Exchange rate pass-through on Japanese prices:
Import price, producer price, and core CPI

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Abstract

Against the background of Japanese two percent inflation targeting started in 2013, we investigate what have impeded the process of passing exchange rate fluctuations to the core consumer price index. To this end, we constructed industry-wise nominal effective exchange rate and industry-wise producer price indices, which are matched with the industry classification of import price indices. Time-varying parameter vector autoregression analysis reveals that exchange rate pass-throughs in general increased especially after the global financial crisis. Amongst pass-throughs at each stage of import price, domestic producer price, and consumer price, we find the weakest link between import price and domestic producer price. However, the impact within an industry is not negligent; what is hindering consumer price to rise after depreciation is little spillover effect to other industries at the producer price stage.

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1. Introduction

In January 2013 the Bank of Japan (BOJ) started to adapt inflation targeting of two percent as an additional tool in revising its unconventional monetary policy of expanding the BOJ's balance sheet along guiding call rate to the lowest possible. However, since the introduction of inflation targeting, the BOJ has continued to fail for achieving inflation rate of two percent annually, despite of further accelerated rate of balance sheet expansion and introduction of negative interest rate. The effect of monetary expansion on nominal prices and wages through raising people's inflation expectation seem not to have worked.

Despite these consequently unsuccessful outcomes, the Japanese yen responded quickly to pick up by November 2012 with market participants' expectation of the beginning of the Abe administration, with its primary goal of increasing inflation rate, and depreciated from 79 yen per US dollar to 101 yen in seven months. This sharp depreciation of the Japanese yen is extraordinary such that it can be classified as 'currency crisis' by Frankel and Rose (1996), which defines currency crisis when a depreciation is greater than 25% and an increase in the rate of depreciation is at least 10%.

Did the depreciation of the Japanese yen help raise inflation rate of core CPI in Japan? To be able to answer 'yes', three transmission stages must be passed through successfully with following scenarios. First, import prices in terms of the Japanese yen need to respond substantially with respect to a change in exchange rate. The choice of invoicing currency plays an important role at least in short term. If invoicing currency is contracted in foreign currency, exchange rate depreciation is fully passed through to import price in Japanese yen. On the other hand, if invoicing currency in contracts are in Japanese yen, Japanese yen prices in contracts prior to a depreciation do not change. In longer term, consequent contract prices are adjusted to reflect the bargaining power of business parties on both sides and price elasticities of imported products in the Japanese markets. Devereux, Dong, and Tomlin (2017) find evidence from Canadian firm-level transaction data that large-size importers and medium-size exporters tend to invoice in importers' currency. Goldberg and Tille (2016) also find the link between the transaction size and invoicing.

Second, the prices of domestically produced products also need to respond to an exchange rate change in order to have impacts on prices of wide arrays of products in Japan. There are two channels considered to have influences on the prices of domestically produced products. The first channel is via competition between foreign manufacturers and domestic producers as in the classical pass-through model of Dornbusch (1987). A profit-maximizing domestic producer adjusts its price accordingly to changes in the prices of imports produced by foreign competitors. The second channel is input-output relation across industries: domestic producers use imported products as their inputs. A rise in the price of imported intermediate products reflects on the final price of domestically produced products.

Third, more naturally, domestic prices at the level of manufacturers and at the level of consumers need to move in concert. The difference between these two prices should consist of distribution costs. Distribution costs were reported by Burnstein, Neves, and Rebelo (2003) to be approximately 40-60 percent of retail prices and were reported by Goldberg and Campa (2010) to be 30-50 percent of the prices of household consumption goods in 21 industrialized countries. The explicit inclusion of the distribution sector in the theoretical macroeconomic model is investigated by Burstein et al. (2003) and Corsetti and Dedola (2005). These models suggest that distribution costs may not be sensitive to exchange rate changes.

With clog even only in one of three transmission steps, a change in exchange rate cannot be passed through on consumer prices. The objective of this paper is to find out how much, if any, consumer prices in Japan responded to changes in exchange rate and what are impediments in transmitting exchange rate effect to consumer price in Japan.

The sample period in this study overlaps with the era of unconventional monetary policy pursued by the BOJ. A regime shift such as moving from conventional to unconventional monetary policy should affect the transmission process of prices at different stages. Mishkin (2008) discusses the important role of exchange rate movements for monetary policy decisions. Mishkin (2008) : "Sizeable depreciations of the nominal exchange rate exert small effects on consumer prices across a wide set of industrial countries, and these effects have declined over the past two decades…Nevertheless, exchange rate fluctuations can still have an effect on inflation and economic activity and hence factor into monetary policy decisions." Devereux and Yetman (2010) build a theoretical model with sticky prices to explain the phenomena of low exchange rate pass-through. They show in their calibration that exchange rate pass-through is positively associated with the level of inflation. Taylor (2000) shows that low-inflation and low-pass-through environment even weakens the link between prices and real economy. Other related studies on the relationship between inflation and exchange rate pass-through include McCarthy (2000), Hahn (2003), Otani et al. (2003), Faruqee (2004), and Hara, Hiraki and Ichise (2015).

The number of papers investigated exchange rate pass-through at the different stages of production-distribution-consumption stream. Among these studies, the empirical approach of Ito and Sato (2006) and Shioji (2012, 2014, and 2015) are similar to our approach. Ito and Sato (2006) investigates exchange rate pass-through at various stages of Japanese prices in vector autoregressive framework. While Ito and Sato (2006) assumed exchange rate pass-through are constant in their sample period, the consecutive studies of Shioji (2012, 2014, 2015) assume exchange rate pass-through coefficients are time-varying in VAR framework. Our study follows the latter line of research and investigate pass-through among prices at various stages in time-varying parameter vector autoregression (TVP-VAR).

The data construction contribution of this paper is two folds. First, nominal effective exchange rates are constructed to precisely fit the BOJ's industry classification of import prices. The country weights for Japanese imports are calculated for each industry and these are modified every year to reflect changes in the industry composition of Japanese imports. Second, to measure direct impact of import price changes on the prices of domestically produced goods in the same category, the industry-level producer price index is reconstructed to match the corresponding industry-level import price index. For some industries, this matching process is simple, but in most of the case careful inspection of sub-categories was necessary.

The innovative part of the empirical approach in this paper is to apply time-varying parameter vector autoregressive analysis on nominal effective exchange rates, and three layers of price indices. By this way, we are able to measure not only the standard pass-through from exchange rate to import price and domestic prices, but also pass-through between prices at the different layer. More precisely, we estimated pass-through at the industry level from import price to domestic producer price and from domestic producer price to core consumer price.

The main empirical findings of this paper is three folds. First, we start at the most general level of prices covering all industries. The nominal effective exchange rate is constructed with the country weights updated every year based on the coverage of BOJ price survey on the custom data. With the general price indices, we find that exchange rate pass-through is substantial (pass-through elasticity of about 0.65-0.75) on import price level and ERPT is much smaller but still statistically and economically significant (pass-through elasticity of about 0.02-0.08) on producer price level. However, ERPT on consumer price level is negligible in the 1990's and the early 2000's but becomes statistically significant (pass-through elasticity of about 0.02) in the post-Global Financial Crisis. ERPT elasticity of two percent is small; however, with a large depreciation of the size of 50 percent, an increase in consumer price induced by depreciation reaches one percent, a halfway to the inflation targeting of two percent.

Second, we proceed to introduce industry level import prices and so-constructed nominal effective exchange rates at the corresponding industry level. It is important to note that we still use general price index at domestic and consumer price level. By this way, we can measure the overall impact of a change in the import price of one particular industry to the domestic prices of other industries as well as the prices of its own industry. Exchange rate pass-throughs on import prices estimated at the industry level are much greater than pass-through measured at the general import price index. Among all ten industries, exchange rate pass-through on import prices are especially large (pass-through elasticity of about 0.70-1.00) for industries with materials and natural resources; namely, wood, metal, and petroleum industries. Pass-through from exchange rate to import prices are also substantial for machinery industries. Only for textile industry, exchange rate pass-through on import prices are less than 0.50. From industry import prices to general domestic producer prices, pass-through elasticities are expectedly much smaller, all being less than 0.10. The evidence of weak link between import prices and domestic prices motivates us to further disentangle the direct effect on the same industry and indirect (or spillover) effect on other industries.

Third, we introduce domestic producer price index reconstructed at the industry level. This data construction is necessary because the product coverage in a particular industry differs between import prices and domestic producer prices. The difference in these two price levels starkly appears in the different number of industries; ten industries at the import price level and 23 industries at the producer price level. The exchange rate pass-through elasticities on industry import prices are similar to the preceding results. However, the direct impact of industry import prices on domestic producer prices in the corresponding industry is larger than those estimated for general domestic producer prices. These results indirectly suggest that spillover effect, pass-through to the price of other industries, is possibly negligent.

What can we conclude about the effect of the Japanese yen movements on consumer price level? TVP-VAR analysis revealed that no effect was found in the 1990's and the early 2000's; however, the two percent ERPT elasticity with the sharp depreciation of 50 percent can fulfill the half of two percent inflation. In this sense, the Japanese yen depreciation in 2013 indeed have helped the BOJ's attempt to achieve its inflation target. However, the BOJ should know better than that this magnitude of depreciation cannot be expected to occur again under the normal circumstances of Japanese economy. Another 50 percent depreciation will be indeed a currency crisis.

Given this small degree of exchange rate pass-through on consumer price level, we further scrutinized the weakest link along the cascade of price levels. Amongst pass-through at each stage of import price, domestic producer price, and consumer price, we find the weakest link is between import price and domestic producer price. However, the pass-through elasticity within an industry is not negligent; what is hindering consumer price to rise after depreciation is little spillover effect from import price of an industry to other industries at the producer price stage.

The rest of this paper is organized as follows. Next section explains how nominal effective exchange rates by industry are constructed and domestic producer price indices are modified to match better with the composition of import price indices. Section 3 introduces our pass-through empirical model in the TVP-VAR framework and presents the results. Section 4 discusses the implications to current monetary policy of BOJ and the conclusion is provided in the last section.

2. Matching and construction of data

2-1. Corporate Goods Price Index

The BOJ collects information on prices of goods being transacted among firms by mailing to the surveyed firms every month. The Corporate Goods Price Index consists of three groups: Producer Price Index (PPI), Export Price Index (EPI), and Import Price Index (IPI). In this paper, we only use PPI and IPI, so we leave out EPI in the following description. There are 23 (10) industries, 93 (37) sub-industries, 235 (96) commodity-groups, and 746 (258) commodities for PPI (IPI). The number of prices collected each month is 5,743 and 1,576 for PPI and IPI, respectively. Prices collected for PPI are those of products produced and purchased by domestic firms and prices for IPI are those of products imported by domestic firms. Weights for constructing indices are based on values of manufacturing shipments for PPI and international trade data collected at the Japan Custom, Ministry of Finance, for IPI.

2-2. Modifying PPI for better match with corresponding IPI

As the number of industries differ between PPI and IPI, i.e. 23 industries for PPI and 10 industries for IPI, we cannot in general directly compare industries between two groups, see appendix Table A1 for the list of industries. However, we propose to circumvent the problem of mis-matched industry lists by checking sub-categories, sometimes even at the level of commodities, of industries between two indices. We proceeded in the following steps. i) A few industries almost match at the industry level. These pairs are: PPI(2) and IPI(2), textiles; PPI(3) and IPI(4), lumber & wood products; PPI(5) and IPI(6), chemicals & related products. For these industries, we make no modifications to the original industry price index. ii) Sub-industries of IPI match with industries of PPI. Three sub-industries of IPI(8) corresponds well with PPI(15), (16), and (17). iii) In other cases, some categories or commodities in producer price index do not exist in the import price index. Therefore, we need to remove those commodities, which do not have corresponding commodities in import, from producer price index. After removing those commodities, we reconstructed producer price index at the level of industry by using weights given at the level of commodities. An example of detailed construction for each producer price index corresponding to import price are fully given in the appendix Table A2.

2-3. Construction of Industry Nominal Effective Exchange Rates

What kind of exchange rate should be chosen for import price indices (and producer price indices so constructed as above)? One natural candidate is nominal effective exchange rate (NEER) so constructed by the BOJ, IMF, or BIS. However, these NEER are not broken down by industry or their classifications of industry category do not match with IPI's. So, we are left with constructing own NEER from scratch.

For each of 258 categories of IPI commodities, the BOJ provides in the list corresponding products in Harmonized System (HS) of international trade classification codes[1]. The construction of industry NEER is described in the following steps. First, for each IPI industry, we sum import values of corresponding HS 9-digit codes by country and by year. Instead of using all possible trade partners of close to 200 countries/economies, we limited the number of countries to top 20. We choose top 90% countries of 1988 imports and top 90% countries of 2014 imports. This process retain over 90% percent of total trade values. Second, the country weight for an industry-year is calculated as the ratio of import value from this country to total Japanese imports in the IPI industry. Third, with the monthly nominal exchange rate of top 20 trade partners and annual country weights, monthly NEER for IPI industry is calculated as weighted average of bilateral exchange rate series. Figure 1 plots country weights for Lumber & wood products and forest products, IPI(4). Figure 2 plots industry NEERs for all ten IPI industries.

[1] The HS codes in Japan consists of nine-digit codes in which the Japan Custom adds three extra codes at its discretion to the international standard of six-digit codes. The number of HS 9-digit codes for Japanese imports is 7,499 in 1988 and 7,972 in 2017.

3. Time-Varying Parameter VAR analysis

3-1. TVP-VAR model [2]

A TVP-VAR model is a recently developed method that enables a VAR evaluation at each point in time by changing parameters according to time. Specifically, a TVP-VAR model is defined as follows.

$$A_t y_t = F_{1t} y_{t-1} + \cdots + F_{st} y_{t-s} + \varepsilon_t \qquad t = s+1, \dots, n \tag{1}$$

Here, y_t is a vector of k × 1 observed variables $(y_t' = (y_{1t}, \dots, y_{kt}))$, A_t, $F_{1t}, \dots, F_{st}$ are k × k matrixes of time-varying coefficients. ε_t is a structural shock of k × 1 and is assumed to be $\varepsilon_t \sim N(0, \Phi_t)$. Here, equation (1) can be rewritten as the following reduced form.

$$\begin{gathered} y_t = B_{1t} y_{t-1} + \cdots + B_{st} y_{t-s} + u_t \\ u_t \sim N(0, \Omega_t) \qquad t = s+1, \dots, n \end{gathered} \tag{2}$$

At this time, $B_{it} = A_t^{-1} F_{it}$ and $u_t = A_t^{-1} \varepsilon_t$ for $i = 1, \dots, s$. Further, u_t is a k×1 error term vector. Then, the variance-covariance matrix of u_t led us to perform a Cholesky decomposition imposing a recursive restriction

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' A_t^{-1\prime} \tag{3}$$

where A_t is a k×k lower-triangular matrix in which the diagonal elements are equal to one

$$A_t = \begin{bmatrix} 1 & 0 & \dots & 0 \\ a_{21t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1t} & \dots & a_{k,k-1,t} & 1 \end{bmatrix}$$

and Σ_t is the k×k diagonal matrix

$$\Sigma_t = \begin{bmatrix} \sigma_{1t} & 0 & \dots & 0 \\ 0 & \sigma_{2t} & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \dots & 0 & \sigma_{kt} \end{bmatrix}$$

Now, we rewrite models (2) and (3) as follows:

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[2] See Primiceri (2005) and Nakajima (2011) for further details on the TVP-VAR methodology.

$$y_t = x_t\beta_t + A_t^{-1}\Sigma_t e_t$$
$$e_t \sim N(0, I_k) \tag{4}$$

where β_t is a $k^2 s \times 1$ vector and is obtained by stacking elements in the rows of $B_{1t}, \ldots, B_{st}$. In addition, we define $x_t = I_k \otimes (y'_{t-1}, \ldots, y'_{t-s})$ in equation (4) (where $\otimes$ denotes the Kronecker product). Next, let $a_t = (a_{21t}, a_{32t}, a_{41}, \ldots, a_{k,k-1,t})'$ be a stacked vector of the lower-triangular elements in A_t and $h_t = (h_{1t}, \ldots, h_{kt})'$ with $h_{jt} = log\sigma_{jt}^2$. Now, we assume that the parameters in equation (4) follow a random walk process as follows:

$$\begin{aligned} \beta_{t+1} &= \beta_t + u_{\beta t} \\ a_{t+1} &= a_t + u_{at} \\ h_{t+1} &= h_t + u_{ht} \end{aligned} \qquad \begin{pmatrix} e_t \\ u_{\beta t} \\ u_{at} \\ u_{ht} \end{pmatrix} \sim N\left(0, \begin{pmatrix} I & 0 & 0 & 0 \\ 0 & \Sigma_\beta & 0 & 0 \\ 0 & 0 & \Sigma_a & 0 \\ 0 & 0 & 0 & \Sigma_h \end{pmatrix}\right),$$

for $t = s+1, \ldots, n$ *where* $\beta_{s+1} \sim N(\mu_{\beta 0}, \Sigma_{\beta 0}), a_{s+1} \sim N(\mu_{a0}, \Sigma_{a0})$ *and* $h_{s+1} \sim N(\mu_{h0}, \Sigma_{h0})$.

In addition, we used the Bayesian inference to estimate the above equation because the TVP-VAR model cannot estimate a posterior distribution with the general maximum likelihood method due to several latent variables. Therefore, most TVP-VAR models use the MCMC method.

3-2. ERPT model

In the following empirical sections, we use the following specification in equation (4) with exchange rate/price indices as y_t: er_t denotes exchange rate index, p_t^{im} denotes import price index, p_t^{dp} denotes domestic producer price index, and p_t^{cpi} denotes (core) consumer price index.

$$\begin{bmatrix} er_t \\ p_t^{im} \\ p_t^{dp} \\ p_t^{cpi} \end{bmatrix} = I_4 \otimes \begin{bmatrix} er_{t-1} & p_{t-1}^{im} & p_{t-1}^{dp} & p_t^{cpi} \cdots er_{t-6} & p_{t-6}^{im} & p_{t-6}^{dp} & p_t^{cpi} \end{bmatrix} \beta_t + \mathrm{A}_t^{-1}\Sigma_t e_t \tag{5}$$

Note that β_t is 96×1 row vector and follows a random walk process.

4. The base model: Overall NEER, general IPI, general PPI, and core CPI

In this section we estimate the base model using the general prices covering all industries. Our final goal is to provide detailed examination of the effect of unconventional monetary policy on core CPI. Among many possible channels, we focus on the exchange rate channel on macro-level prices including core CPI.

As the base model, we apply equation (4) for the general price index, i.e., aggregated prices over all industries. The number of lags is chosen to be six months, long enough to allow rich dynamics but not troubled with estimating too many parameters. Overall NEER is constructed in the same manner as industry NEER described in section 2-3, replacing industry-level county weights by country weights in total imports of Japan.

4-1. Exchange rate pass-through on consumer price (core CPI)

First of all, we are interested the effect of exchange rate changes on core CPI, which is the target of BOJ's current monetary policy. Figure 3 (a) shows the accumulated median impulse responses to depreciation shock of exchange rate on core CPI. The 3D image shows the ratio of the following two accumulated median impulse responses. On the numerator, we have the accumulated median impulse responses of core CPI to depreciation shock of exchange rate and on the denominator, we have the accumulated impulse responses of exchanger rate to its own shock[3]. Here, the vertical axis represents the strength of the response, the left horizontal axis represents the response period, and the right horizontal axis represents the year. From this figure, it is shown that the ERPT on core CPI is very small, from -0.02 to 0.02 during the period. The pass-through rate once declined, but it started to rise after 2003. The three possible explanation why the ERPT on core CPI is not so big. First, CPI includes services items which are hardly affected by exchange rates. The share of service in core CPI is about 50%. Second, the exchange rates are affecting on core CPI through imported final goods and domestic final goods using imported raw material or imported energy. Third, there are spillover effects coming from price competition with imported goods. Forth, distributors and retailers sometimes absorb the part of exchange rate risks.

The rightmost figure in top panel in Figure 4 corresponds to TVP impulse response figure in Figure 3 dissected at specific year. At January 1990 in Figure 4 (a), ERPT on consumer price is not statistically significant. Similarly, ERPT on consumer price is still not statistically significant at January 2009 in Figure 4 (b). However, ERPT on consumer price become statistically significant on the fifth month after the initial shock of exchange rate at January 2010. In 2017, the number of months after the initial shock in which ERPT becomes statistically significant increases. The level of ERPT is very low level, but its economic significance is not negligible. After 2012 the Japanese exchange rate experienced the size of depreciation of more than fifty percent. With this fifty percent change in exchange rate, the estimated level of 0.02 ERPT on consumer price bring forth inflation rate of one percent. This is not so small because this makes up about a half of inflation targeting goal of Japanese monetary policy. But we should note that the depreciation impact on core CPI is one time event and not last for long time. Thus, the effect existed but that was very small.

4-2. Exchange rate pass-through on import price

In this section, we show the effect of exchange rates on import prices. Figure 3 (b) shows the accumulated median impulse responses to depreciation shock of exchange rate on general import price

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[3] Shioji * states that **** and we adopt this method to estimating the depreciation shock on prices.

index (IPI): It is the exchange rate pass through (ERPT) on import prices which corresponds with the ordinary estimation done in the ERPT papers. The shape of impulse responses along the left horizontal axis (evaluated at any years) shows that ERPT at the first or second month is the highest and declines about five percentage point at the sixth month. Along the right horizontal axis (representing different years in the sample) shows that the ERPT increased from around 0.65 to around 0.75 evaluated at the first month. ERPT starts getting higher from around 2000. This means that the yen deprecation shock since 2012 had more impact on import price than before 2000.

The observed high ERPT might reflect large share of invoice in foreign currency; More than seventy percent of Japanese import is denominated by foreign currency in 2018[4]. It takes several months or a year to change invoiced price because of the predetermined contracts and possibly other obstructs such as menu cost. However, recent uprising of ERPT depends on other factors because invoice currency share of Japanese import has been stable. Campa and Goldberg (2005?), Otani et al. (2003) and other papers showed that the declining of ERPT are world trend and the same thing happens in Japan by around 2000. Those papers pointed out that the change of imports goods, low inflation, and menu cost were the possible explanation about the decline. But recent researches such as Shioji (?), Sasaki and Yoshida (2018) and Sasaki (2019) showed that the ERPT in Japan started to rise since around Global Financial Crises. They mention that the reasons might be related with high volatility of exchange rates and that of oil price.

4-3. Exchange rate pass-through on domestic producer price

Figure 3 (c) shows the accumulated median impulse responses to depreciation shock of exchange rate on general domestic price index (PPI). The shape of ERPT as impulse response along the left horizontal axis resembles that of ERPT on IPI in Figure 3 (b). The level of ERPT, however, is very little, ranging from0.02 to 0.09. The ERPT though not very high is still statistically significant throughout the sample years as shown in the figure in the top row and third column in Figure 4. The pass-through rate began to rise from 2002 and peaked around 2015. It is important to note that PPI only consists of domestically produced products and no imported products. The channel from exchange rate to PPI is mainly through imported inputs such as raw material and intermediate goods. We come back to the effect of this channel when we discuss Figure 3 (d) in the following.

4-4. Pass-through from import price to domestic producer price

Figure 3 (a) through (c) show the effects of exchange rate shock on core CPI at different levels, also reflecting interrelationship among three price indices. Impulse response in the figures reflect the direct effect from exchange rate and also the indirect effects from two other price indices. IPI can

[4] Japan's Ministry of Finance shows the share of Japanese Yen as import currencies is 24.6% in the first half year of 2018. http://www.customs.go.jp/toukei/shinbun/trade-st/tuuka.files/tuuka30fh.pdf

possibly affects PPI in two ways. First, the effect through input structure can transmit changes in import price to domestic producer price. The prices of imported raw material and imported intermediate goods are included in PPI as part of production cost. For example, 23 percent of electronical machinery is imported materials. Second, competitive or substitution effect should be detected between import products and home-produced products in the same industry. The first effect may appear across different industries, but the second effect can only happen within the same industry.

To see how an initial shock in import price affect domestic producer price, Figure 3 (d) shows the accumulated median impulse responses to a shock of IPI on PPI. The level of pass-through from import price to producer price is around 0.1. Ten percent pass-through is relatively small; however, the effect of import prices on producer price is statistically significant throughout the sample period. The figures in the second row and third column in Figure 4 (a) through (d) show that the lower confidence interval line is above zero.

4-5. Pass-through from domestic producer price to consumer price

Services constitute about half of core CPI components. Therefore, only indirectly if any, producer prices affect prices of services. The rest of core CPI consists of domestic final goods and imported final goods. Domestic final goods must be strongly affected by producer price level, PPI. Figure 3 (e) shows the accumulated median impulse responses to a shock of PPI on core CPI. The maximum value of around 0.4 is in accordance with the case in which producer price is fully passed through on the prices of final goods and zero pass-through on services.

4-6. Summary on the results of the base model

The base model uses general price indices, which aggregate prices across industries, so that transmission from a higher level of prices (or exchange rate) to a lower level of prices involve both within industry effect and spillover effect across industries. By estimating exchange rate and three stages of price indices in TVP-VAR framework, we find that from exchange rate to import prices, producer prices, and consumer prices, ERPT are 65-75 percent, 2–9 percent, and about 2 percent, respectively. ERPT decreases as the level of prices moves to lower (from upstream to downstream in the distribution system) level. ERPT at import price level and producer price level are statistically significant throughout the all sample years; however, ERPT at consumer price level only becomes statistically significant in years after 2010. In addition, pass-through from import prices to producer prices is about 10 percent and pass-through from producer prices to consumer prices is about 40 percent.

The table 1 is the imported inputs share by industry. The table is listing 18 industries whose share is above 10% out of 37industries. The share of imported material is 97% in mining industry, and that of textile products is 57%. Industries whose share is over 50% are only two, and 19 industries not listed here use less than 10% imported material. This is direct use of imported material but most company use import materials indirectly through energy supplies, mainly petroleum which is mostly imported. Table 2 shows that the share of petroleum and coal products inputs and the share of mining inputs. The table shows top 10 industry who use petroleum and coal products, which includes top 2 industries for mining inputs. Transport and postal services, Chemical products, and Electricity and gas and heat supply, use petroleum and coal products inputs and the share is 11%, 8% and 8%, respectively. As for mining, Petroleum and coal products and Electricity, gas and heat supply use mining and the share is 66% and 33%. In summary, it seems that the following industries listed here are effected by exchange rate changes directly or indirectly through petroleum , coal or mining; mining, textile, Transport and postal services, Chemical products, and Electricity and gas and heat supply, Petroleum and coal products and Electricity, gas and heat supply.

5. Which import sector is the most influential? Industry NEER, industry import price, general domestic producer price, and consumer price index

Having used general price indices, estimated results obtained in the previous subsection includes both within-industry effect and spillover effect across industries. Within-industry effect is transmission of price change in an industry at an upper level to the price change in the *same industry* at a lower level. For example, higher price of domestically produced electronics product brought forth by an increase in the price of imported electronics products is within-industry effect. On the other hand, spillover effect is transmission of price change in an industry at an upper level to the price change in *different industries* at a lower level. For example, a higher price of home-produced electronical machinery product caused by a higher price of imported petroleum is spillover effect. In this subsection we report the results of TVP-VAR estimation using NEER constructed at the industry level, import price index at industry level, general domestic producer price, and consumer price.

5-1. Exchange rate pass-through on import price

In Figure 5 we present exchange rate pass-through on industry import price. More specifically, exchange rate pass-through is based on cumulated impulse responses with industry-level nominal effective rate and import price index decomposed at the industry level. There are three noteworthy findings in this industry-level analysis. First, for many industries the level of ERPT increased over years. Along the right horizontal axis (measured at the 25th month period), there are about 30 percentage increase in metals industry, 20 percentage points increase in wood products industry, 15 percentage points increase in petroleum industry, 10 percentage points increase in chemical industry, 8 percentage points increase in electronics industry, and 25 percentage points increase in others industry. Second, ERPT jumps in a short-term period after an initial shock. Almost in all industries, ERPT moves up and down, forming a hump shape, within six months period after an initial shock along the left horizon axis. The degree of variation and consequent dynamics after six months vary by industries. Third, the degrees of ERPT are relatively high, higher than 0.5 except for textiles industry in the whole sample period and chemical industry in first half of the sample.

5-2. Pass-through from industry import price to general producer price

To see how an initial shock in import price at industry level affect general producer price, Each figure of Figure 6 shows the accumulated median impulse responses to a shock of industry-level IPI on general PPI. The levels of pass-through from industry-level import price to general producer price are all below 0.1, many of them staying below 0.06 throughout the whole sample years. These levels are comparable to ten percent pass-through estimated in Figure 3 (d).

Along the right-horizontal axis (representing a change in the level of pass-through annually), a sudden increase in pass-through after 2000, shown as a break in slope, can be observed for seven (out of nine) industries, namely, textiles, wood products, petroleum, chemical, electronics, transportation, and others-industry. On the other hand, dynamic paths of pass-through along the left-horizontal axis are not alike; oscillating (textiles, wood products, chemicals), increasing to the peak within a year (metals, petroleum, others), large drop (general machinery), and v-shaped within a year (electronics, transportation).

5-3. Discussions and summary

Since the main difference in the selection of variables in this subsection from previous subsection 3-2 is introduction of exchange rate and import price at the industry-level, we only discussed estimation results directly involving industry-level import price. We suppress the estimation results for the following analysis because of small changes in comparison with the previous analysis; exchange rate pass-through on general producer price, exchange rate pass-through on core CPI, pass-through from general producer price to core CPI.

The analysis based on the import prices and exchange rates decomposed at the industry level revealed the different dynamic paths of ERPT among industries. Industries associated with resource or material (wood products and petroleum) show relatively higher ERPT, closer to complete pass-through.

6. Direct effect on the same industry: Industry NEER, industry import price, industry domestic producer price, and consumer price index

Substituting industry-wise domestic producer price index for general domestic producer price for overall industries does not affect qualitatively on the relationship between prices not involving producer price index. Figure 7 shows ERPT on import price at the industry level. Changes in shape of three-dimensional figure representing dynamic paths of time-varying pass-through are noticeable for some industries; however, the overall level of ERPT are similar between Figure 5 and Figure 7. On the other hand, the pass-through from industry import price index to industry producer price index in Figure 8 differs substantially from the pass-through estimated for general producer price index in Figure 6. The important difference between the estimated results in Figure 8 and that of Figure 6 is that the former only captures within-industry effect whereas the latter also cover across-industry effect in addition to within-industry effect. However, in Figure 6, these effects are averaged out and we only observed low pass-through, below ten percent for all industries.

6-1. Pass-through from industry import price to industry producer price

The most import result in Figure 8, distinct from previous analysis based on general producer price in Figure 6, is the elevated level of pass-through. For the most of industries, about 30 percentage points increase in pass-through, relative to the estimates obtained for general producer price analysis, is observed. This evidence supports that within-industry effect, in which domestic producers adjust the prices of their own products in accordance with the prices of similar imported products, is not low (above 30 percent). Combined with evidence obtained from general producer price analysis in Figure 6, it can be induced that spillover effect, in which a change in the price of imported products in one industry affects the price of domestically produced products in other industries, is low or negligible.

6-2. Pass-through from industry producer price to general consumer price

Figure 9 provides for each industry the pass-through from industry-level producer price to overall consumer price. The level of pass-through evaluated at the longer horizon of more than twelve months is below 10 percent, except for textile and metal industries. These levels are much smaller than around 30 percent of pass-through obtained in Figure 3 (e). In terms of time-varying ERPT along response period on the left-horizontal axis, a hump shape of jumping up and down within a year is observed for many industries, resembling the dynamics of ERPT on import prices.

6-3. Discussions and summary

From the base model results in Figure 3 (c), we learned ERPT on core CPI is only less than three percent despite that ERPT on general import price is above 65 percent. We also find that small pass-through of less than 20 percent from general import price to producer price is the obstacle to passing through price changes to the final price at the consumer level, i.e., core CPI. The evidence obtained from industry-level producer prices in this subsection revealed the core obstacle is the absence of price linkage of imported products and domestically produce products between different industries. We can conclude from these evidences that exchange rate pass-through on the price of imported products is high, but negligibly small pass-through from import price of one industry to domestic producer price of another industry reduces the effect of exchange rate changes on consumer price level.

7. Discussions and policy implications

The estimated results from the base model provides clear-cut evidence on statistically significant but economically weak effect of the Japanese yen depreciation on core consumer prices. However, ERPT on consumer price is increasing in recent years, coinciding with the Abe administration. In this study, we also estimated exchange rate pass-through on other stages of prices in Japan. At the import price level, exchange rate pass-through is substantial; however, it becomes very low of about 2-8 percent at the producer price level. Our results confirm the claim of Mishkin (2008) that exchange rate fluctuations matter, but we also find that the effect is a little.

What are the impediments that hold exchange rate fluctuations from exerting substantial effect on core consumer price index? By estimating pass-through between consecutive stages, we found that it is the transmission from import prices to domestic producer price. Running TVP-VAR model by industry NEER and industry IPI demonstrate that there is not much heterogeneity of pass-through effects (from industry IPI to general PPI) among IPI industries. This evidence can be supported by two possible scenarios. First, when the import price of one industry fluctuates, competing domestic producers in the industry do not respond because their products fall in different category or elasticity of substitution for their products is low. Second, because of general producer prices used in the model, the spillover effect to producer prices of other industries is limited although pass-through on producer price of the same industry is relatively large. To distinguish these two possible scenarios, as an additional robustness check, we run TVP-VAR model with industry NEER, industry IPI, industry PPI, and core CPI. The estimated results are shown in Figure 8. The pass-throughs from import price to producer price in the same industry are substantial, i.e. from 10 (general machinery) to 50 (petroleum) percent. We conclude that exchange rate effect on consumer price is small because of weak spillover effect of industry import price to domestic producer prices of other industries.

On the dynamic paths of pass-through based on the estimated time-varying coefficients, two key results are obtained. First, in terms of responses to an initial shock, ERPT on import prices and also pass-through from producer price to consumer price demonstrate a hump-shape of jumping up and down within a year. Second, the ERPT had gradually increased in the 1990s and the rate of increase becomes larger in the 2000s.

8. Conclusion

Against the background of Japanese two percent inflation targeting started in 2013, we investigate what have impeded the process of passing exchange rate fluctuations to core consumer price index. To this end, we constructed industry-wise nominal effective exchange rate and industry-wise producer price indices, which are matched with import price indices. Time-varying parameter vector autoregression analysis reveals that exchange rate pass-throughs in general increased especially after, and possibly prior to, the global financial crisis. In terms of pass-through at each stage of import price, domestic producer price, and consumer price, we find the weakest link lies between import price and domestic producer price. However, the impact within an industry is not negligent; what is hindering consumer price to rise after depreciation is little spillover effect to other industries at the producer price stage.

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Appendix.

Table A1. Industry list for produce price index (PPI) and import price index (IPI)

Producer Price Index	Import Price Index
(1) Beverages & foods	(1) Beverages & foods and agriculture products for food
(2) Textile products	(2) Textiles
(3) Lumber & wood products	(3) Metals & related products
(4) Pulp, paper & related products	(4) Lumber & wood products and forest products
(5) Chemicals & related products	(5) Petroleum, coal & natural gas
(6) Petroleum & coal products	(6) Chemicals & related products
(7) Plastic products	(7) General purpose, production & business-oriented machinery
(8) Ceramic, stone & clay products	(8) Electric & electronic products
(9) Iron & steel	(9) Transportation equipment
(10) Nonferrous metals	(10) Other primary products & manufactured goods
(11) Metal products	
(12) General purpose machinery	
(13) Production machinery	
(14) Business oriented machinery	
(15) Electronic components & devices	
(16) Electrical machinery & equipment	
(17) Information & communications equipment	
(18) Transportation equipment	
(19) Other manufacturing industry products	
(20) Agriculture, forestry & fishery products	
(21) Minerals	
(22) Electric power, gas & water	
(23) Scrap & waste	

Table A2. An example of corresponding Table between IPI categories and PPI categories

<table>
<tr><th colspan="2">Import Price Index (IPI)</th><th colspan="2">Producer Price Index (PPI)</th></tr>
<tr><td>IPI industry</td><td>IPI sub-industry</td><td>PPI industry</td><td>PPI sub-industry PPI group of commodities</td></tr>
<tr><td rowspan="2">IPI(1) Beverages & foods and agriculture products for food (80.4)</td><td>Agriculture products for food (21.6)

Livestock products for food (14.6)</td><td>PPI(20) Agriculture, forestry & fishery products (35.8)</td><td>Agriculture products (17.3)

Livestock products (15.0)

*Fishery products (2.5)

*Forestry products (1.0)</td></tr>
<tr><td>Primary processed foodstuffs (2.0)

Prepared & preserved foodstuffs (25.9)

Beverages (7.0)

Tobacco products (5.2)

Foodstuffs (4.1)</td><td>PPI(1) Beverages & foods (141.6)</td><td>Primary processed foodstuffs (5.2)

Prepared & preserved foodstuffs (94.2)

Beverages (25.9)

Tobacco products (9.7)(9.7)

Foodstuffs (6.4)

*Ice (0.2)</td></tr>
</table>

Note: IPI() and PPI() correspond to industries listed in the Table A1. Figures in parenthesis indicate the weight of corresponding industry/sub-industry out of 1,000. * indicates that there is no corresponding product category in import price index. This table is only for Food & Beverage industry. Similar tables are constructed for other industries are available upon request.

Table 1. Imports share by industry (>0.1)

	Imports / Domestic Demand
Mining	0.97
Textile products	0.57
Information and communication electronics equipment	0.45
Non-ferrous metals	0.35
Electronic components	0.29
Electrical machinery	0.23
Business oriented machinery	0.22
Miscellaneous manufacturing products	0.21
Chemical products	0.2
Agriculture, forestry and fishery	0.18
Petroleum and coal products	0.17
Beverages and Foods	0.16
Pulp, paper and wooden products	0.15
General-purpose machinery	0.14
Production machinery	0.13
Plastic and rubber products	0.11

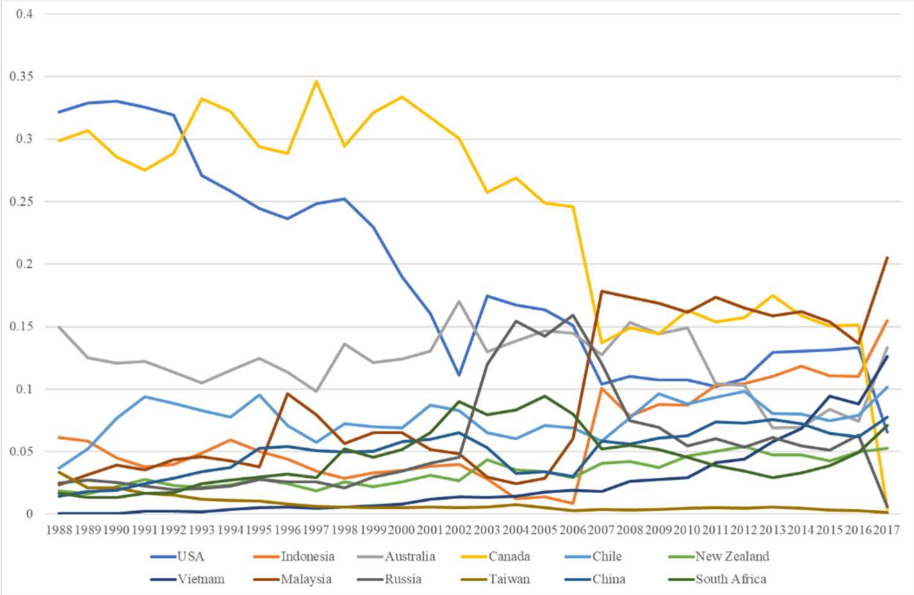
(Source) Input output tables, Ministry of internal affairs and communications

Table 2. Petroleum and coal products and mining inputs

	Share of Petroleum and coal products	Share of Mining	Total of intermediate sectors	Total of gross value added sectors
Transport and postal services	0.11	0	0.5	0.5
Chemical products	0.08	0	0.75	0.25
Electricity, gas and heat supply	0.08	0.33	0.77	0.23
Petroleum and coal products	0.06	0.66	0.78	0.22
Iron and steel	0.04	0.06	0.81	0.19
Mining	0.03	0	0.55	0.45
Ceramic, stone and clay products	0.03	0.06	0.56	0.44
Activities not elsewhere classified	0.03	0	0.6	0.4
Agriculture, forestry and fishery	0.02	0	0.51	0.49
Water supply	0.02	0	0.52	0.48

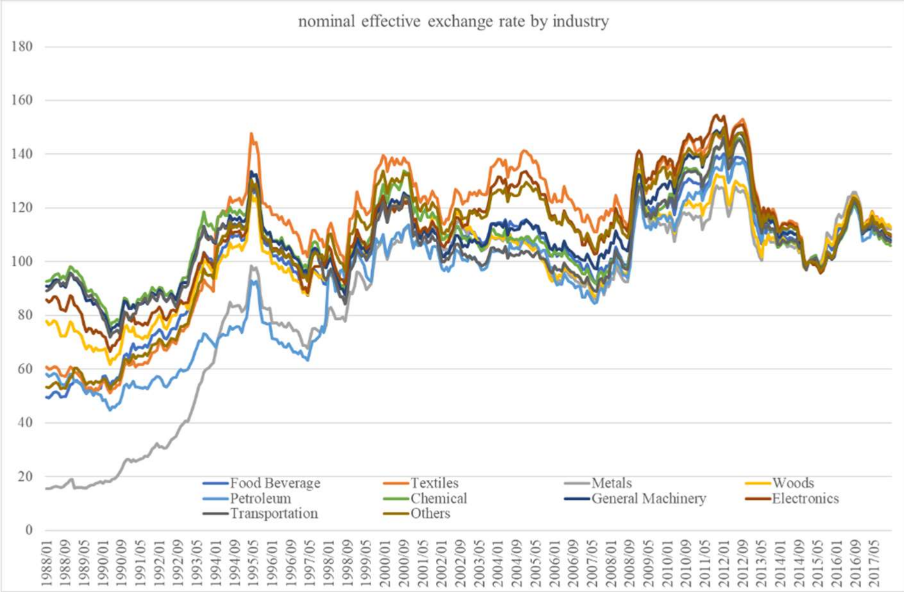
(Source) Input output tables, Ministry of internal affairs and communications

Figure 1. Country weights for IPI(4) ‘Wooden Products’



Note: Country weights are calculated as the ratio of the value of partner country’s export to Japan to the total import value of Japan for corresponding industry for each year.

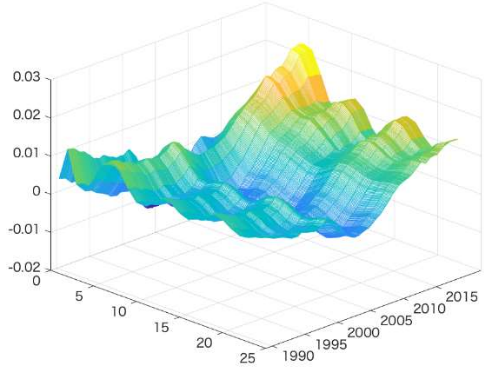
Figure 2. Nominal effective exchange rate by industry



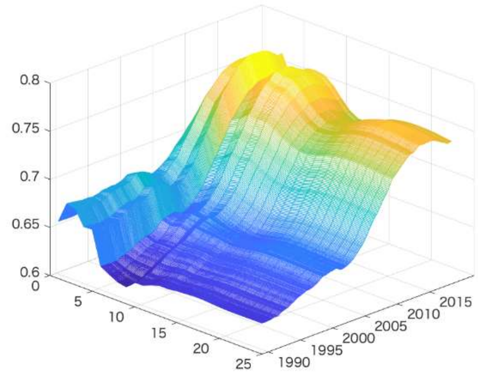
Note: The definitions of industries correspond to Import Price Indices by the Bank of Japan. The annual import values of top twenty trade partners of Japan for each industry are used for weight in calculating nominal effective exchange rates at monthly frequency.

Figure 3. Base model (NEER, general IPI, general PPI, core CPI)

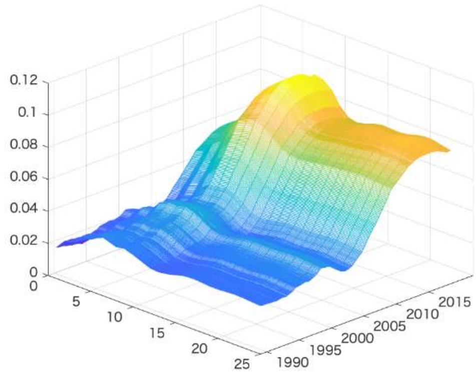
(a) exchange rate pass-through on core CPI



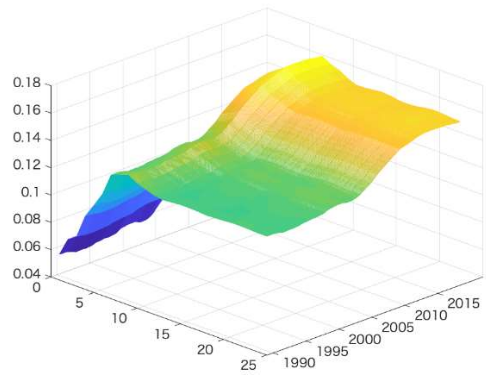
(b) exchange rate pass-through on IPI



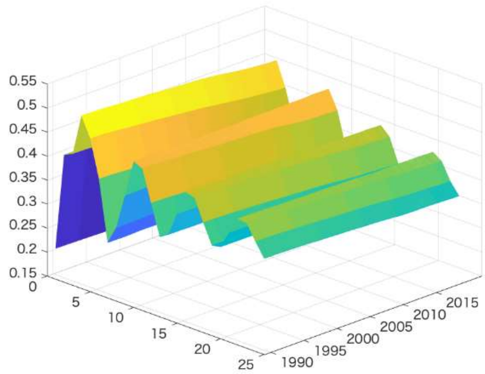
(c) exchange rate pass-through on PPI



(d) pass-through from IPI to PPI



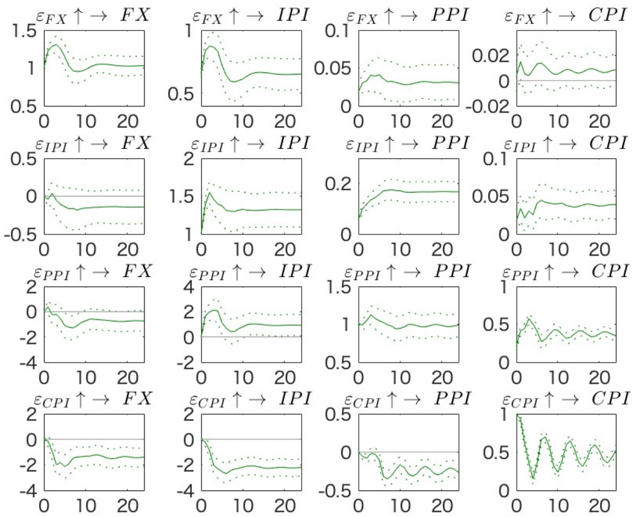
(e) pass-through from PPI to core CPI



Note: TVP-VAR are estimated with 6 lags. Pass-through is calculated as the ratio of the following cumulated impulse responses. On the numerator, cumulated impulse responses of target price to a shock of source price is used. On the denominator, cumulated impulse responses of source price to a shock of own (source) price is used.

Figure 4. Impulse responses of base model

(a) 1990.1



(b) 2000.1

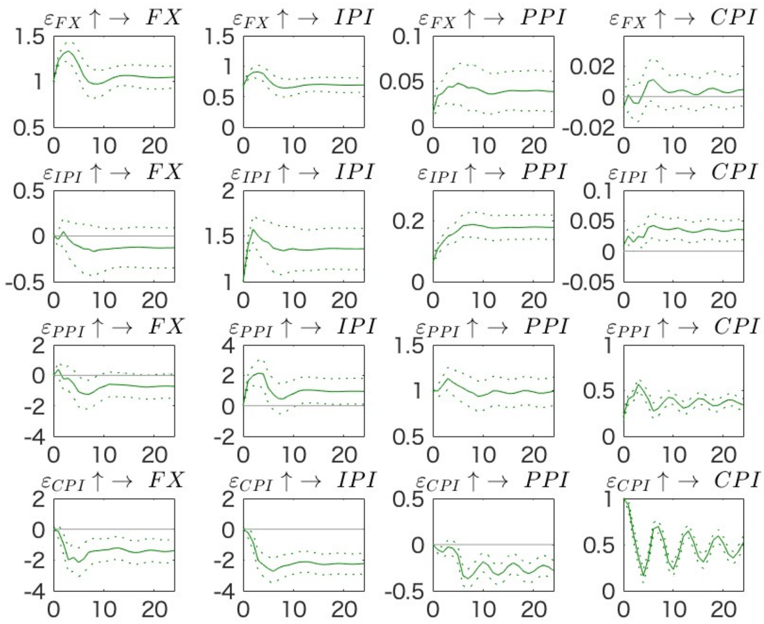
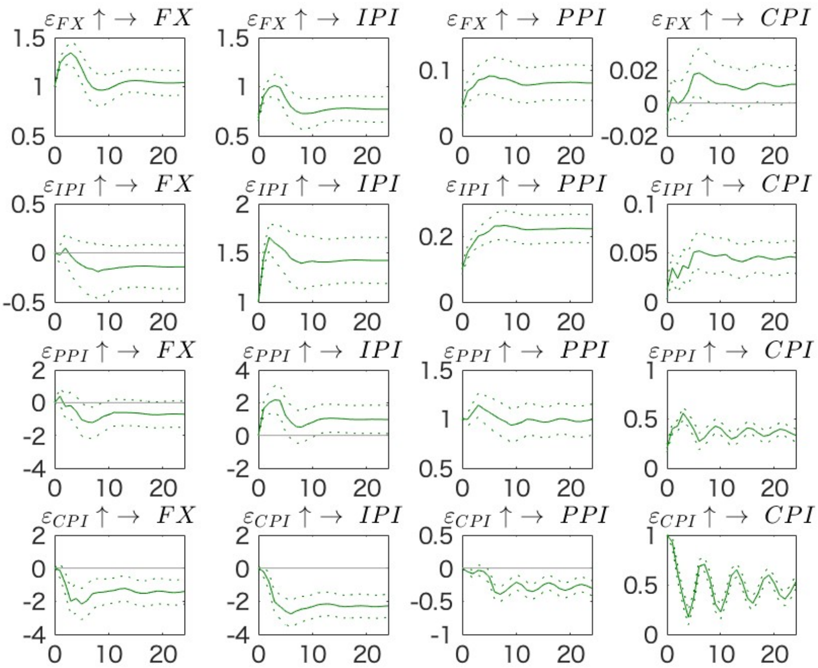


Figure 4. Impulse responses of base model (continued)

(c) 2010.1



(d) 2017.1

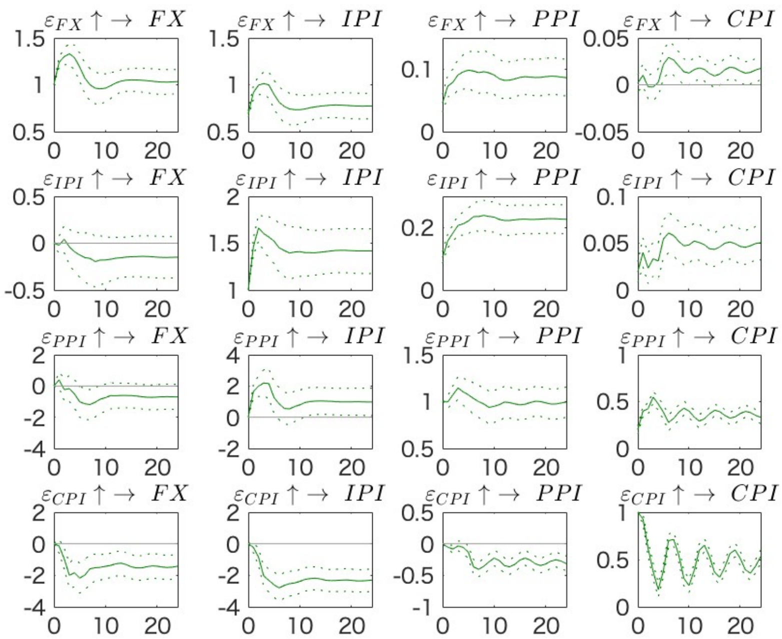
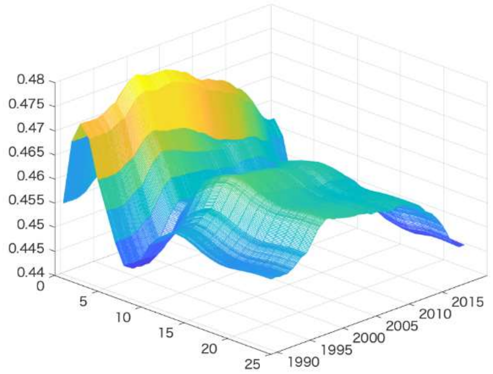
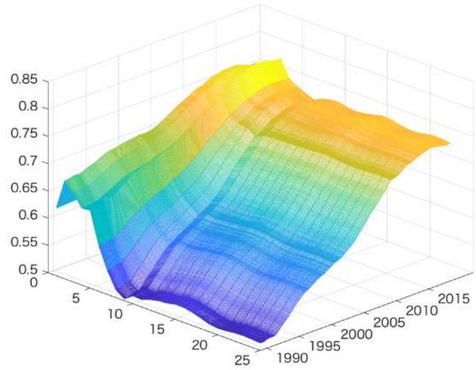


Figure 5. Exchange rate pass-through on industry import price, (industry-NEER, industry-IPI, general PPI, core CPI)

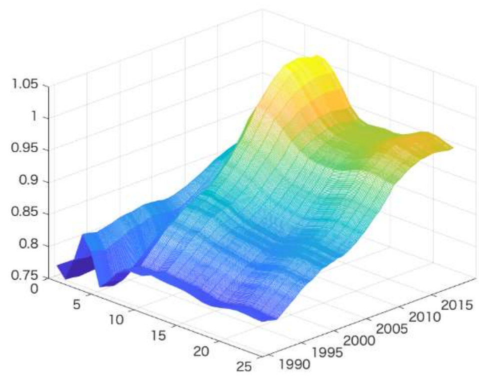
(a) textiles



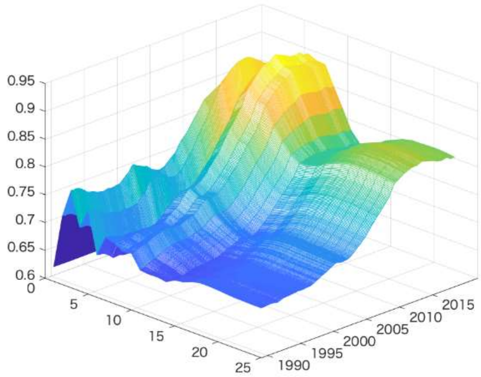
(b) metals



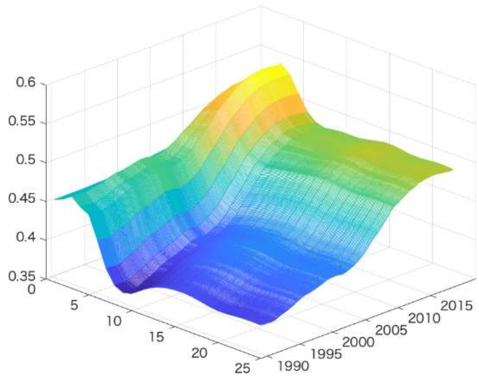
(c) wood products



(d) petroleum



(e) chemical



(f) general machinery

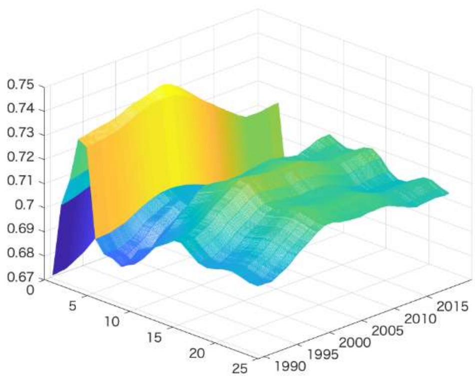
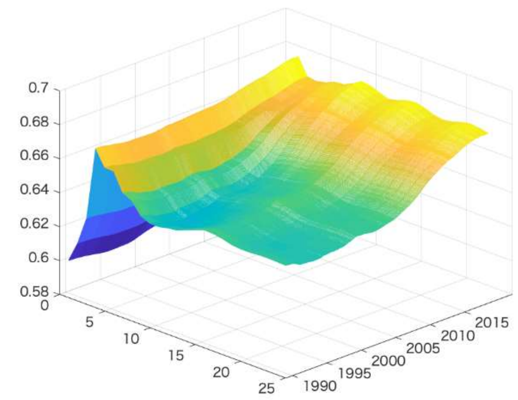
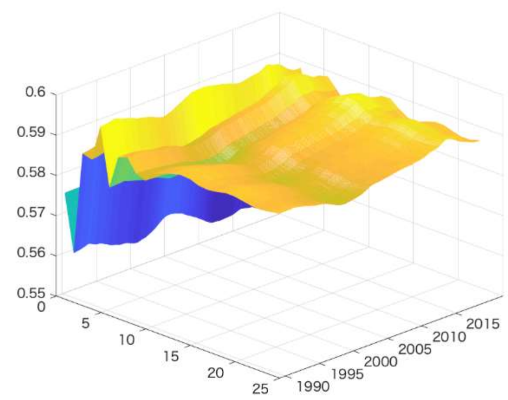


Figure 5 (continued) Exchange rate pass-through on industry import price, (industry-NEER, industry-IPI, general PPI, core CPI)

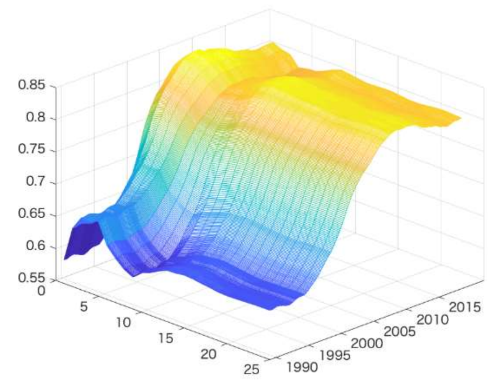
(g) electronics



(h) transportation



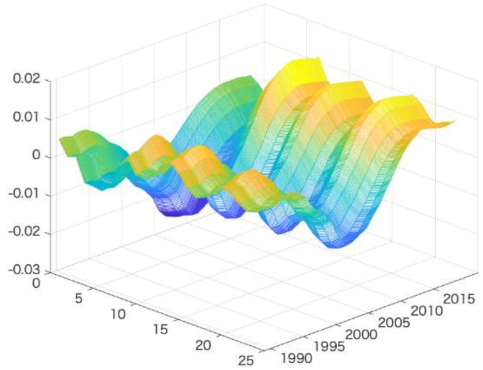
(i) others



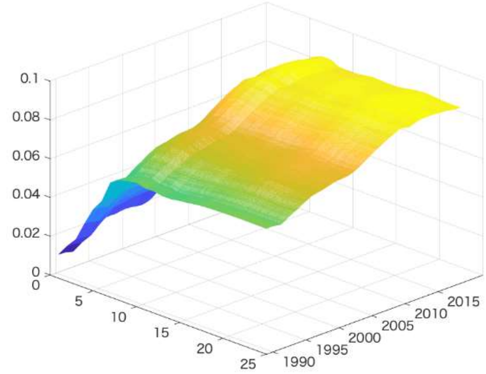
Note: see the note under the Figure 3.

Figure 6. Pass-through from industry import price to general producer price index, (industry-NEER, industry-IPI, general PPI, core CPI)

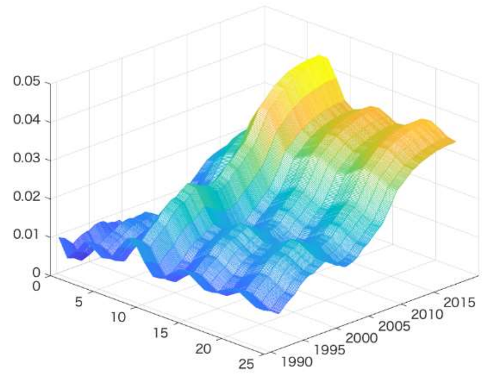
(a) textiles



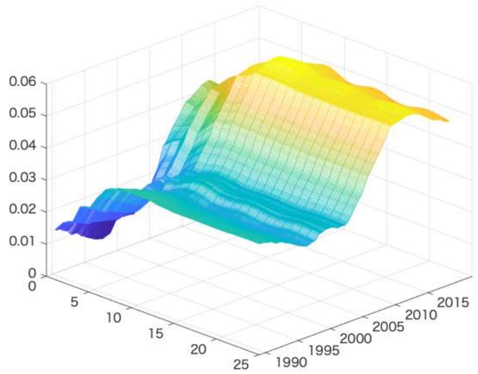
(b) metals



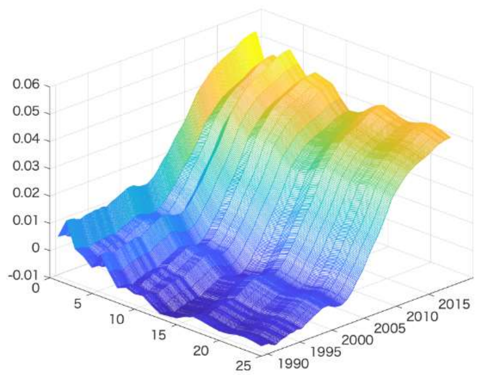
(c) wood products



(d) petroleum



(e) chemical



(f) general machinery

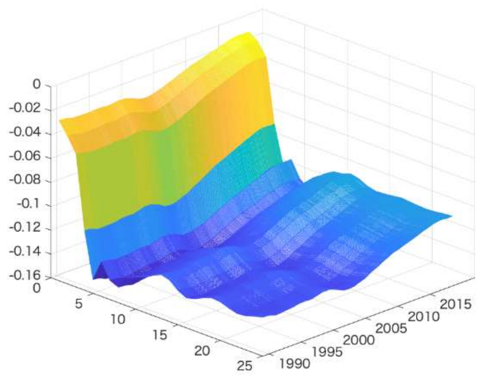
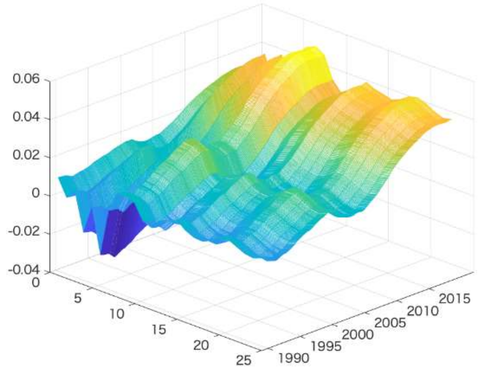
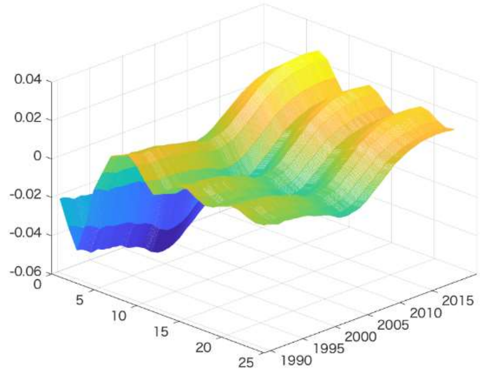


Figure 6. (continued) Pass-through from industry import price to general producer price index, (industry-NEER, industry-IPI, general PPI, core CPI)

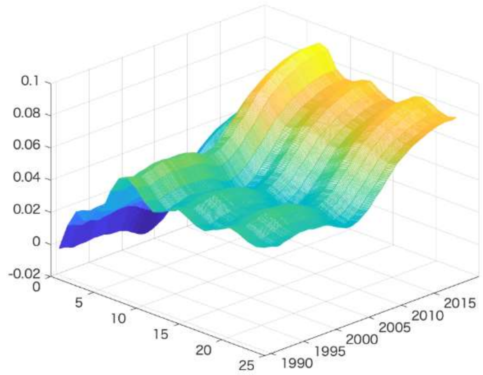
(g) electronics



(h) transportation



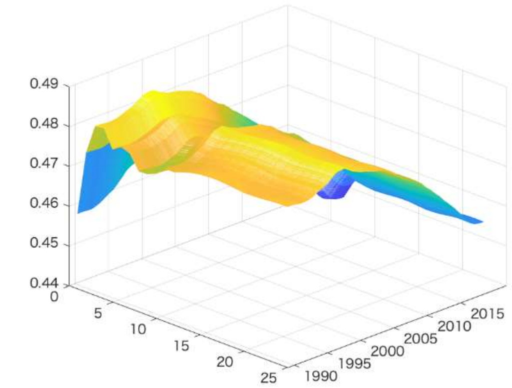
(i) others



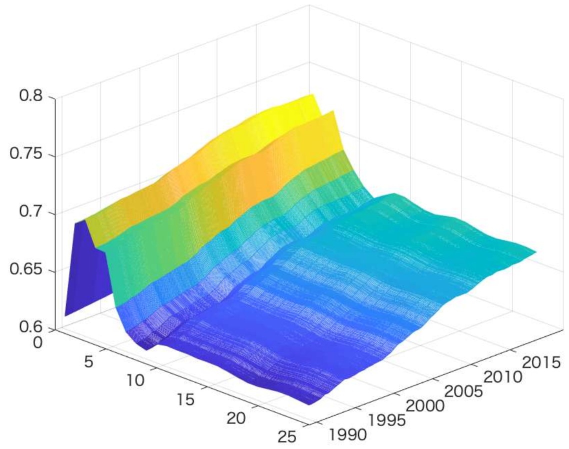
Note: Nominal effective exchange rates and import prices are by industry. General domestic producer price index is the weighted average of all industries. See also the notes under the Figure 3.

Figure 7. Exchange rate pass-through on industry import price, (industry-NEER, industry-IPI, industry- PPI, core CPI)

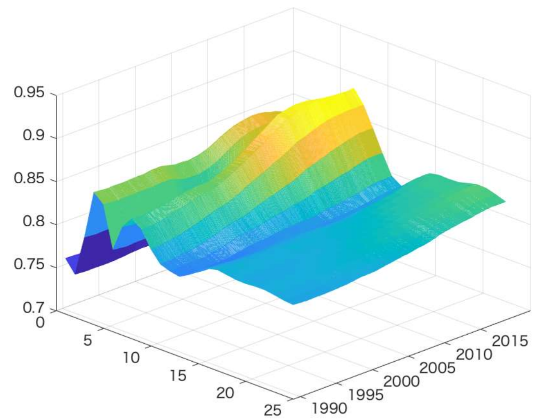
(a) textiles



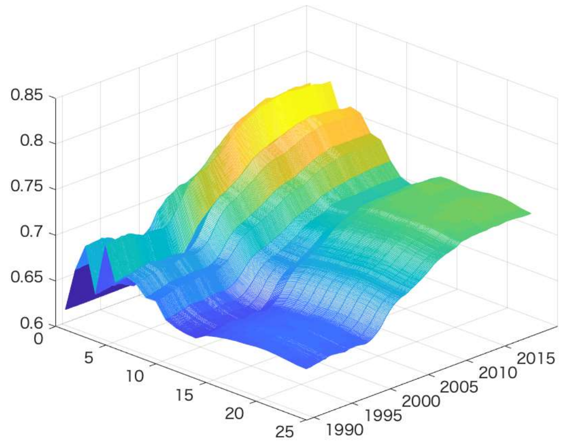
(b) metals（IPI weight）



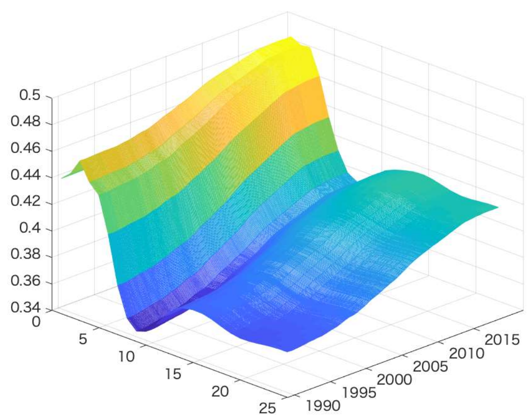
(c) wood products



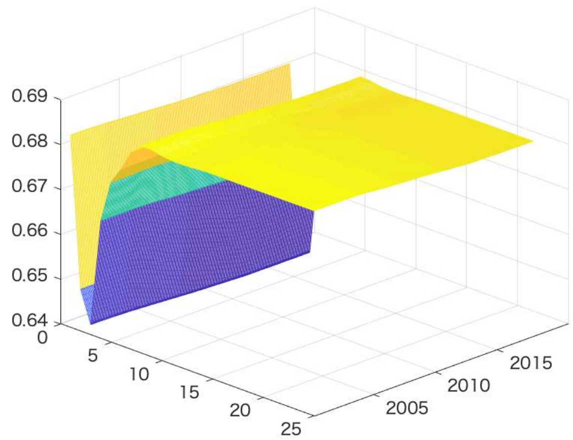
(d) petroleum



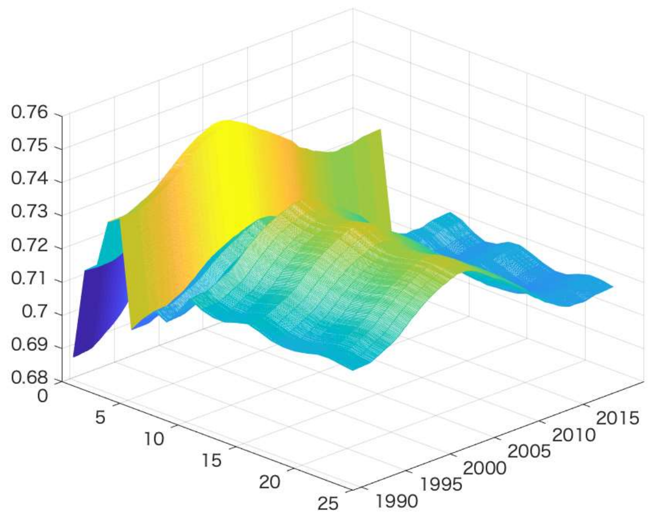
(e) chemical



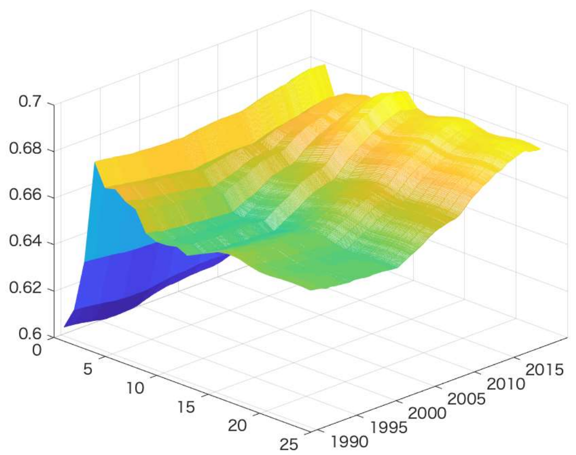
(f) general machinery_iw



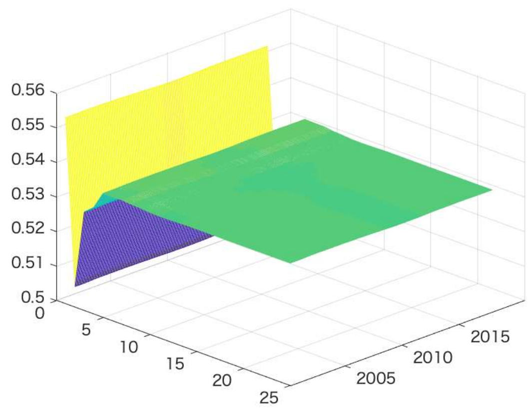
(f) general machinery_(PPI weight)



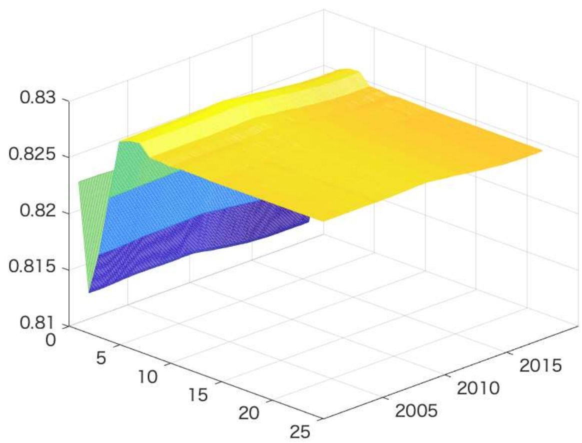
(g) electronics (IPI weight)



(h) transportation (From2000 lag3)



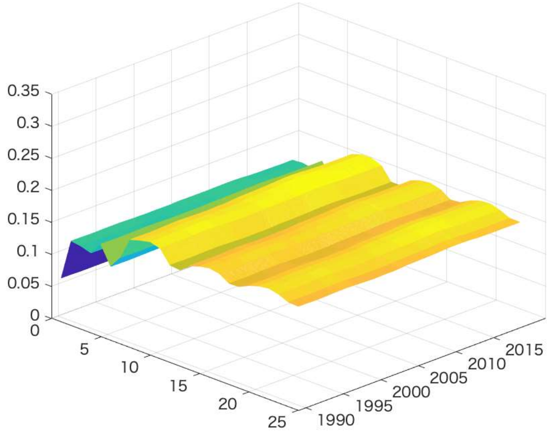
(i) others (From2000 lag3)



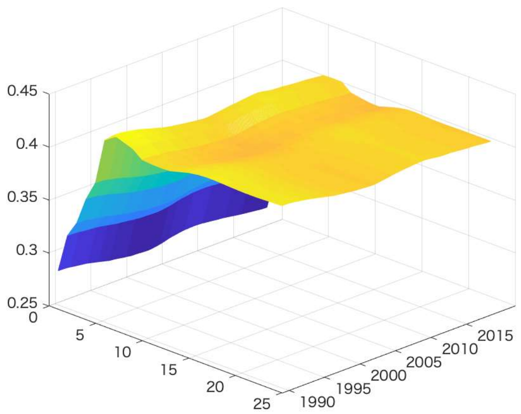
Note: See the notes under the Figure 3.

Figure 8. Pass-through from industry import price to industry producer price index, (industry-NEER, industry-IPI, industry-PPI, core CPI)

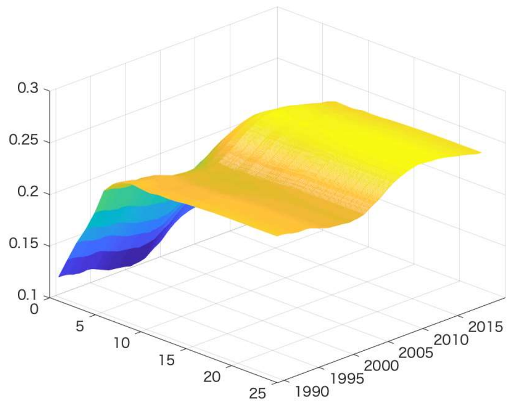
(a) textiles



(b-1) Metals (IPI weights)



(b-2) Metals (PPI weights)



(c) wood products

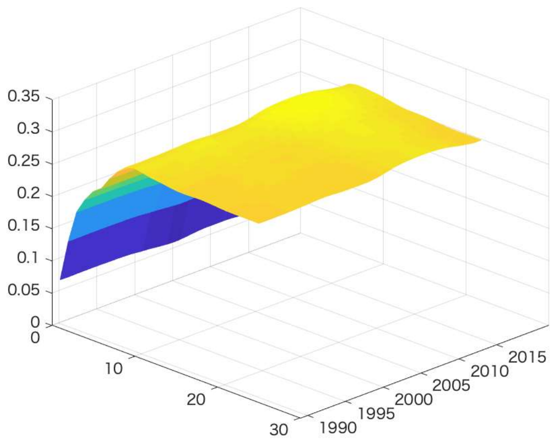
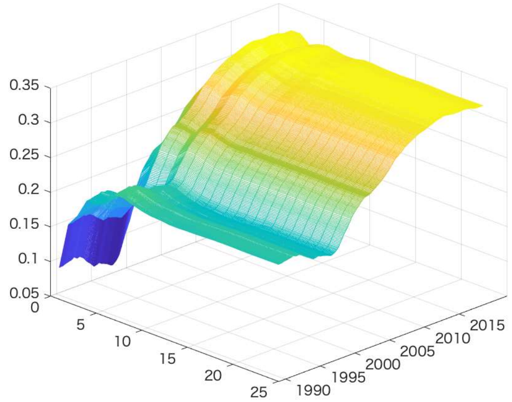
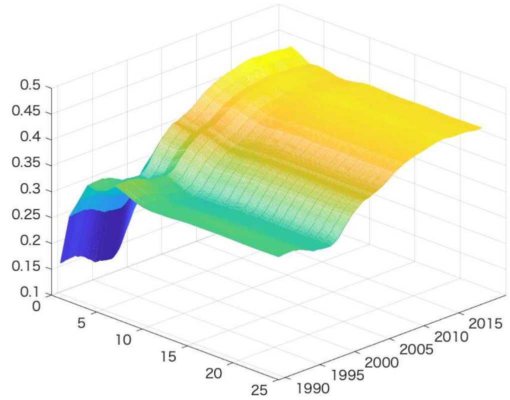


Figure 8. Pass-through from industry import price to industry producer price index, (industry-NEER, industry-IPI, industry-PPI, core CPI), continued

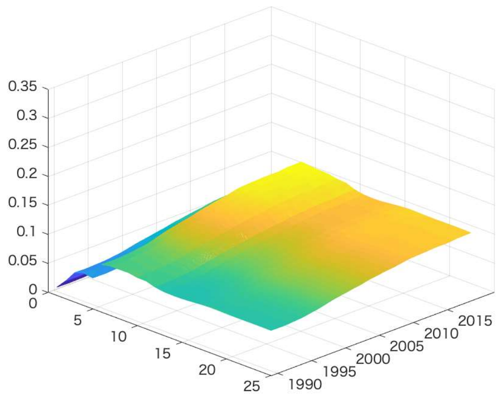
(d-1) petroleum (IPI weights)



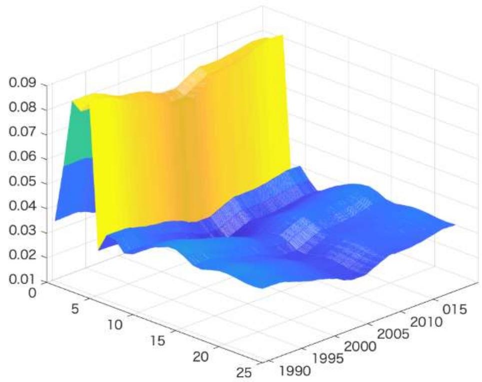
(d-2) petroleum (PPI weights)



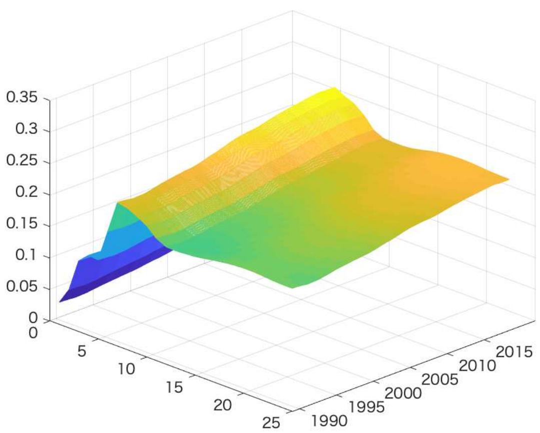
(e) chemical



(f) general machinery (PPI weights)



(g) electronics

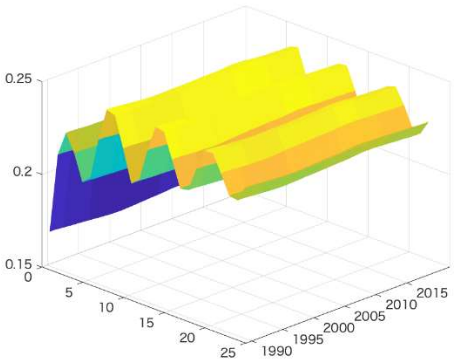


(h) transportation

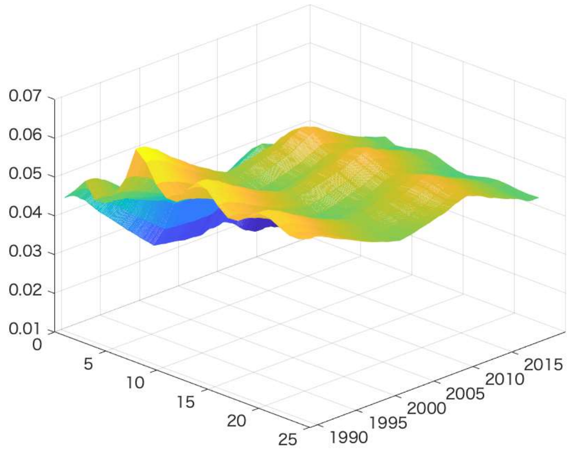
Note: See the notes under the Figure 3.

Figure 9. Pass-through from industry producer price index to core CPI, (industry-NEER, industry-IPI, industry-PPI, core CPI)

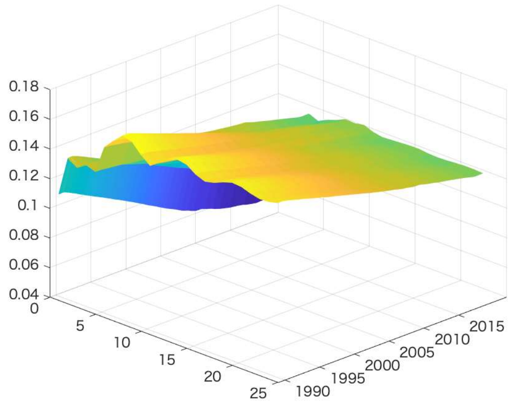
(a) Textiles (IPI)



(b-1) Metals (IPI weights)



(b-2) Metals (PPI weights)



(c) wood products

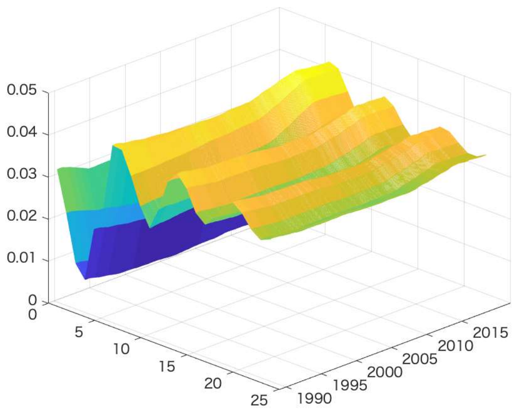
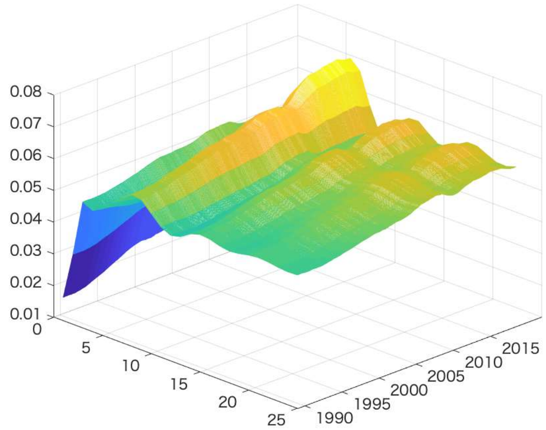
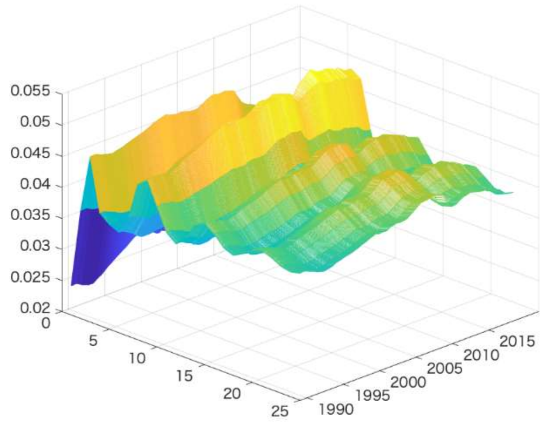


Figure 9. Pass-through from industry producer price index to core CPI, (industry-NEER, industry-IPI, industry-PPI, core CPI) continued.

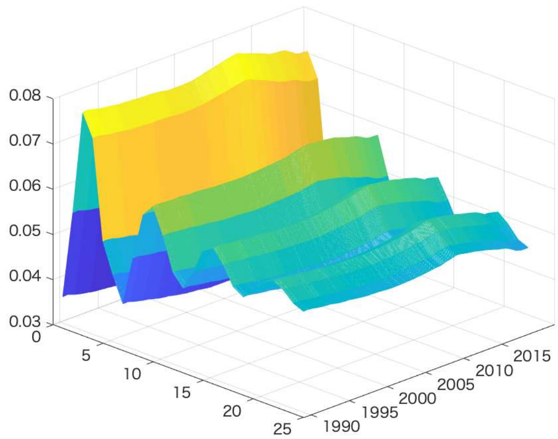
(d-1) petroleum (IPI weights)



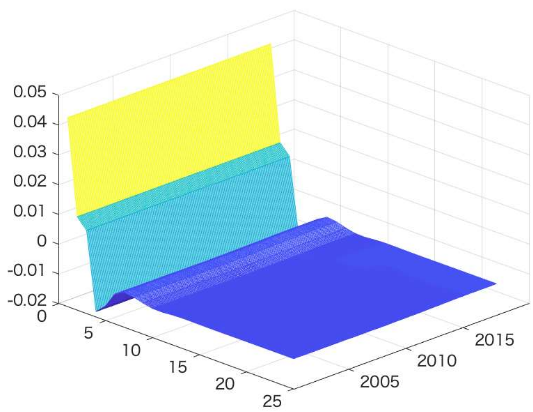
(d-2) petroleum (PPI weights)



(e) chemical



(f) general machinery (IPI weights) from2000



(f-2) general machinery (PW weights)

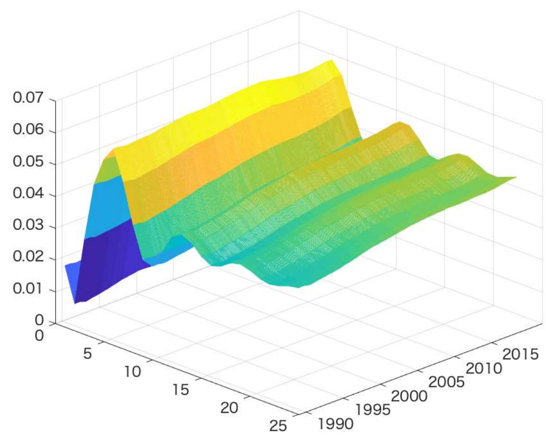
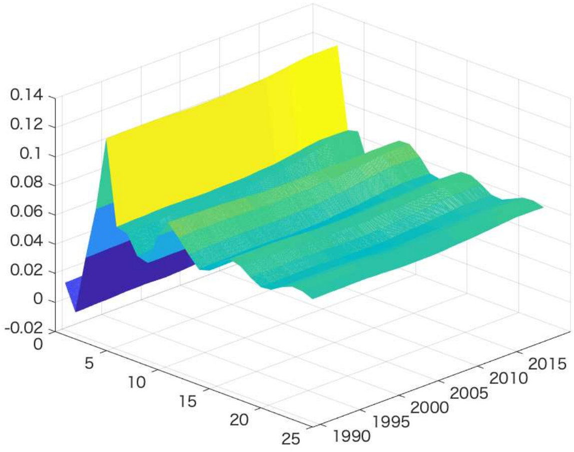
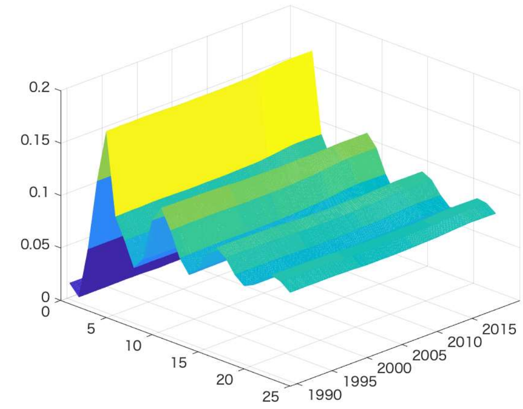


Figure 9. Pass-through from industry producer price index to core CPI, (industry-NEER, industry-IPI, industry-PPI, core CPI) continued.

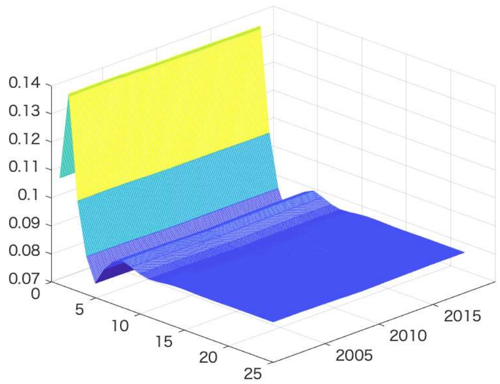
(g) electronics(IPI weights)



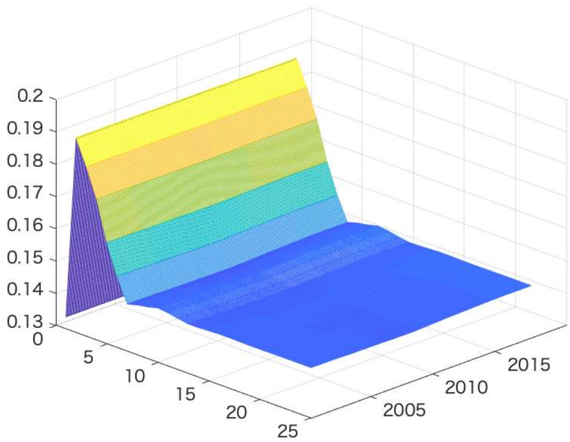
(g) electronics(PPI weights)



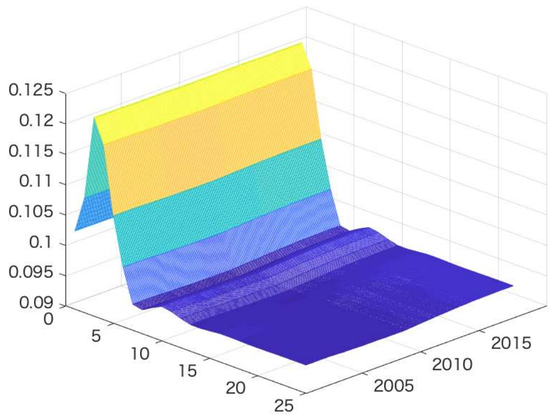
(h) transportation (From 2000, lag3)



(i) other(IPI weights) (from 2000 lag3)



(i) other(PPI weights)(from 2000 lag3)



Note: see the notes under Figure 3.