the value of $10^{-2.5}$ for the second parameter for the above distribution, which amounts to allowing for more time variations in the reduced form coefficients. For the variances of the error term in the stochastic process for *a*, the contemporaneous coefficients, it is customary to use an inverse Gamma distribution, and report its two parameters (known as "shape" and "scale" parameters). However, usually, those distribution parameters themselves do not contain much economic meaning. For that reason, I decided to specify the median and the 95th upper percentile of the distribution and derive the corresponding distribution parameters. The benchmark specification is:

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

Figure 2 demonstrates the shape of this distribution. It can be seen that the mass of the distribution is in a region which implies relatively low time variations in *a*'s. Still, by construction, a non-negligible weight is given to the possibility of large time variation, namely the case in which the variances of the unit root processes for *a*'s exceed 0.01. As alternative specifications, I tried an Inverse Gamma distribution with a lower median (0.0001) but the same 95th percentile, and the same distribution with the same low median (0.0001) and a lower 95th percentile (0.001).

The following results are qualitatively unchanged under different specifications of hyperparameters, except when the benchmark specification for *a* is combined with the alternative specification for *b* (that is, allowing wide variations in both of them): in that case, I have not been able to obtain convergence of the estimation process, and, in what was obtained, the error bands turned out to be very wide.

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

IV. Estimation results

Estimated parameters

Figure 3-1 demonstrates time-series evolution of the estimated intercept terms (posterior means with 1 standard error bands). It is particularly noteworthy that the intercept term for CGPI-CONS shows a clear downward trend. Note that the standard, fixed coefficient VAR method could not take this kind of feature of the data into account. This figure thus indicates an advantage of using a TVP approach, particularly when using a long sample as the current paper attempts.

Figure 3-2 shows the estimated volatility (log of the variances of the structural shock terms), along with the 68% intervals.There are clear signs of time-varying volatility for all the variables. The volatility of the CGPI-CONS shock shows a clear downward trend until the trend is abruptly reversed in recent years. Note that the traditional TVP-VAR, which does not allow time variations in volatility, could not take those movements into consideration.

Figure 3-3 reports the estimated contemporaneous coefficients, or the *a*'s, along with their 68% bands. Note that, for example, in the upper right panel, the contemporaneous coefficient of EXR in the PIM Equation is negative, meaning that EXR has a positive effect on PIM, contemporaneously. The size of this effect initially decreases over time, but then gradually increases. This implies that the within-month pass-through from EXR to PIM declines initially but then comes back.

Impulse responses to EXR

Figure 4-1 through 4-6 report impulse responses of different variables to an EXR shock or a PIM shock. Although the estimations are carried out with first differenced series, I report cumulative impulse responses 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 4-1 shows the impulse response of EXR to "own shock", namely an EXR shock. As the shape of the response function was virtually unchanged throughout the sample, only the estimates for a single point in time, January 2010, are reported. To gain quantitative understanding of the results reported later, it is important to keep in mind that, here, we are talking about a shock that depreciates the currency by about 2.42 log points in the short run, and about 3.55 log points in the long run.

Figure 4-2 shows the response of PIM to "itself", evaluated in January 2010. Again, I found that the shape of this function does not change throughout the sample. It will be useful for understanding empirical results presented later to keep in mind that this shock increases PIM by about 0.94 log points in the short run, and 1.92 log points in the long run.

Figure 4-3, 4-4, and 4-5 report responses of PIM, CGPI-INT and CGPI-CONS (respectively) to an EXR shock, evaluated at different points in time, namely every five years starting January 1980 until January 2010, plus January 2013. All the three figures are consistent with the view that pass-through is initially strong, then declines, and then comes back, over time. In Figure 4-3, it can be seen that, in 1980, PIM would increase by almost 3 log points within 6 months after an EXR shock strikes. The magnitude of the response goes down to around 2 by 1985. After inching up little by little, it surpasses the 1980 level in 2010. In Figure 4-4, the response of CGPI-INT to EXR is very large in 1980: within less than a year, the cumulative response goes up to around 0.8. The magnitude of the response goes down to about half by 1985, and then continues to decline till 1995. Between that year and 2000, the response goes up to the same level as in 1985. Again, between 2005 and 2010, there is a big jump in the response, and the size of the response exceeds that in 1980. In Figure 4-5, the response of CGPI-CONS is large in 1980: one year after the shock, the cumulative response is around 0.4. Then the response declines throughout the 1980s. After a minor increase in the early 2000s, the response jumps up between 2010 and 2013.

Figure 4-6 and 4-7 report impulse responses of CGPI-INT and CGPI-CONS, respectively, to PIM. Again, the broad picture is that, over the recent history, the response starts strong, goes down, and comes back again. In Figure 4-6, the response of CGPI-INT starts from around 0.8 (one year after the shock) and declines substantially through the 1980s. A big change comes between 1995 and 2000, when the response becomes almost 50% larger. Figure 4-7 demonstrates that the response of CGPI-CONS is initially around 0.2 (cumulative response, one year after the shock) but declines till 1995, when the response turns mostly insignificant except for the first few months. The response goes up slightly by 2000, and experiences a substantial increase between 2010 and 2013.

Summary and quantitative implications

The five figures thus give us broadly similar pictures. However, the timings of the jumpsin the impulse responses are slightly different. For the response of PIM to EXR, the “biggest moment” is between 2005 and 2010 (Figure 4-3). For the responses of CGPI-INT to EXR and PIM, in addition to that period, we observe another substantial increase between 1995 and 2000 (Figure 4-4 and Figure 4-6). Finally, for the responses of CGPI-CONS to EXR and PIM, though we do see minor increases between 1995 and 2000, the substantial leap comes between 2010 and 2013.

What are the quantitative implications of the most recent estimates? For example, in October 2012, the yen-dollar rate stood at around 78 JPY per USD. By May 22 of the following year, it was about 103. This is a depreciation of about 0.28 log points. Suppose that all this has been caused by a series of EXR shocks. The estimated impulse responses evaluated at January 2013 indicate that this would contribute to an increase in PIM of 0.24 log points, while CGPI-INT and CGPI-CONS would increase by 0.064 and 0.04 log points, respectively, in medium to long runs. Those numbers can be considered substantial, especially given the recent low levels and low volatilities of the Japanese inflation rates (refer to Figure 1-1 and 1-2)[4].

IV. Cost structure and pass-through

In this final section, I look for a possible explanation for the recent resurgence of pass-through. In the literature, researchers have come up with three hypotheses to explain the declining pass-through of the 1980s and the 1990s. They are: (1) enhanced credibility of monetary policy, (2) enhanced wage flexibility, and (3) changes in the cost structure. Here, I investigate the third candidate; I ask if changing structure of production costs in Japan could explain both the declining pass-through in earlier years and the recent revival at the same time.

Here, the analysis relies heavily on Shioji and Uchino (2011). In the literature of the Input-Output Analysis, researchers often compute predicted percentage response of a certain sector's price, under the assumption that the price of imported goods in another sector has increased by 1%. The basic structure of an Input-Output model with *N* sectors, which incorporates international trade, is:

$$x = Ax + d + e - M(Ax + d). \qquad (7)$$

In the above, *x* is the vector of output ($N \times 1$), *A* is the input coefficient matrix, *d* is the vector of domestic final demand ($N \times 1$), *e* is the vector of exports ($N \times 1$), and *M* is the matrix of import coefficients. The matrix *M* is a diagonal matrix whose *i*th diagonal element is the ratio of the imports of the *i*th sector to the sum of intermediate inputs from the *i*th sector to all the sectors plus the domestic final demand to this sector's output. From here, the following pricing equation can be derived:

$$\Delta p = \left[\left(I - \left(I - M \right) A \right)^{-1} \right]' \cdot A' M' \cdot \Delta p^{m}. \qquad (8)$$

In the above, Δp is a vector which contains rates of changes of domestic prices in

[4]Note, however, that those are predicted effects on the *level* of PIM and CGPI, while in monetary policy, the target is usually defined with respect to the *inflation rate*. According to the estimates, the depreciation would boost the CGPI inflation for a few months. After that, although the levels of CGPI would be permanently higher, its rate of increase would go back to the normal level.

different sectors, while Δp^m is a vector whose elements are rates changes of imported goods prices in each sector. For example, suppose that the metal sector is the *J*th sector and that we wish to study impacts of one percentage increase in prices of imported metals. To do that, we set the *J*th element of the vector Δp^m to be 1 and all the other elements to be 0. Then each element of Δp would indicate the predicted percentage response in the domestic prices of goods in each sector, under the assumption of 100% pass-through of production costs at each production stage.

Likewise, it is possible to derive predicted price responses of all sectors when prices of all the imported goods have increased by 1%, by setting all the elements of Δp^m to be equal to 1 simultaneously. This is done in Figure 5-1 and 5-2, in which the overall means of predicted price responses across sectors are reported. Figure 5-1 is based on detailed I-O Tables complied by RIETI (Research Institute for Economy, Trade and Industry) which consists of over 500 (row) sectors for years 1980, 1985, 1990, 1995 and 2000. Figure 5-2 uses more aggregated I-O Tables provided by METI (Ministry of Economy, Trade and Industry) which consists of only 73 sectors, for the period 2000-2007 (data for 2001 and 2002 are missing). Refer to Shioji and Uchino (2011) for details of the analysis.

It can be seen that, in the overall cost structure in Japan, the role of imports declined substantially between 1980 and 1995: the predicted impact on overall prices drops to half the original size, from 0.2 to 0.1 (Figure 5-1). But then imports gradually regain importance in the Japanese cost structure. Their predicted impact on overall domestic prices increases by about 70% between 2000 and 2007 (Figure 5-2).

The analysis in this section suggests that the changing cost structure could go a long way toward explaining both the declining pass-through in the 1980s and the early 1990s, as well as its recent resurgence. Formally relating the time series analysis in the previous section and the I-O analysis in this section will be a hopeful venue for future research.

V. Conclusions

This paper has utilized the TVP-VAR (with Stochastic Volatility) method to examine evolution of pass-through in Japan. It has been found that, after a long period of a decline and stagnation, pass-through has made notable come back. This implies that the exchange rate may have regained the status of an important policy transmission mechanism to domestic prices. An important topic for future research is to study if a similar phenomenon can be found in recent data sets from other countries. If the pass-through resurgence turns out to be a global trend, rather than a Japan-specific anomaly, the underlying cause of the revival is also likely to be a global one.

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Table 1-1 Correlation, all in log 12 months differences

(i) January 1971 – April 2012 (except for EXR which starts in January 1974)

	CPI	CGPI	CGPI-CONS	CGPI-INT	PIM	EXR
CPI						
CGPI	0.804					
CGPI-CONS	0.943	0.914				
CGPI-INT	0.683	0.973	0.834			
PIM	0.471	0.776	0.657	0.854		
EXR	0.134	0.273	0.266	0.350	0.662	

(ii) January 1971 – December 1989 (except for EXR which starts in January 1974)

	CPI	CGPI	CGPI-CONS	CGPI-INT	PIM	EXR
CPI						
CGPI	0.839					
CGPI-CONS	0.968	0.933				
CGPI-INT	0.753	0.983	0.867			
PIM	0.616	0.832	0.727	0.877		
EXR	0.317	0.458	0.407	0.509	0.791	

(iii) January 1990 – April 2013

	CPI	CGPI	CGPI-CONS	CGPI-INT	PIM	EXR
CPI						
CGPI	0.459					
CGPI-CONS	0.592	0.724				
CGPI-INT	0.227	0.934	0.671			
PIM	0.064	0.675	0.652	0.829		
EXR	−0.045	−0.041	0.239	0.106	0.465	

Figure 1-1 Comparison of CPI (all items less fresh food), CGPI (all commodities) and CGPI (final goods, consumption goods; CGPI-CONS), all in log 12 months differences

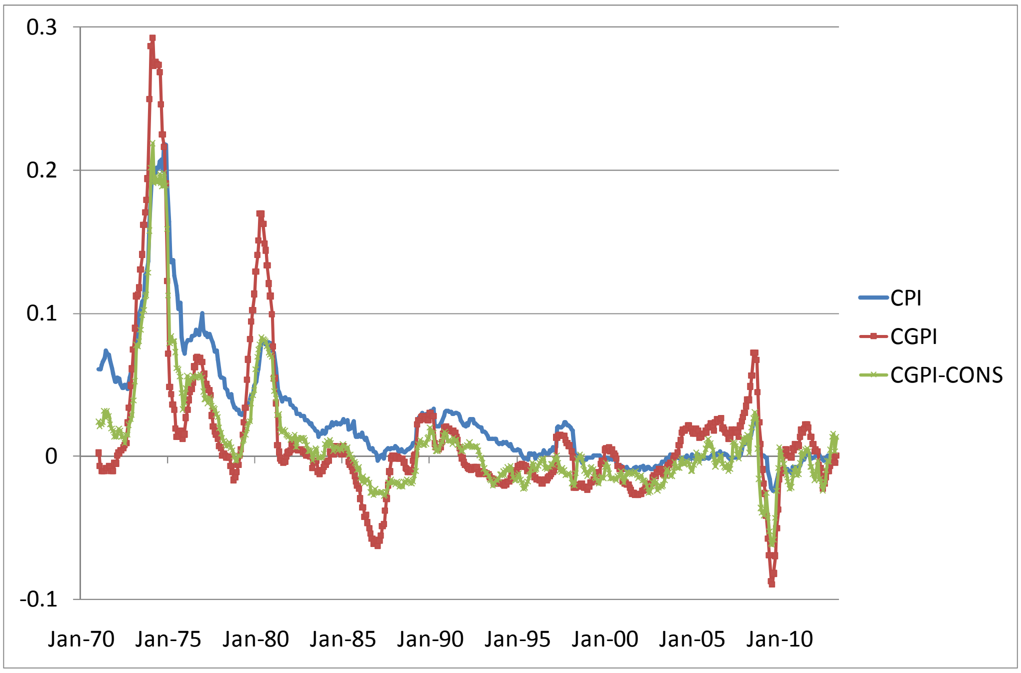


Figure 1-2 Comparison of CGPI (intermediate goods, CGPI-INT), Import Price Index (PIM) and the JPY-USD spot rate (EXR), all in log 12 months differences

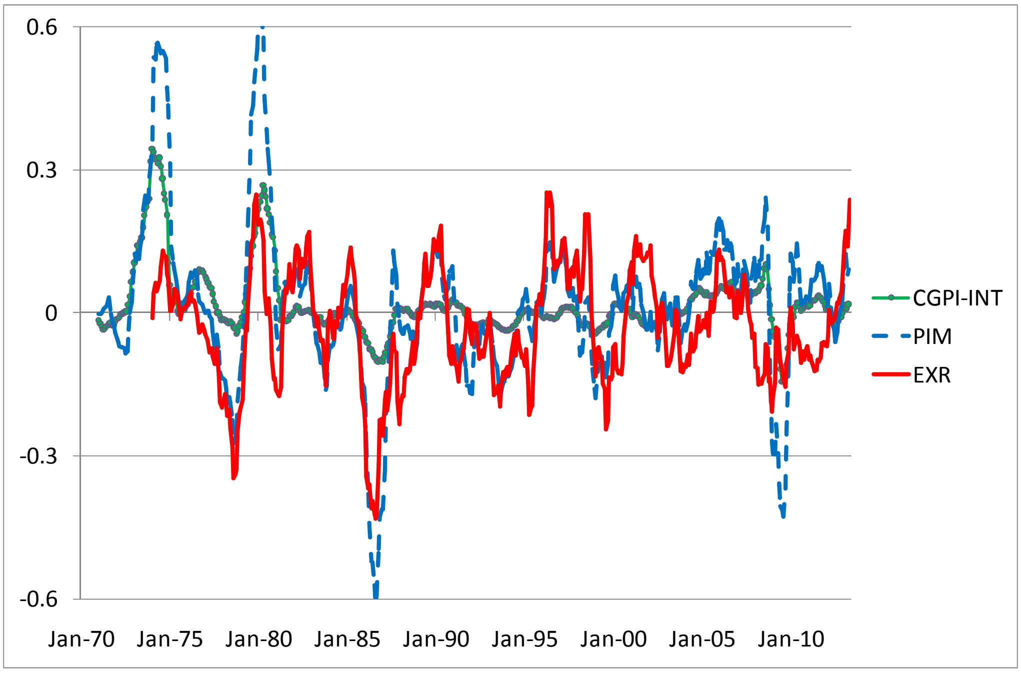


Figure 2: Distribution of Σ_a under the benchmark setting of hyperparameters

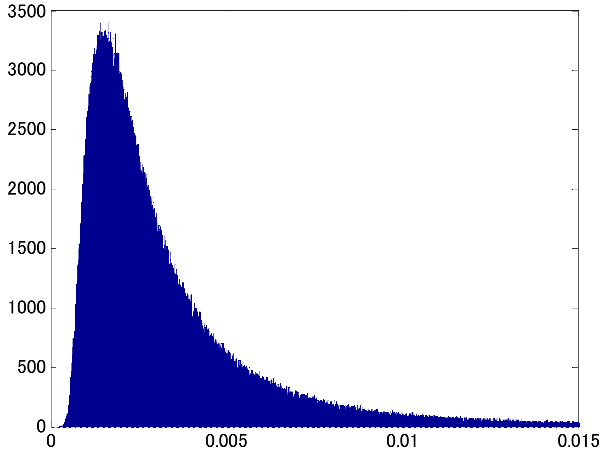


Figure 3-1: Time variations in the intercept terms, posterior means with 1 standard error bands

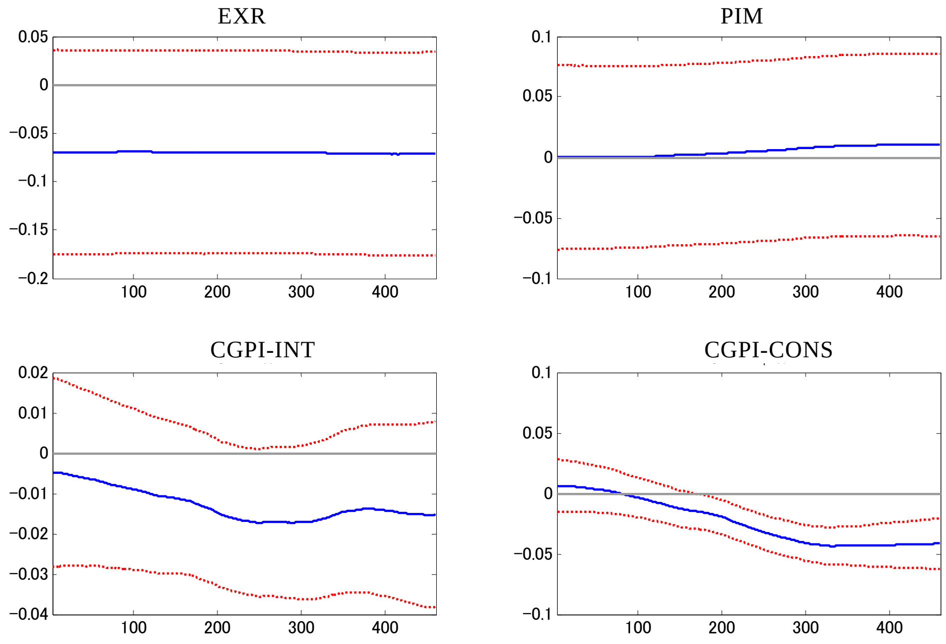
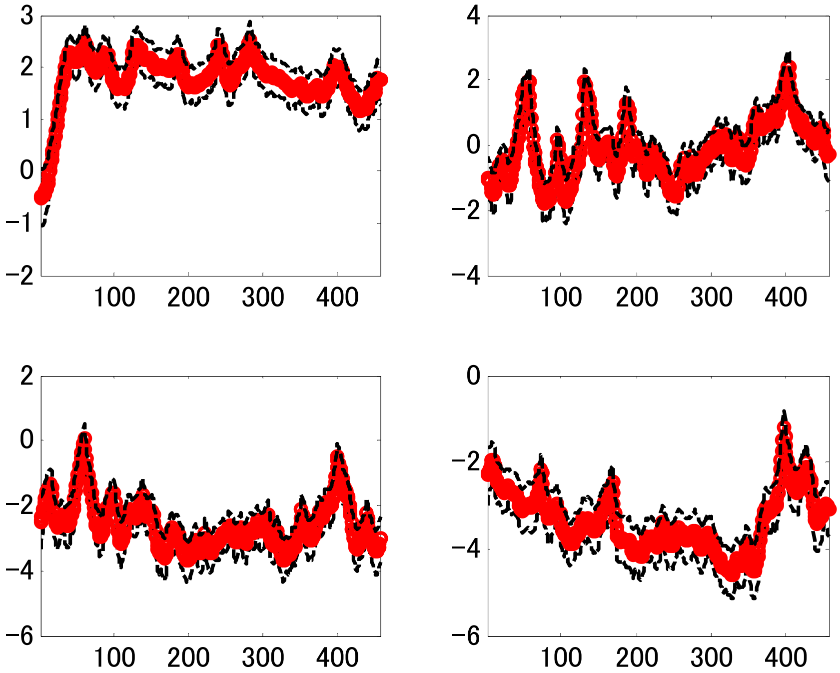


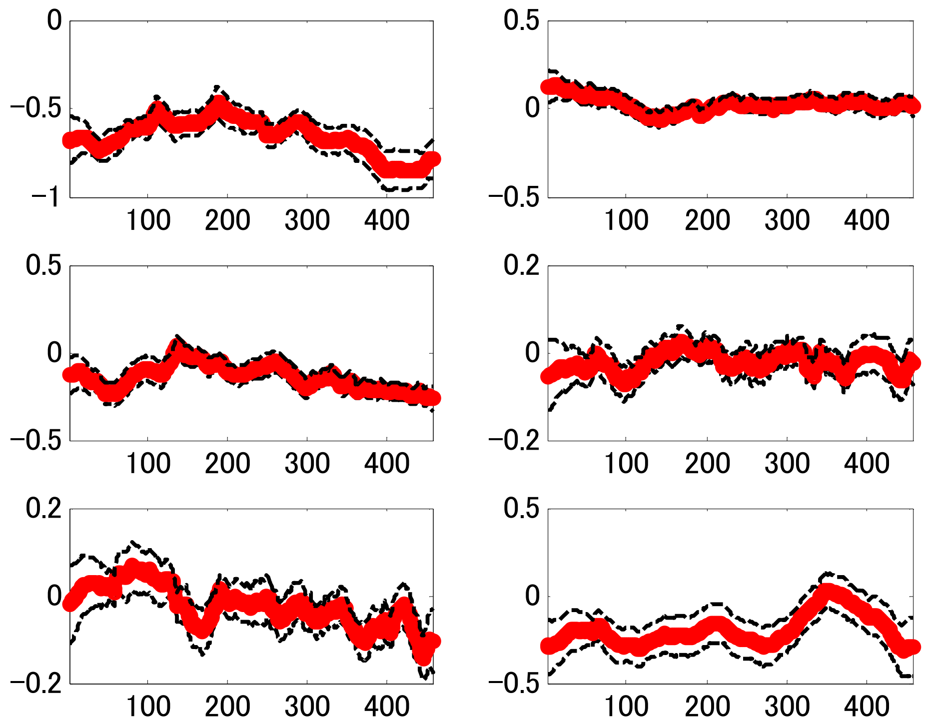
Figure 3-2 Time variations in the log of volatility of structural shocks



Horizontal axis: time (from May 1975 to April 2013)

Upper left: EXR, Upper right: PIM, Lower left: CGPI-INT, Lower right: CGPI-CONS.

Figure 3-3 Time variations in the contemporaneous coefficients



Horizontal axis: time (from May 1975 to April 2013)

Upper left: Equation: PIM, Variable: EXR

Upper right: Equation: CGPI-INT, Variable: EXR

Middle left: Equation: CGPI-INT, Variable: PIM

Middle right: Equation: CGPI-CONS, Variable: EXR

Lower left: Equation: CGPI-CONS, Variable: PIM

Lower right: Equation: CGPI-CONS, Variable: CGPI-INT

Figure 4-1 Response of EXR to “itself”

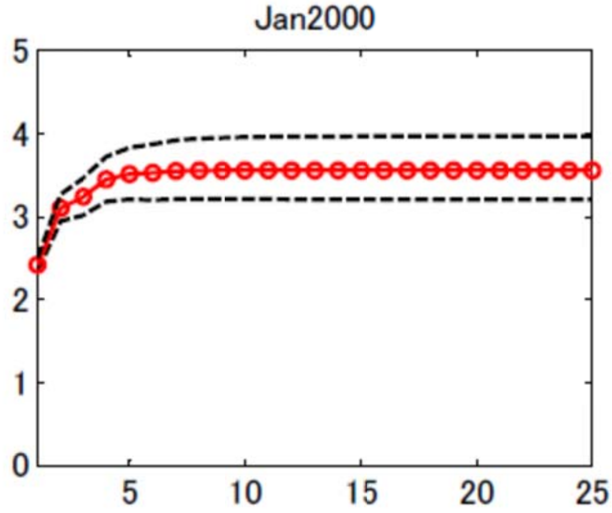


Figure 4-2 Response of PIM to “itself”

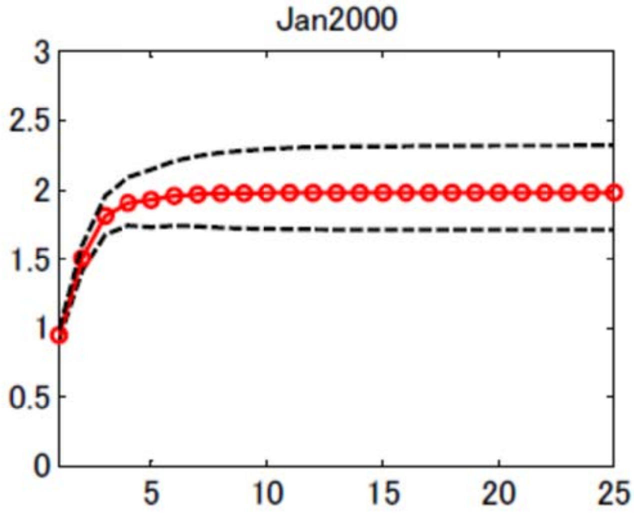


Figure 4-3 Response of PIM to EXR

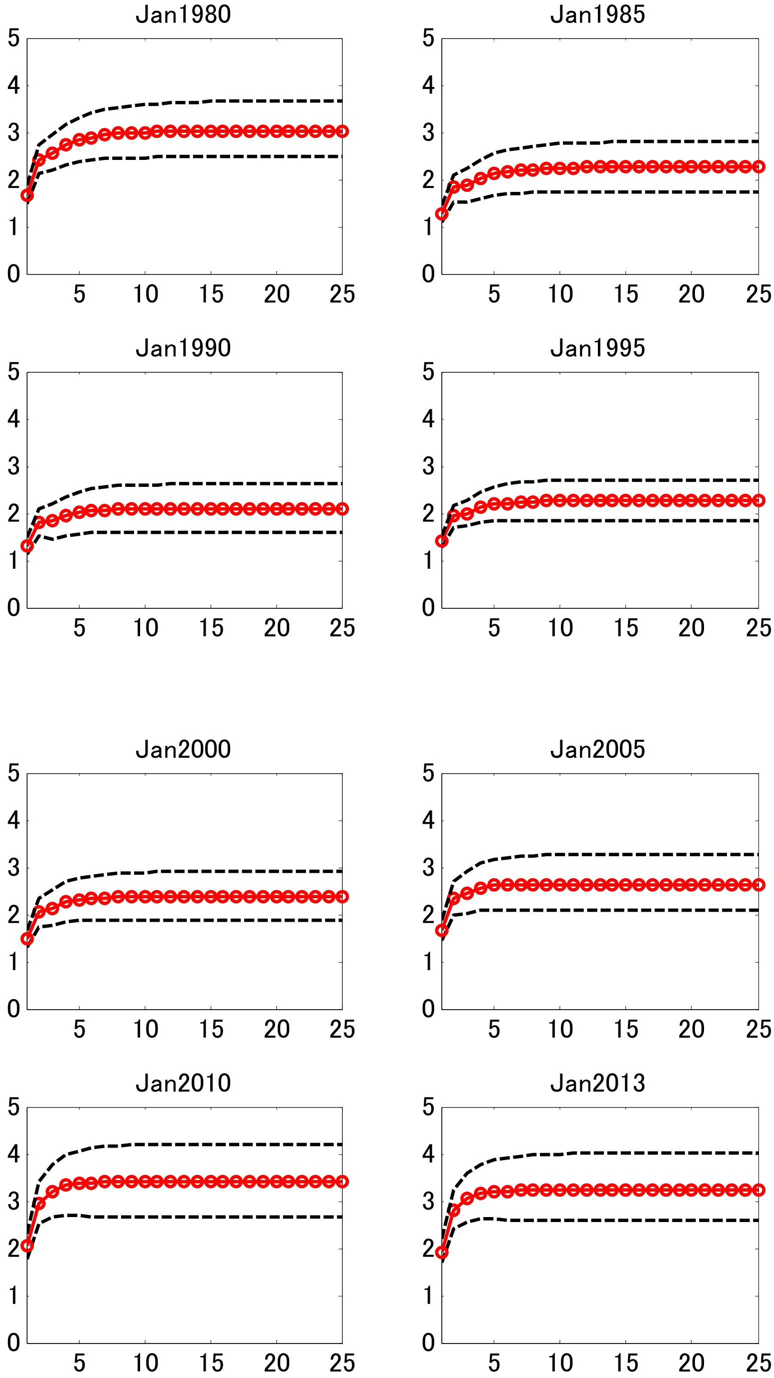


Figure 4-4 Response of CGPI-INT to EXR

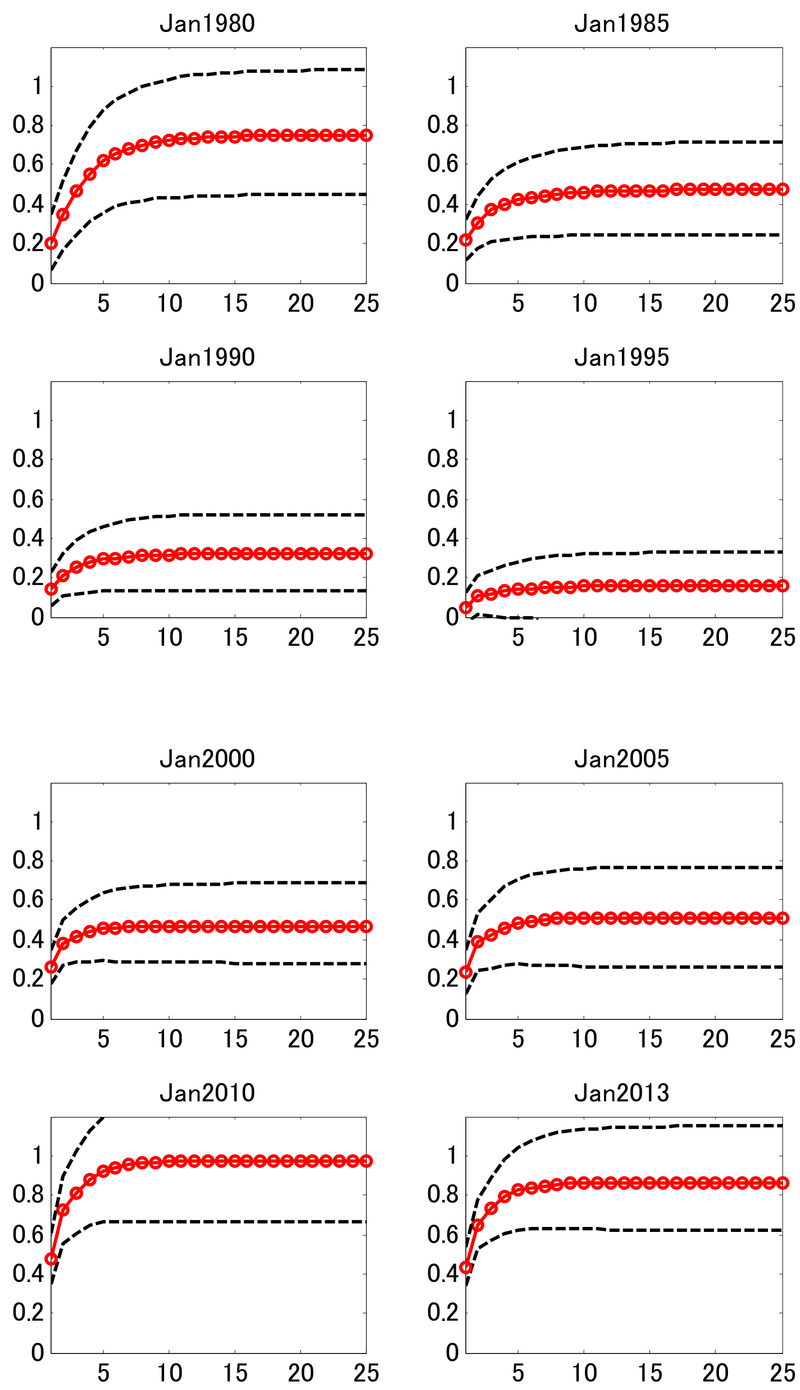


Figure 4-5 Response of CGPI-CONS to EXR

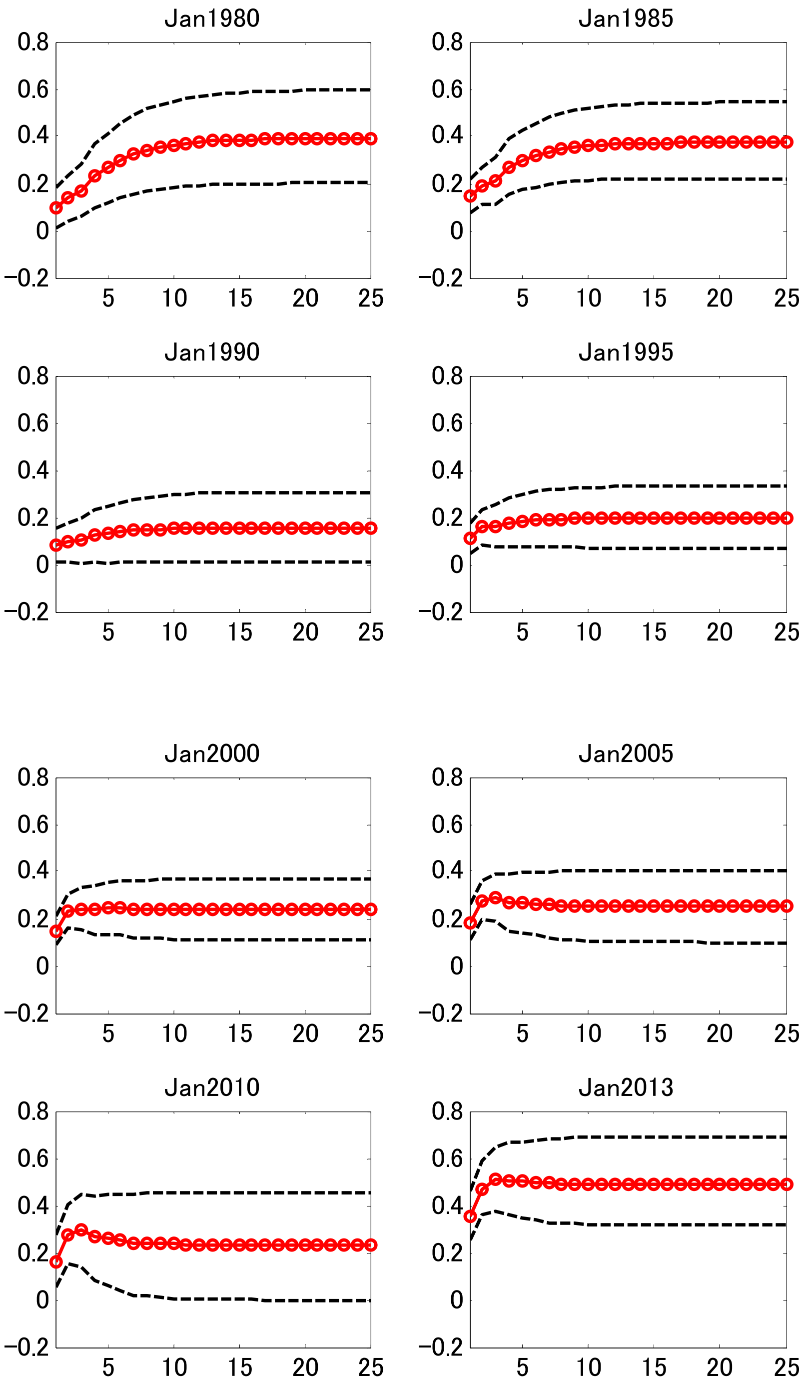


Figure 4-6 Response of CGPI-INT to PIM

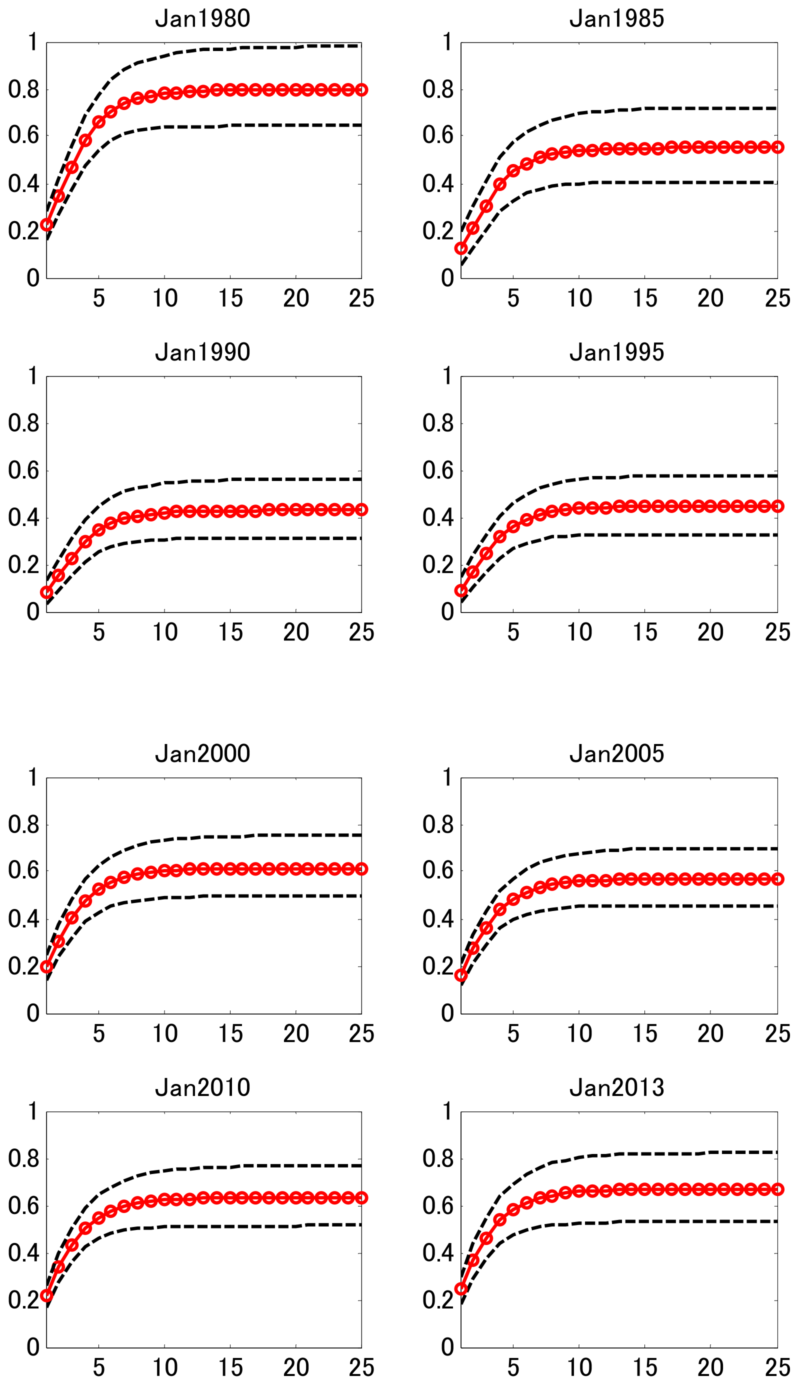


Figure 4-7 Response of CGPI-CONS to PIM

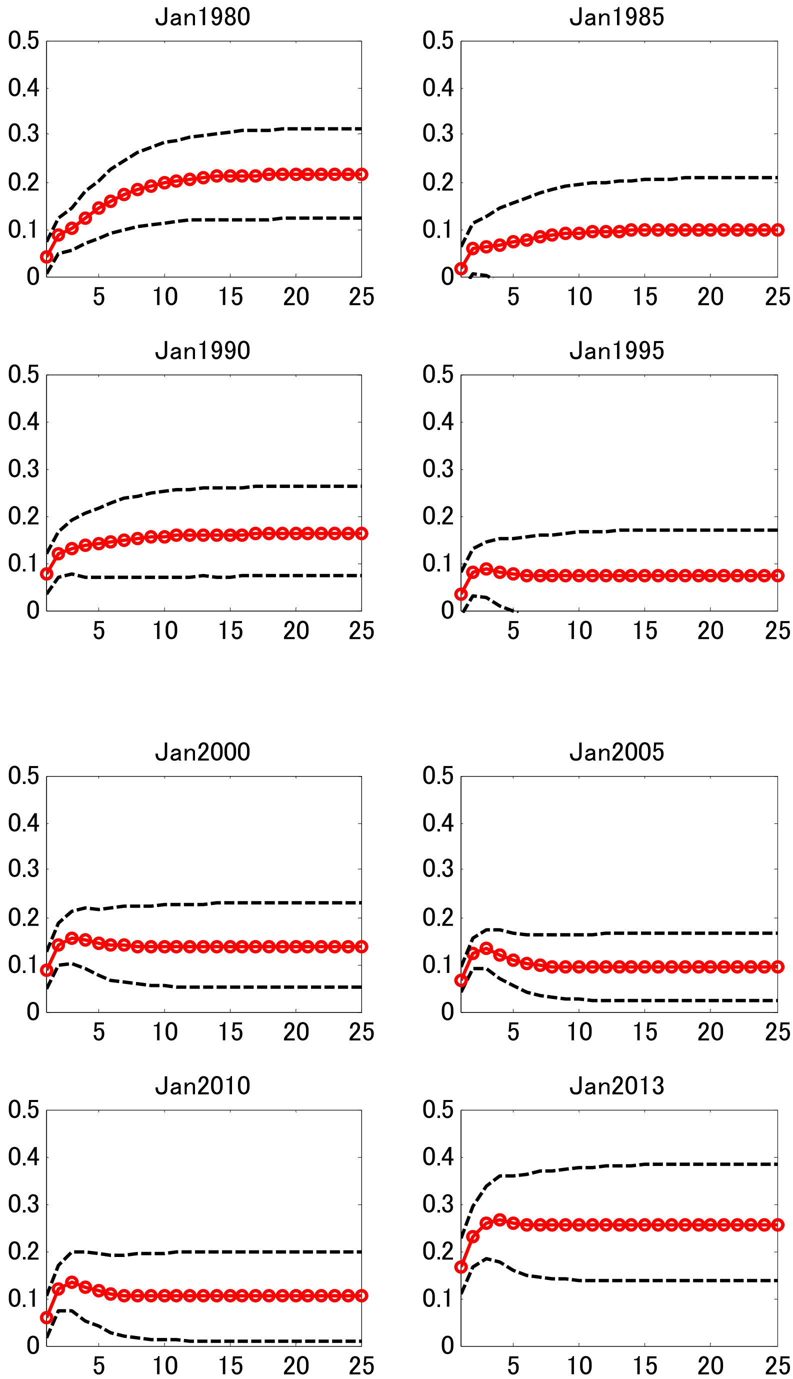
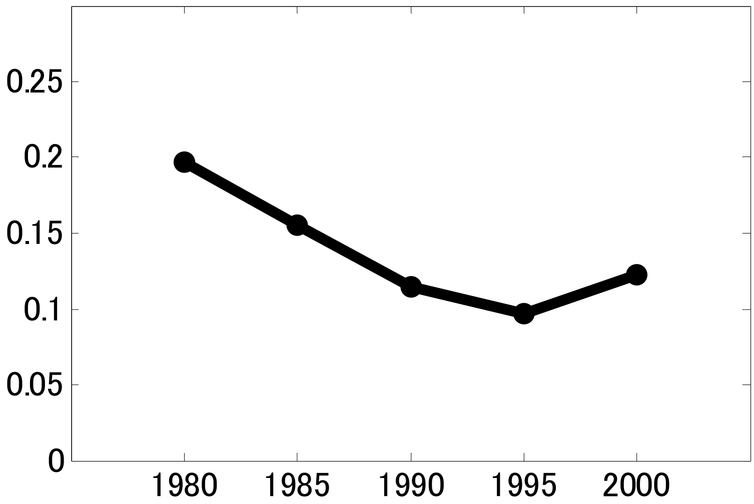
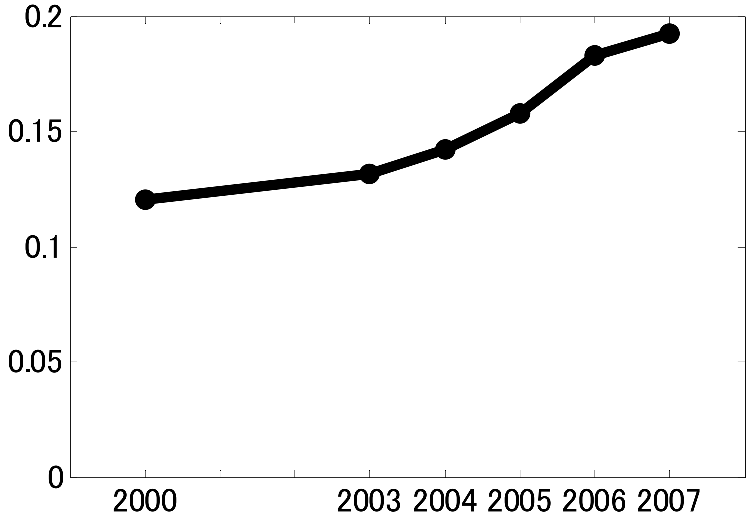


Figure 5-1 I-O based prediction on the response of the average price of consumer goods (manufacturing only) to 1% increase in all import prices, 1980-2000.



(Note) Based on the RIETI I-O table, nominal.

Figure 5-2 I-O based prediction on the response of the average price of consumer goods (manufacturing only) to 1% increase in all import prices, 2000-2007.



(Note) Based on the METI I-O table, nominal.