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Abstract

In this paper, with a brief examination of the global inflation synchronization, we analyze the effects of domestic and global factors on Japan's consumer price inflation and related variables (inflation expectations, nominal wages, etc.) since the late 1990s, when Japan fell into deflation, mainly using structural vector autoregression (SVAR) models with short- and long-run zero and sign restrictions. Historical decompositions show that various types of global shocks, including downward cost pressure due to globalization, had continuously pushed down Japan's consumer prices until the late 2010s. Subsequently, their contribution reversed, significantly pushing up prices, especially in the high-inflation phase after the pandemic. In addition, we find that service prices and nominal wages, which had not been much affected by global shocks, have also been pushed up significantly by global shocks in the recent period.

JEL classification numbers: E31, E52, F62
Keywords: inflation, monetary policy, globalization

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1. Introduction

Many countries have experienced high inflation in recent years, under tight market conditions following the resumption of economic activity after the COVID-19 pandemic and a surge in energy prices in the wake of heightened geopolitical tensions. Japan is no exception, with the year-on-year consumer price inflation exceeding 4 percent in January 2023 for the first time in nearly 40 years. This global inflation synchronization can be attributed partly to the result of similar shocks and structural changes facing each country such as tighter labor market conditions, but also largely reflects the spillover of shocks across countries such as energy price fluctuations and supply chain disruptions.

Discussions about the global inflation synchronization before the pandemic pointed to an increasing trend of synchronization, especially since the early 2000s when emerging markets increased their integration into the global economy, mainly lowering inflation in each country (Ha, Kose, and Ohnsorge, 2023). The factors identified at that time were the increased independence of central banks in many countries including emerging markets, with the introduction of common policy frameworks such as inflation targeting; and the supply of products produced in emerging markets with their abundant resources and labor forces to global markets, which led to intense price competition combined with deregulation and other factors (Rogoff, 2003). Subsequently, in the 2010s, as many countries, especially advanced economies, experienced low inflation below the central banks' targets, a particular attention was paid to factors such as the impacts of the global financial crisis and the declining natural rate of interest. As wage levels in emerging markets rose and the gap with advanced economies narrowed, and as the growth of world trade and foreign direct investment flows slowed, the downward pressure on prices from emerging markets that had been seen in the early 2000s attracted less attention. Rather, the geopolitical tensions and protectionist trade moves that were already evident before the pandemic, and the slowing trend in the expansion of supply capacity due to aging populations and other factors in emerging markets, pointed to the possibility that the earlier downward pressure on prices could turn into upward pressure (Goodhart and Pradhan, 2020).

In order to stabilize inflation in their respective countries, central banks have conducted monetary policies that basically influence domestic factors such as the output gap. At the same time, they have also paid attention to the effects of global factors that could synchronize prices across countries on their own prices, including exchange rates that affect relative prices across countries. For example, even in the U.S., which is considered relatively insensitive to global factors because of its large size of the economy, Federal

Reserve officials in the 2000s pointed to downward pressure on U.S. prices as emerging market economies such as China and India became more integrated into the global production and trade system[1] (Greenspan, 2005; Kohn, 2006). Later in the 2010s, while there were various discussions about the impact of the Fed's monetary policy on emerging market economies through international financial markets, such as the taper tantrum, Fed officials focused on temporary and localized factors affecting U.S. prices, such as commodity price fluctuations and the slowdown in Chinese economy[2] (Fischer, 2014, 2015). Turning to Europe, the Bank of England recognized the inflationary pressure associated with de-globalization (e.g., increased tariffs and supply chain disruptions) in the process of the United Kingdom's withdrawal from the European Union in the late 2010s and responded to the extent possible within the existing monetary policy framework including the inflation targeting (Carney, 2017). The European Central Bank (ECB), in its Strategy Review completed in 2021, conducted a set of analyses implying that the downward pressure of globalization on inflation in the euro area (which at that time had been persistently below the ECB's target) had not been very large in recent years and concluded that globalization had not significantly impeded the ECB's ability to achieve price stability autonomously (Lodge et al., 2021). The Bank of Japan has been aware since the early 2000s that the inflow of low-priced goods from emerging economies has contributed to some extent to Japan's deflation, but it has pointed out, especially since the 2010s, that a deflationary mindset has taken hold among the public as prices continued to fall due to various factors, including that mentioned above, and that better-anchored inflation expectations would be one way to deal with the spillover of global factors to domestic inflation (Kuroda, 2015, 2018).

As summarized above, there have been various discussions on the factors behind the global inflation synchronization and its implications for monetary policy, depending on the situation in each country and over time. In this paper, with a brief examination of the global inflation synchronization including the post-pandemic period, we empirically analyze the effects of domestic and global factors on Japan's consumer prices inflation

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[1] In response to these statements by Fed officials, there were many counterarguments, mainly from the academia, that inflation is determined solely by monetary policy in the long run and that the effect of globalization through increased trade with emerging economies should not be overstated (e.g., Ball, 2006). At the same time, there was also an empirical debate among central bankers in various countries about whether prices in advanced economies are affected by the output gap not only in their own countries but also in other countries including emerging market economies (Borio and Filardo, 2007; Ihrig et al, 2010).

[2] Obstfeld (2020) discusses extensively the various implications of global factors for the U.S. monetary policy through prices, interest rates, exchange rates, etc. He concludes that the Fed's ability to control the price level over the long term is not necessarily undermined by global factors themselves.

and related variables since the late 1990s, when Japan fell into deflation. Main results are as follows. First, the global inflation synchronization has increased significantly after the pandemic, both for the consumer prices including and excluding energy prices. Second, with regard to the historical developments of Japanese consumer prices, various types of global shocks, including downward cost pressure due to globalization, in addition to negative domestic demand shocks and other shocks, had exerted downward pressure on prices continuously until the late 2010s. After the Bank of Japan introduced the Quantitative and Qualitative Monetary Easing (QQE) in 2013, domestic shocks, mainly monetary policy shocks, contributed to price increases, but the downward pressure from the aforementioned global shocks offset this to some extent. However, the contribution of these global shocks, which include not only temporary but also persistent shocks, reversed and significantly pushed up prices especially in the post-pandemic period of high inflation. As for other variables related to consumer prices, the effect of global shocks on medium- and long-term inflation expectations has been limited so far, but service prices and nominal wages have been pushed up significantly by global shocks in the recent period, in contrast to the past.

The main analytical tool in this paper is structural vector autoregression (SVAR) models estimated using Bayesian methods with a combination of short- and long-run zero and sign restrictions. The baseline model includes macroeconomic variables such as real GDP and consumer prices for Japan and other countries (G20 excluding Japan), and the nominal effective exchange rate of the Japanese yen, treating domestic and foreign variables symmetrically to capture various types of global shocks in a systematic way. Alternative models to check the robustness include variables corresponding to specific global shocks, such as oil prices and the global supply chain pressure index, which confirm that the main results of the baseline model remain largely unchanged. In addition, as the short-term interest rates were significantly affected by the effective lower bound during the estimation period (especially in Japan), the 2-year, 10-year, and shadow interest rates are alternately used to capture monetary policy shocks and confirm the robustness of the results. In the analysis of price-related variables, the above SVAR models are re-organized by adding the domestic price-related variable to be analyzed (inflation expectations, nominal wages, etc.) while using only one foreign variable (foreign consumer prices) to avoid complicating the model. Furthermore, as a preparatory analysis separate from the SVAR, we estimate a Phillips curve with Japanese consumer price inflation as the dependent variable and the domestic output gap and inflation expectations as well as import prices, exchange rates, and the foreign output gap as explanatory variables, and check the explanatory power of each foreign variable.

Although the robustness of our SVAR analysis is checked as described above, the results should be interpreted with caveats in part because the theoretical restrictions are kept to the minimum. In particular, substantial uncertainty about the estimated impacts of monetary policy shocks should be noted. Having said that, a straightforward interpretation of our results suggests that the effects on consumer prices of the Bank of Japan's successive monetary easing measures implemented over the period since the late 1990s, including the QQE introduced in 2013, have been more or less offset by the effects of various types of global shocks. While it is unusual for factors other than monetary policy to continue to influence prices in one direction over a long period of time,[3] the persistent effects of global shocks identified in our SVAR models may imply, for instance, that the downward cost pressure from the deepening global value chains continued even in the 2010s in Japan.[4] Our analysis of price-related variables suggests that the effect of global shocks on medium- and long-term inflation expectations has been limited so far, which may be related to the deep-rooted deflationary mindset and social norms taking low inflation for granted. The analysis also suggests, however, that nominal wages and service prices have recently been pushed up significantly by global shocks, and these effects on nominal wages and service prices may spill over into inflation expectations over time. In forecasting future trends, it is necessary to consider not only the persistence of the global shocks themselves, but also their domestic propagation mechanisms. While the analysis in this paper may provide some guidance, for a deeper interpretation of our results and their implications for monetary policy, it would be beneficial to compare our results with those from other analyses using more theoretically oriented structural models, such as dynamic stochastic general equilibrium (DSGE) models, and empirical analyses using more detailed data on firm behavior, etc.

While empirical analyses of consumer prices and related variables using SVAR models are conducted in previous studies in various countries, global factors are often captured only in terms of import prices, energy prices, and exchange rates, and there are few analyses that attempt to capture various types of global shocks in a systematic way by

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[3] Even if the consumer price inflation is determined solely by monetary policy (e.g., an inflation target) in the long run, it is conceivable that the inflation rate could deviate from (but eventually return to) its long-run equilibrium value on a sustained basis due to changes in import prices and wages relative to domestic consumer prices caused by globalization and other factors. In an empirical analysis assuming such a mechanism, Sekine (2009) finds that the persistent downward trend in inflation in advanced economies, including Japan, from the 1970s-80s to the 90s-mid-2000s is explained more by changes in relative prices than by monetary policy (although inflation may eventually turn upward).

[4] For issues related to the response of Japanese firms to changes in the global economic landscape and their implications for Japan's economy, see Hogen et al (2024).

treating foreign variables symmetrically with domestic variables, as this paper does. The SVAR model of Forbes, Hjortsoe, and Nenova (2020) is the closest to our approach, although they focus on exchange rates rather than consumer prices.[5] Other recent studies that analyze the effect of global factors on consumer prices in different countries using SVAR models include Bobeica and Jarociński (2019), which focuses mainly on the euro area, Ha et al. (2019), which covers a wide range of countries and regions including emerging market economies, and Finck and Tillmann (2022) for emerging Asian countries.[6] There are also a number of analyses of the effects of global factors on prices in Japan, mainly focusing on the pass-through from the exchange rate and commodity prices to consumer prices,[7] but to our limited knowledge, there are no studies that analyze the effects of various types of global shocks in Japan using similar approaches to ours.[8] There are also no studies that analyze the effects of global shocks on price-related variables such as inflation expectations and nominal wages using similar approaches, including studies on other countries.

The rest of this paper is outlined as follows. Section 2 presents a principal component analysis of global inflation synchronization. Section 3 presents a preparatory analysis of the effect of global factors on Japan's consumer prices in the Phillips curve framework. Section 4 presents the main SVAR analysis of this paper. Section 5 presents the SVAR analysis of the effect of domestic and global shocks on inflation expectations, nominal wages, and goods and services prices. Section 6 concludes.

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[5] Forbes, Hjortsoe, and Nenova (2020) use an SVAR model similar to ours to show that the pass-through from the exchange rate to consumer prices depends on what caused the exchange rate movements. Forbes, Hjortsoe, and Nenova (2018) also conduct a similar analysis focusing on the exchange rate pass-through in the United Kingdom. Moreover, Forbes (2019) estimates the global principal component for inflation and the Phillips curves including foreign explanatory variables using cross-country panel data, as we do as a preparatory analysis mainly using Japanese data.

[6] Recent studies that conduct similar analyses using time series methods other than SVAR (e.g., dynamic factor models) include Auer, Levchenko, and Sauré (2019), Kamber and Wong (2020), and Bäurle, Gubler, and Känzig (2021), among others.

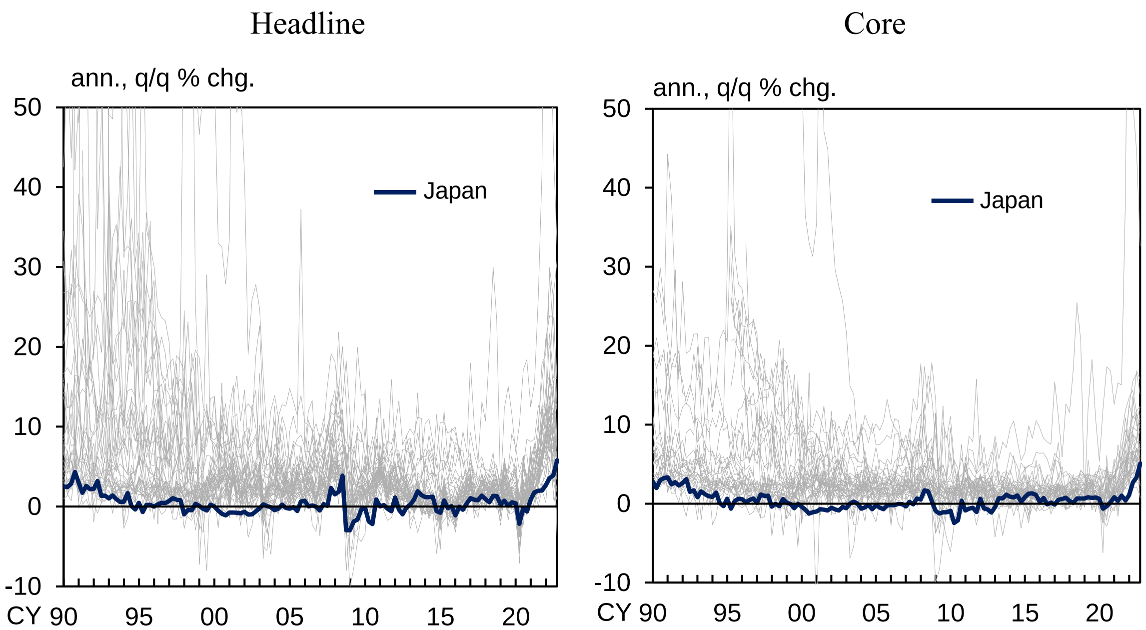
[7] Empirical analyses of the pass-through from exchange rates and commodity prices to Japan's consumer prices include Shioji (2014) and Yagi et al. (2022). The causes of low inflation in Japan, including global factors, are extensively discussed in Nishizaki, Sekine, and Ueno (2014), and Ikeda et al. (2022), among others.

[8] An, Wynne, and Zhang (2021) analyze the pass-through from the Japanese exchange rate to import and consumer prices using an SVAR model that incorporates not only short- and long-run zero and sign restrictions but also narrative sign restrictions, although the types of global shocks are limited unlike in our SVAR model. Kamada and Hirakata (2002), using an SVAR model that includes the import penetration ratio (without sign restrictions), find that Japan's loss of international competitiveness had exerted continuous downward pressure on consumer prices.

2. Global Inflation Synchronization

In this section, we examine global inflation synchronization. Simple plots of headline consumer price inflation (for Japan, "all items less fresh food"[9]) and core inflation (for Japan, "all items less fresh food and energy") for 43 countries (26 countries for core inflation) continuously available at the IMF, OECD or other data sources show that the large dispersion across countries seen in the 1990s has narrowed since the 2000s (Figure 1). Subsequently, regarding headline inflation, there were synchronizations across countries around 2008 when energy prices saw a large swing and in the post-pandemic inflationary phase. Core inflation had been relatively stable, but there was a clear synchronization in the post-pandemic phase. Japan's inflation rate has been near the bottom of the distribution of the countries, but there appears to be some degree of synchronization with other countries.

(Figure 1) Consumer price inflation by country

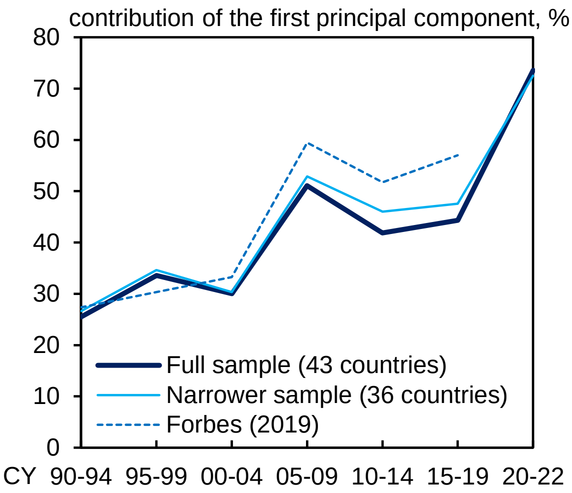


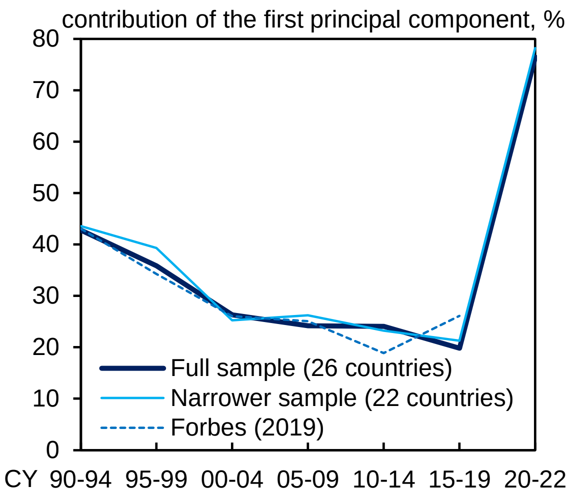
Note: Gray lines represent consumer price inflation for 43 countries (left panel) and core inflation for 26 countries (right panel). Japan's inflation rates are all items less fresh food (left panel) and all items less fresh food and energy (right panel).
Source: OECD, IMF, Statistics Bureaus of each country, Bank of Japan

[9] Japanese consumer price data used in this paper are Bank of Japan staff estimates, after excluding mobile phone charges and the effects of the consumption tax rate hikes, policies concerning the provision of free education, and travel subsidy programs.

While previous studies use a variety of methods to quantitatively assess the global inflation synchronization,[10] we consider the first principal component estimated by principal component analysis as the shared global component and check the extent to which it contributes to the variation of inflation, following Forbes (2019). Specifically, we calculate the contribution of the first principal component to the variation of inflation in all countries, separated by time period, using the seasonally adjusted quarterly changes in consumer prices for the above 43 countries (26 countries for core inflation). As in Forbes (2019), the inflation data is winsorized at the 10 percent level for each tail to replace outliers with the threshold values. The results (Figure 2) show that for headline inflation, the contribution of the first principal component, which was less than 30 percent in the early 1990s, rises continuously to a level above 70 percent after 2020, suggesting that the synchronization across countries has gradually increased. On the other hand, for core inflation, the contribution of the first principal component, which was over 40 percent in the early 1990s and had declined to around 20 percent in the late 2010s, has risen sharply to a level close to 80 percent after 2020. This suggests that core inflation, which saw limited synchronization across countries before the pandemic, became much more synchronized after the pandemic.

(Figure 2) Principal component analysis of inflation across countries





Note: Principal component analysis conducted on the sample in Figure 1 (43 countries for headline and 26 countries for core). "Narrower Sample (36 countries for headline and 22 countries for core)" covers countries in the G20 or EU. Forbes (2019) covers developed countries (31 countries) as defined by the IMF, with data through 2017. Outliers exceeding the upper and lower 10 percentiles are replaced by the threshold values (winsorized).

[10] Ha, Kose, and Ohnsorge (2019) estimate a global inflation factor using a dynamic factor model to assess the global inflation synchronization considering its lag structures.

These results confirm that the synchronization of consumer prices, both including and excluding energy prices, across countries has increased significantly after the pandemic. However, this analysis does not explain the background to the increase in synchronization, which can be explained by the impact of shocks at the global level (e.g., energy price fluctuations), the stronger propagation of shocks due to the deeper integration of production, trade, and finance across countries (e.g., business cycle synchronization[11] and supply chain disruptions), concurrent structural changes and policy responses across countries (e.g., tightening of domestic labor market conditions and fiscal expansion). In the following analysis, we focus on Japanese consumer prices and related variables and identify domestic and global factors that affected them.

3. Analysis of Japanese Consumer Prices Using the Phillips Curve

In this section, as a preparatory analysis before presenting the SVAR analysis in the next section and beyond, we examine the effect of global factors on changes in Japanese consumer prices using the Phillips curve framework. In this section, we consider the following formulation of the Phillips curve.

$$\pi_t = \beta_0 + \beta_1 E_t \pi_{t+k} + (1 - \beta_1)\pi_{t-1} + \beta_2 x_t + \beta_3 \pi_t^m + \beta_4 e_t + \beta_5 x_t^f + \epsilon_t$$

π_t is the seasonally adjusted quarterly change in consumer prices (all items less fresh food or all items less fresh food and energy), $E_t \pi_{t+k}$ is the medium- to long-term inflation expectation,[12] x_t is the domestic output gap (estimated by the Research and Statistics Department, Bank of Japan). The foreign variables include the quarterly changes in import prices (contract currency basis), π_t^m, and yen's nominal effective exchange rate, e_t. Following Borio and Filardo (2007), foreign output gap, x_t^f, is also included.[13] ε_t is the error term. Alternative specifications are examined, including

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[11] There is also a large body of literature on the global synchronization of business cycles, including theoretical investigations of the mechanisms by which productivity and business cycle fluctuations spill over across countries, leading to large synchronization in nominal variables such as price levels and nominal interest rates (Henriksen, Kydland, and Šustek, 2013).

[12] The medium- to long-term inflation expectation is an average of various indicators of inflation expectations (2-11 years ahead) of economists, market participants, households, and firms, all of which are shown in the Bank of Japan's "Outlook for Economic Activity and Prices." Since the available periods of these indicators are different, the average level is adjusted when some indicators become unavailable to avoid discontinuous changes.

[13] The foreign output gap is a weighted average of the output gaps for developed countries defined by the IMF and China (using data from its National Bureau of Statistics), using their shares of GDP (in purchasing power parity terms) as weights. Only the US output gap is used as the foreign output gap prior to 1994 because of data unavailability for other countries.

alternative data for each explanatory variable, different lag structure, and restrictions on the coefficient (β_1), but these do not change the results qualitatively. Therefore, only the results using the above formulation are presented below. The estimation period starts at the first quarter of 1990, right after the burst of the asset prices bubble. When consumer price inflation including energy prices (all items less fresh food) is used as the dependent variable (Figure 3), the explanatory power of the regression (adjusted R^2) increases when foreign variables are added as explanatory variables. Although the increase of the adjusted R^2 is limited and the explanatory power of each foreign variable is weak before 2007, the foreign variables have stronger explanatory power as the estimation period is extended thereafter. However, the foreign output gap does not have statistically significant explanatory power in any estimation period. Note that the estimated coefficient of the domestic output gap decreases slightly when the foreign variables are added, but it does not have much effect on their statistical significance.[14]

(Figure 3) Phillips curve (all items less fresh food)

Variables	Domestic variables only				+ Import prices and Exchange rates				+ Foreign output gap (Full model)			
	90-07	90-12	90-19	90-22	90-07	90-12	90-19	90-22	90-07	90-12	90-19	90-22
β_0 Constant term	-0.49 ***	-0.73 ***	-0.68 ***	-0.31 -	-0.48 ***	-0.65 ***	-0.60 ***	-0.32 *	-0.53 ***	-0.67 ***	-0.64 ***	-0.31 -
β_1 Inflation expectations / own lag	0.53 ***	0.79 ***	0.76 ***	0.46 **	0.48 ***	0.64 ***	0.65 ***	0.41 **	0.50 ***	0.64 ***	0.66 ***	0.41 ***
β_2 Domestic output gap	0.14 **	0.23 ***	0.23 ***	0.13 -	0.12 **	0.17 ***	0.18 ***	0.09 *	0.12 **	0.17 ***	0.18 ***	0.09 *
β_3 Import prices					0.02 **	0.03 ***	0.03 ***	0.03 ***	0.02 **	0.03 ***	0.03 ***	0.03 ***
β_4 Nominal effective exchange					0.00 -	-0.01 **	-0.01 ***	-0.01 ***	0.00 -	-0.01 **	-0.01 ***	-0.01 ***
β_5 Foreign output gap									-0.04 -	-0.03 -	-0.04 -	0.01 -
Adjusted R^2	0.72	0.58	0.55	0.52	0.74	0.71	0.74	0.69	0.74	0.70	0.69	0.68

Note: The Phillips curve equation in the text is estimated by OLS. ***, **, and * represent 1%, 5%, and 10% significance, respectively. Newey-West standard errors are calculated.

When consumer price inflation excluding energy prices (all items less fresh food and energy) is used as the dependent variable (Figure 4), the foreign variables do not have statistical significance in most of the estimation periods. When the post-pandemic period is added in the estimation period, they barely become significant, but the improvement in the explanatory power of the regression is limited.

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[14] Forbes (2019) estimates a similar Phillips curve using cross-country panel data and argues that globalization (increased import share) contributes to a flattening of the Phillips curve because the estimated coefficient on domestic slack increases when it is interacted with the country's import share. However, in our estimation, the coefficient on the domestic output gap does not increase when it is interacted with Japan's import share and any result implying a flattening of the Phillips curve is not obtained before the pandemic.

(Figure 4) Phillips curve (all items less fresh food and energy)

Variables	Domestic variables only				+ Import prices and Exchange rates				+ Foreign output gap (Full model)			
	90-07	90-12	90-19	90-22	90-07	90-12	90-19	90-22	90-07	90-12	90-19	90-22
β_0 Constant term	-0.39 ***	-0.49 ***	-0.45 ***	-0.21 -	-0.39 ***	-0.46 ***	-0.42 ***	-0.17 -	-0.50 ***	-0.46 ***	-0.44 ***	-0.15 -
β_1 Inflation expectations / own lag	0.39 ***	0.48 ***	0.48 ***	0.30 **	0.40 ***	0.45 ***	0.46 ***	0.24 -	0.46 ***	0.45 ***	0.46 ***	0.24 -
β_2 Domestic output gap	0.10 **	0.14 ***	0.14 ***	0.09 **	0.10 **	0.13 ***	0.13 ***	0.08 **	0.10 **	0.13 ***	0.14 ***	0.08 **
β_3 Import prices					0.00 -	0.00 -	0.00 -	0.01 **	0.00 -	0.00 -	0.00 -	0.01 **
β_4 Nominal effective exchange					0.00 -	0.00 -	0.00 -	-0.01 *	0.00 -	0.00 -	0.00 -	-0.01 *
β_5 Foreign output gap									-0.08 -	0.00 -	-0.01 -	0.03 -
Adjusted R^2	0.80	0.76	0.74	0.70	0.79	0.76	0.74	0.72	0.79	0.75	0.74	0.72

Note: The Phillips curve equation in the text is estimated by OLS. ***, **, and * represent 1%, 5%, and 10% significance, respectively. Newey-West standard errors are calculated.

In sum, according to the standard Phillips curve estimation, the influence of global factors on Japanese consumer prices has been on an increasing trend, but appears to be largely through the effects through energy prices, import prices, and exchange rates. However, this analytical framework does not explicitly consider the role of monetary policy, nor does it adequately consider the sources and propagation mechanisms of global factors, leaving some doubt as to whether the above conclusions are generally valid. In what follows, we present an analysis based on the SVAR models that more explicitly takes these points into account.

4. Analysis of Japanese Consumer Prices Using SVAR Models

In this section, we use SVAR models with Japanese and foreign macroeconomic variables to identify various types of domestic and global shocks and analyze their effects on consumer prices in Japan. In the baseline model, we treat macroeconomic variables for Japan and other countries (G20 excluding Japan) symmetrically, and use data on real GDP, consumer prices, nominal interest rates, and the nominal effective exchange rate of the yen to identify domestic and global supply shocks, demand shocks, monetary policy shocks, and exchange rate shock (seven shocks in total), the latter of which is not explained by other shocks. We use the quarterly changes in real GDP, consumer prices, and the nominal effective exchange rate (real GDP and consumer prices are seasonally adjusted), and the levels of the nominal interest rates after removing their linear trends. To identify these shocks, we employ Bayesian techniques to estimate the models with short- and long-run zero restrictions and short-run sign restrictions, as explained below. The details of the data and estimation method are explained in Appendices 1 and 2.

4-1. Shock Identification and Impulse Responses

The restrictions for identifying the seven types of shocks in the baseline model largely follow Forbes, Hjortsoe, and Nenova (2020) and are summarized in Figure 5 below. We impose long-run zero restrictions that domestic and global demand shocks and monetary policy shocks have no long-run effect on the levels of domestic and foreign real GDP (cumulative impulse response). We also consider the small open economy assumption, which imposes short- and long-run zero restrictions such that domestic supply, demand, and monetary policy shocks have no effect on foreign variables in the short and long run. However, as it is not clear whether the small open economy assumption can be applied to Japan,[15] which has been the second or third largest economy in terms of GDP in the world during the estimation period, we do not impose zero restrictions on foreign real GDP and, following Bobeica and Jarociński (2019), who analyze the euro area, we identify domestic and global shocks by sign restrictions (see below for details) depending on whether Japan's real GDP and its share in world real GDP (G20 countries) move in the same or opposite direction (identified as domestic shocks if they move in the same direction and as global shocks if they move in opposite directions).[16] Also, unlike Forbes, Hjortsoe, and Nenova (2020), we explicitly identify shocks to the nominal effective exchange rate by imposing short- and long-run restrictions such that the exchange rate shock does not affect foreign monetary policy (nominal interest rates) contemporaneously and in the long run, as a partial small open economy assumption.[17]

[15] Forbes, Hjortsoe, and Nenova (2020) estimate SVAR models both including Japan as a small open economy and that excluding Japan. They exclude the US, China, and the euro area in their model.

[16] For consumer prices and nominal interest rates, we impose short- and long-run sign restrictions based on small open economy assumptions (domestic shocks do not affect foreign prices and nominal interest rates both contemporaneously and in the long run). Following Bobeica and Jarociński (2019), we also tried to identify shocks by imposing alternative sign restrictions for consumer prices, as for real GDP, that depend on the direction of the relative price response between Japanese and foreign prices, but the results are not significantly different from those of the baseline model, especially for the relative contributions of domestic and global shocks.

[17] The SVAR model of Forbes, Hjortsoe, and Nenova (2020), which use the same seven variables as in our model, imposes no identification restrictions on one shock and considers it as an unidentified shock that does not correspond to any other shocks. In contrast, the model of Forbes, Hjortsoe, and Nenova (2018), which focus on the United Kingdom in a similar framework, explicitly identifies the exchange rate shock by imposing short- and long-run restrictions (small open economy assumptions) that the shock has no contemporaneous and long-run effects on foreign export prices.

(Figure 5) Identification restrictions for the baseline model

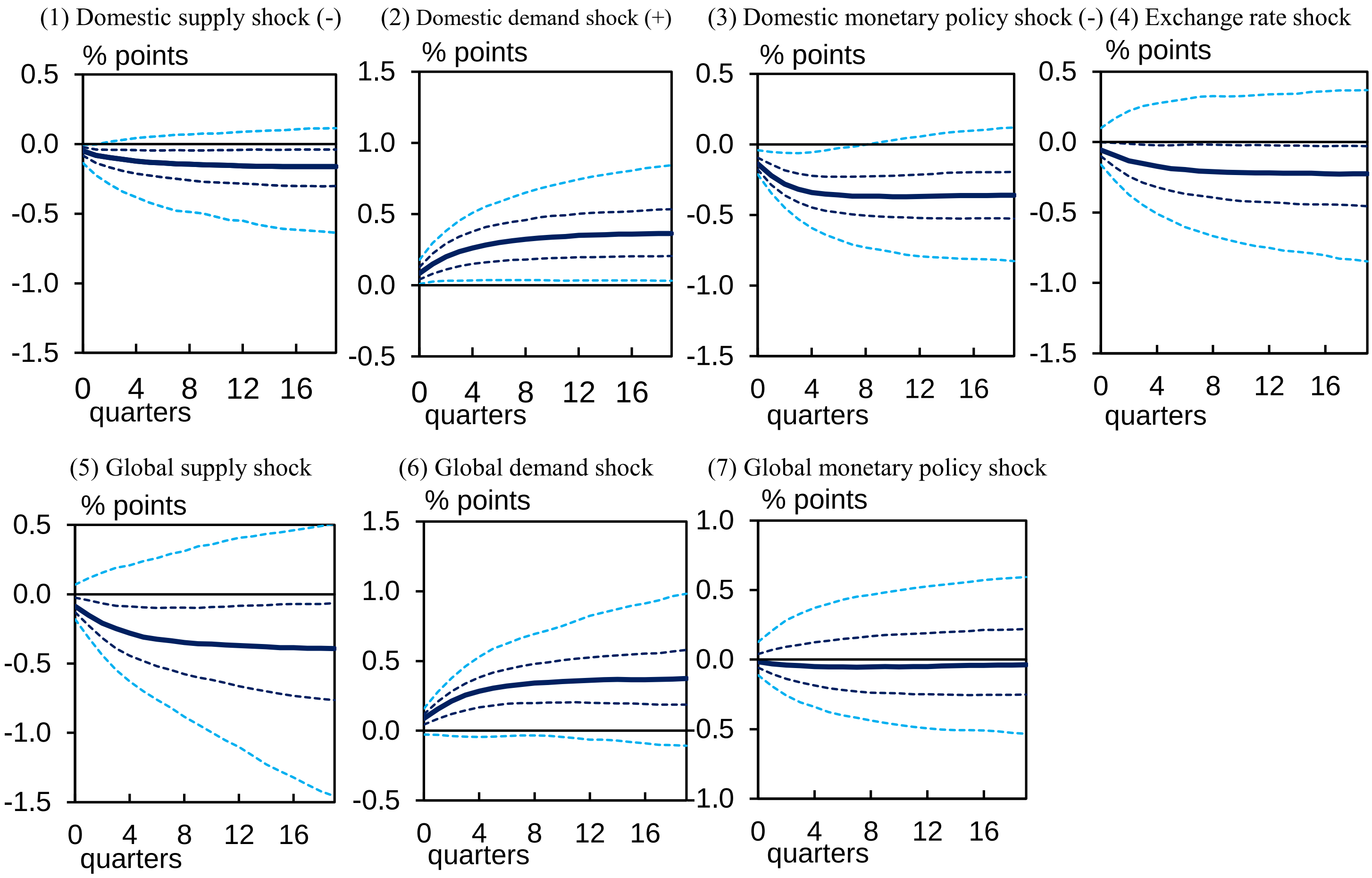
Variables / Shocks			Domestic Supply	Domestic Demand	Domestic Monetary policy	Exchange rate	Global Supply	Global Demand	Global Monetary policy
Short-run restrictions	Domestic	1. Real GDP	+	+	-				
		2. Consumer prices	-	+	-				
		3. Nominal interest rate		+	+				
		4. Nominal effective exchange rate		+	+	+			
	Foreign	5. Share of Japan's real GDP in world real GDP	+	+	-		-	-	+
		6. Consumer prices	0	0	0		-	+	-
		7. Nominal interest rate	0	0	0	0		+	+
Long-run restrictions	Domestic	1. Real GDP		0	0			0	0
		2. Consumer prices							
		3. Nominal interest rate							
		4. Nominal effective exchange rate							
	Foreign	5. Share of Japan's real GDP in world real GDP	0	0	0			0	0
		6. Consumer prices	0	0	0				
		7. Nominal interest rate	0	0	0	0			

+ Sign restriction (+)
- Sign restriction (-)
0 Long-run restriction
0 Small open economy assumption

In addition to these zero restrictions, we impose the following short-run sign restrictions. A domestic supply shock moves Japan's real GDP and consumer prices in opposite directions, while a domestic demand shock moves them in the same direction. Moreover, a positive domestic demand shock raises Japan's nominal interest rate and leads to Japanese yen's appreciation. A domestic monetary policy shock (in the direction of tightening) also raises the nominal interest rate and causes yen's appreciation, but it has a negative effect on real GDP and consumer prices (in contrast to a domestic demand shock). These sign restrictions on demand, supply, and monetary policy shocks are the standard ones used in many previous studies. Furthermore, while all three domestic shocks above have no contemporaneous and long-run effects on foreign consumer prices and nominal interest rates under the small open economy assumption, we impose a sign restriction that the domestic shocks move the share of Japan's real GDP in world real GDP in the same direction as Japan's real GDP, as mentioned above. As for the three types of global shocks, a global supply shock moves foreign real GDP and consumer prices in opposite directions (the share of Japan's real GDP and foreign consumer prices in the same direction), and a global demand shock moves them in the same direction (the share of Japan's real GDP and foreign consumer prices in opposite directions). A positive global demand shock raises foreign nominal interest rates, but we do not impose a sign restriction on the direction in which it moves the nominal effective exchange rate of the yen because the relationship between various currencies may be ambiguous. While a global monetary policy shock raises foreign nominal interest rates, it has a negative effect on foreign real GDP and consumer prices (and a positive effect on Japan's share of real GDP). Finally, the sign restriction on the exchange rate shock applies only to the exchange rate, and no sign restriction is imposed on the relationship with other variables.

The impulse responses of Japanese consumer prices (all items less fresh food) to the seven types of shocks identified by the above restrictions are shown in Figure 6. The signs of the responses of domestic consumer prices to the three domestic shocks are consistent with the sign restrictions and the confidence intervals are relatively small. On the other hand, as for the responses to the three global shocks, the confidence intervals are larger, partly because there are no sign restrictions imposed, but the median responses to the global supply and demand shocks, which are standardized to one standard deviation, are larger than and in the same direction as the corresponding domestic supply and demand shocks, respectively. The median response to the global monetary policy shock is close to zero and smaller than that to the domestic monetary policy shock. A possible interpretation of the latter is that the shock that tightens foreign monetary policy has a negative effect on domestic prices through depressing overseas economies and prices but also has a positive effect on domestic prices through yen's depreciation (foreign currency appreciation), which offset each other. Finally, the responses of domestic prices to the shock that causes the yen's appreciation (which is not explained by other shocks) is negative, in line with the theory despite no sign restriction. Note that the cumulative impulse responses shown in Figure 6 represent the effects on the price level. The responses on the inflation rate (seasonally adjusted, quarterly) converge to zero in about 4 to 5 years after the domestic and global supply and demand shocks, and in 2 to 3 years after the monetary policy and exchange rate shocks. While the cumulative responses of real GDP to the demand and monetary policy shocks converge to zero in the long run due to the long-run zero restrictions, the responses of price level persist even in the long run and those of inflation are also somewhat persistent.

(Figure 6) Impulse responses of Japanese consumer prices (all items less fresh food)



Notes 1. Cumulative impulse responses of Japanese consumer prices inflation (all items less fresh food, seasonally adjusted, quarterly) to one standard deviation of each shock.
2. Thick lines represent the median response. Inner dotted lines represent 25 and 75 percentiles, and outer dotted lines represent 5 and 95 percentiles.
3. (+) or (-) following the shock name indicates the corresponding sign restrictions.

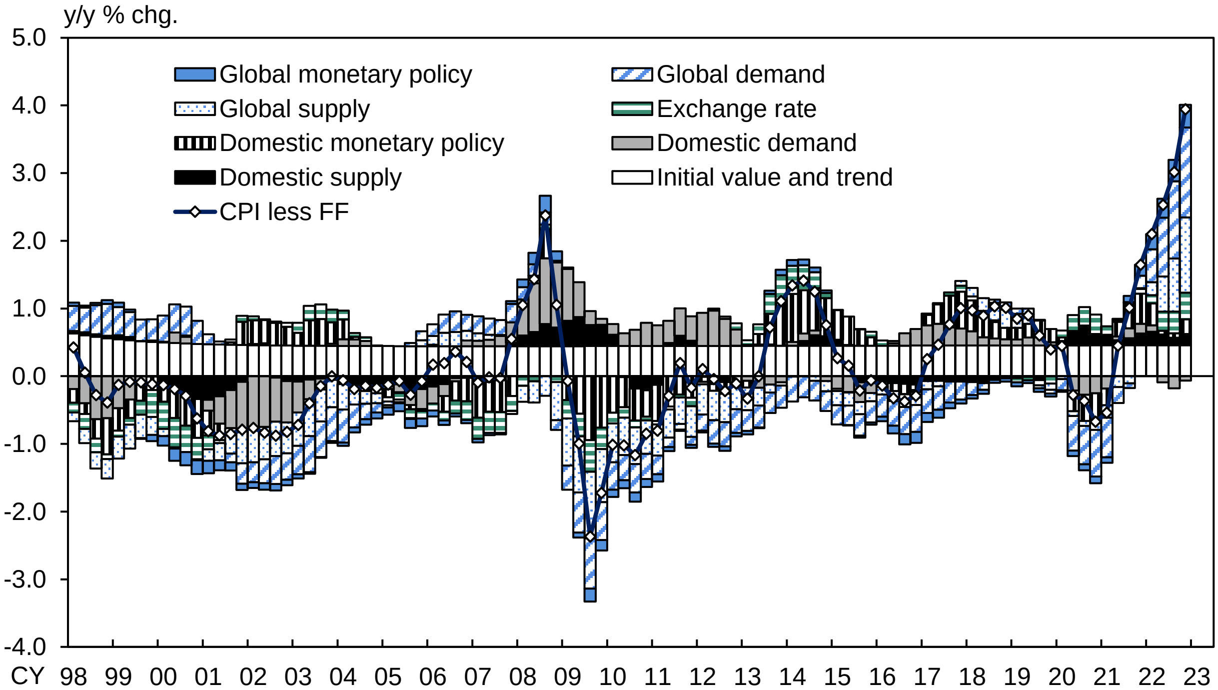
Before presenting historical decompositions and other results below, we briefly discuss the interpretation of the seven types of shocks. Domestic and global demand shocks reflect their respective business cycle fluctuations. The effects of global demand shocks on domestic prices may also include the effects of energy price fluctuations caused by changes in global energy demand. Domestic and global supply shocks can affect their respective potential output, which may reflect productivity gains/losses that influence prices through production costs (e.g., unit labor costs). The effects of global supply shocks on domestic prices may also include the impact of higher (or lower) energy prices due to supply-side factors that could exert persistent downward (or upward) pressure on the world economy, and the impact of an inflow of low-priced goods caused by higher productivity abroad. Monetary policy shocks capture the effects of changes in the monetary policy stance that are not explained by the demand and supply shocks described above, and do not necessarily correspond to whether monetary policy is actually loosened or tightened (for example, a monetary easing that is less than expected can be identified as a tightening shock). Finally, exchange rate shocks capture changes in the nominal effective exchange rate of Japanese yen that are not explained by other shocks, particularly its movements that deviate from fundamentals, such as changes in market sentiments. When we refer to "domestic shocks" and "global shocks" collectively in the following, they include respective demand, supply, and monetary policy shocks, but the exchange rate shock is not included in either domestic or global shocks because of the partial small open economy assumption.

4-2. Historical Decomposition

In the following, we present the results of historical decomposition of the past fluctuations in Japanese consumer prices (all items less fresh food and all items less fresh food and energy) into the effects of the seven types of shocks identified by the SVAR model described above. The estimation period starts from the fourth quarter of 1995 (data from the second quarter of the same year are used because the lag order of the model is two periods) and ends in the second quarter of 2023 (the latest Japanese GDP data is the second preliminary estimate) when using Japanese consumer prices of all items less fresh food and energy (hereafter "CPI less FFE"). In the case of consumer prices of all items less fresh food (hereafter "CPI less FF"), the estimation period is limited to the fourth quarter of 2022 because the data from the first quarter of 2023 onward reflect a large effect of the government's economic measures to reduce the household burden of energy prices, which may make the estimation results unstable. For foreign consumer prices, headline values including energy prices are used in all cases (regardless of Japanese consumer prices). For nominal interest rates, we use the 2-year interest rates for both Japan and foreign countries as many of these countries faced effective lower bounds during the estimation period.[18] Note that while the model is estimated using seasonally adjusted quarterly data for consumer prices, the following figures show the results of the historical decomposition converted to the year-on-year inflation rate.

[18] The results of the historical decomposition do not change substantially even when the 10-year interest rates or the shadow rates are used as the nominal interest rates (Supplementary Figures 1 and 2). For these interest rates (as done for 2-year rates), we use the levels after removing their linear trends.

(Figure 7) Historical decomposition of Japanese CPI less FF (including energy prices)



Note: The result from the baseline (global monetary policy) model using CPI for all items less fresh food (Bank of Japan staff estimates, excluding mobile phone charges and the effects of the consumption tax rate hikes, policies concerning the provision of free education, and travel subsidy programs; the same hereafter). Estimation period is 1995/Q4 - 2022/Q4.

The historical decomposition of CPI less FF (including energy prices) is shown in Figure 7. Domestic shocks, especially domestic demand shocks, exerted downward pressure on prices around 1998, when deflation began. At the same time, global demand shocks pushed up prices, reflecting the steady expansion of the world economy due to the dot-com bubble in the U.S. and other factors. Subsequently, from around 2001, following the bursting of the dot-com bubble, the contribution of global demand shocks turned negative, with the negative contribution of domestic demand shocks also expanding (domestic supply shocks also showed a negative contribution around 2000), leading to full-fledged deflation.[19] In addition, global supply shocks, reflecting the inflow of low-priced goods from emerging market economies along with their productivity growth, had also exerted downward pressure on prices continuously since the late 1990s. Meanwhile, domestic monetary policy shocks, which reflect the Bank of Japan's quantitative easing introduced in 2001, contributed to pushing up prices, but they could not fully offset the deflationary pressures mentioned above.

[19] In March 2001, Japanese government officially admitted that Japan's economy was “in a mild deflationary phase” in the Monthly Economic Report.

Inflation returned to around zero in the mid-2000s and rose to clearly positive territory, above 2 percent for CPI less FF, toward 2008, driven mainly by domestic shocks, especially domestic demand shocks. Following the global financial crisis, however, inflation fell sharply and returned to deeply negative territory, mainly due to global shocks.[20] In this period, the Bank of Japan implemented a "comprehensive monetary easing" policy and other measures, but it is identified as a tightening domestic monetary policy shock as the degree of monetary easing was weaker than implied by the average relationship between output levels, inflation, and other factors during the model's estimation period.[21] Subsequently, after the Bank of Japan introduced QQE in 2013, it was identified as an accommodative domestic monetary policy shock and became the main cause of the subsequent rise in inflation in the 2010s. However, the downward pressure on prices due to global shocks since the global financial crisis continued even after the introduction of QQE, partly offsetting the inflationary effects of QQE.

After the pandemic pushed inflation back into negative territory in 2020, an upward phase of inflation began around 2021,[22] driven mainly by global shocks. Global demand shocks, which had almost consistently contributed in a negative direction since the global financial crisis, global supply shocks, which turned slightly positive around 2017 before the pandemic, and global monetary policy shocks, which had made a limited contribution before the pandemic, all contributed to the acceleration of inflation after the pandemic.

The historical decomposition of CPI less FFE (excluding energy prices), shown in Figure 8, can be interpreted largely in a similar way. The deflation up to the mid-2000s can be attributed mainly to the negative contribution of domestic demand shocks and global shocks, and the deflation after the global financial crisis in 2008 was due to the negative contribution of global shocks and domestic monetary policy shocks. The

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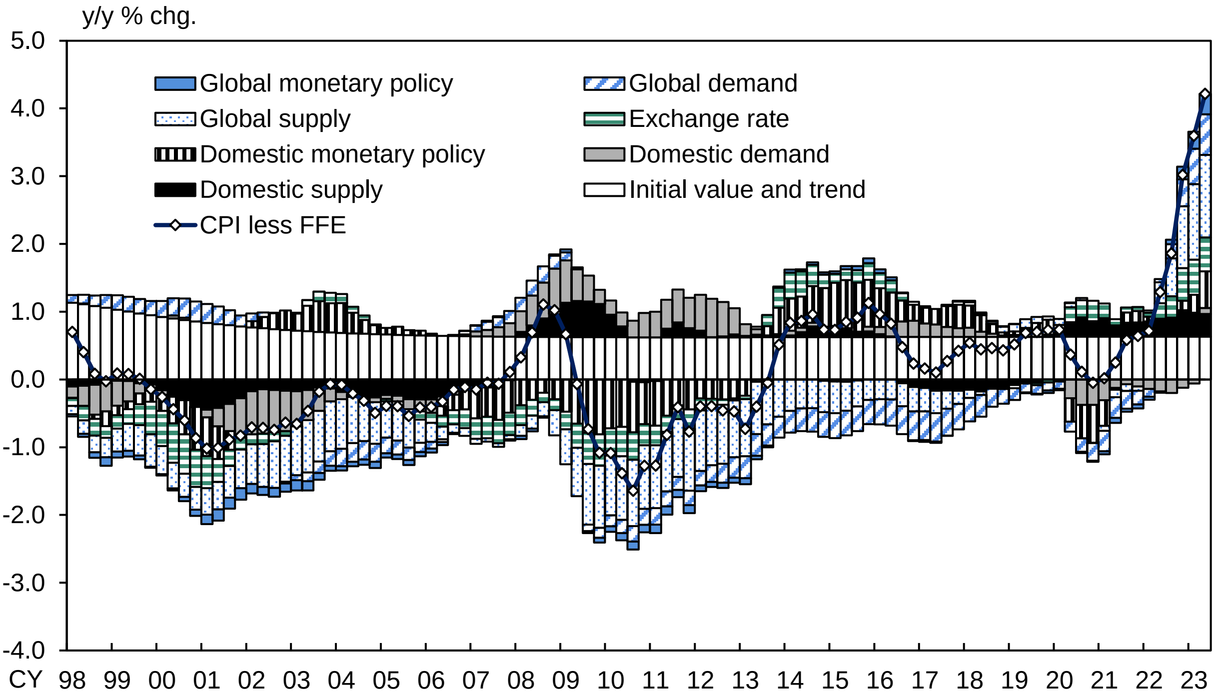
[20] Even after the global financial crisis, domestic demand shocks contributed to price increases for some time (domestic supply shocks also contributed to price increases, reflecting the decline in potential growth), which may be related to the relatively rapid recovery of the output gap relative to consumer prices.

[21] While monetary policy shocks in this model capture changes in the monetary policy stance that are not explained by demand and supply shocks (and thus do not necessarily correspond to whether monetary policy has been actually loosened or tightened, as explained in Section 4-1), a policy reaction function or monetary policy regime (the relationship between the economy, prices, interest rates, and other factors) is assumed to be constant during the estimation period. If the monetary policy regime changed around 2013 when QQE was introduced (for example, Miyao and Okimoto (2020) explicitly considers this possibility), monetary policy shocks around that time may be identified as larger, including those caused by the regime change.

[22] The year-on-year change in consumer prices was negative or close to zero in 2021 due to a large drop in mobile phone charges in April 2021, but the data used in this analysis exclude this effect.

contribution of domestic monetary policy shocks turned positive after the introduction of QQE in 2013, but the negative impact of global shocks persisted. The increase in inflation after the pandemic was driven mainly by global shocks, which turned positive. The main difference between the historical decompositions of CPI less FF and less FFE is that the contribution of global demand shocks was larger in the former, while in the latter, the contribution of global supply shocks was more prominent among global shocks. This suggests that the energy price fluctuations, which account for the difference between the two, were mainly explained by global demand shocks.[23] Note that the recent positive contribution of global shocks in CPI less FFE reflects a significant pass-through of the increase in energy prices.[24]

(Figure 8) Historical decomposition of Japanese CPI less FFE (excluding energy prices)



Note: The result from the baseline (global monetary policy) model using CPI for all items less fresh food and energy. Estimation period is 1995/Q4 - 2023/Q2.

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[23] Kilian (2009) shows that the rise in oil prices in the 2000s was mainly explained by demand factors, such as the growing presence of emerging economies in the global economy, using an SVAR analysis.

[24] One possible explanation for the larger pass-through of energy price increases to consumer prices in the recent phase of high energy prices compared to the previous phase (around 2008) is that the degree of pass-through may have risen nonlinearly due to the large magnitude of energy price increases in the recent phase (Sasaki, Yamamoto, and Nakajima, 2023).

What specific factors were captured by global supply shocks that had exerted downward pressure on Japanese CPI (especially less FFE) almost continuously from the late 1990s to the late 2010s, including after the introduction of QQE? As mentioned above, the shocks reflected the inflow of low-priced goods from emerging market economies along with their productivity growth until around the mid-2000s, but since then, the downward pressure on domestic prices from imports has waned somewhat, partly because wage gap between Japan and emerging market economies has been narrowing along with the increase in wage levels in emerging market economies. Since the import penetration ratio continued to rise even after the global financial crisis, especially for consumer durables, the channel through imported goods remained important in Japan, unlike other advanced economies. However, not only through imported goods but also through the deepening of global value chains (Japanese firms' foreign direct investment continued to increase steadily in the 2010s), indirect downward pressure on production costs and price markups of Japanese firms might also have intensified.[25] In this regard, the fact that the contribution of global supply shocks turned slightly positive around 2017-18, when the U.S.-China trade conflict intensified, may suggest that the trend of globalization and the direction of global supply shocks are somehow correlated. The large positive contribution of global supply shocks after the pandemic, however, cannot necessarily be explained solely by a change (reversal) in the trend of globalization, but may also be influenced by temporary supply constraints and other factors. This point is explored in an alternative model below.

4-3. Historical Decomposition using Alternative Models

In the following, to confirm the robustness of the results of the above baseline model, we present historical decompositions from two alternative models in which some variables and types of shocks are changed. In both models, instead of a global monetary policy shock, which shows a limited contribution to domestic prices in the baseline model, another specific global shock is considered: an oil price shock in the first alternative model and a temporary global supply shock in the second alternative model. The latter shock is assumed not to have long-run effects on the levels of domestic and foreign real GDP, and included in the second alternative model in addition to the (persistent) global

[25] Specific mechanisms might include lower production costs due to diffusion of technological progress through global value chains, downward pressure on prices of non-tradable goods through stagnant wages resulting from sluggish productivity growth of tradable goods relative to their trading partners (the Balassa-Samuelson effect), and lower price mark-ups on domestic goods due to increased competition from imported goods.

supply shocks already included in the baseline model. For those purposes, instead of the foreign interest rate, the first alternative model ("oil price model") uses the oil price, and the second alternative model ("global supply chain <GSC> model") uses the GSC pressure index released by the Federal Reserve Bank of New York.[26]

The restrictions for identifying seven types of shocks in the oil price model are summarized in Figure 9. We impose short-run sign restrictions that global demand shocks and oil price shocks move oil prices and foreign consumer prices in the same direction. We do not impose a long-run restriction for oil price shocks, taking into account the possibility that higher oil prices may lead to energy-saving technological progress. On the other hand, we impose zero restrictions for the domestic shocks and the exchange rate shock following the small open economy assumption that they do not affect oil prices contemporaneously and in the long run. The restrictions for the other shocks are the same as in the baseline model.

(Figure 9) Identification restrictions for the oil price model

Variables / Shocks			Domestic				Global		
			Supply	Demand	Monetary policy	Exchange rate	Supply	Demand	Oil price
Short-run restrictions	Domestic	1. Real GDP	+	+	-				
		2. Consumer prices	-	+	-				
		3. Nominal interest rate		+	+				
		4. Nominal effective exchange rate		+	+	+			
	Foreign	5. Share of Japan's real GDP in world real GDP	+	+	-		-	-	
		6. Consumer prices	0	0	0		-	+	+
		7. Oil price	0	0	0	0		+	+
Long-run restrictions	Domestic	1. Real GDP		0	0			0	
		2. Consumer prices							
		3. Nominal interest rate							
		4. Nominal effective exchange rate							
	Foreign	5. Share of Japan's real GDP in world real GDP	0	0	0			0	
		6. Consumer prices	0	0	0				
		7. Oil price	0	0	0	0			

+ Sign restriction (+)
- Sign restriction (-)
0 Long-run restriction
0 Small open economy assumption

[26] Since the GSC pressure index (the level after removing its linear trend) is only available after 1998, the estimation period of the GSC model starts from the third quarter of 1998, differently from the other models.

The restrictions for identifying seven types of shocks in the GSC model are summarized in Figure 10. A temporary global supply shock, like a persistent global supply shock, moves foreign real GDP and foreign consumer prices in opposite directions (Japanese real GDP share and foreign consumer prices in the same direction) and moves foreign consumer prices and the GSC pressure index in the same direction. The only difference between the temporary and persistent global supply shocks is that the long-run zero restrictions are imposed that the former shock has no effect on either domestic or foreign real GDP in the long run. No short-run sign or zero restrictions are imposed for the effect of global demand shocks on the GSC pressure index. We impose zero restrictions following the small open economy assumption that domestic and exchange rate shocks do not affect the GSC pressure index contemporaneously and in the long run. The restrictions for the other shocks are the same as in the baseline model.

(Figure 10) Identification restrictions for the GSC model

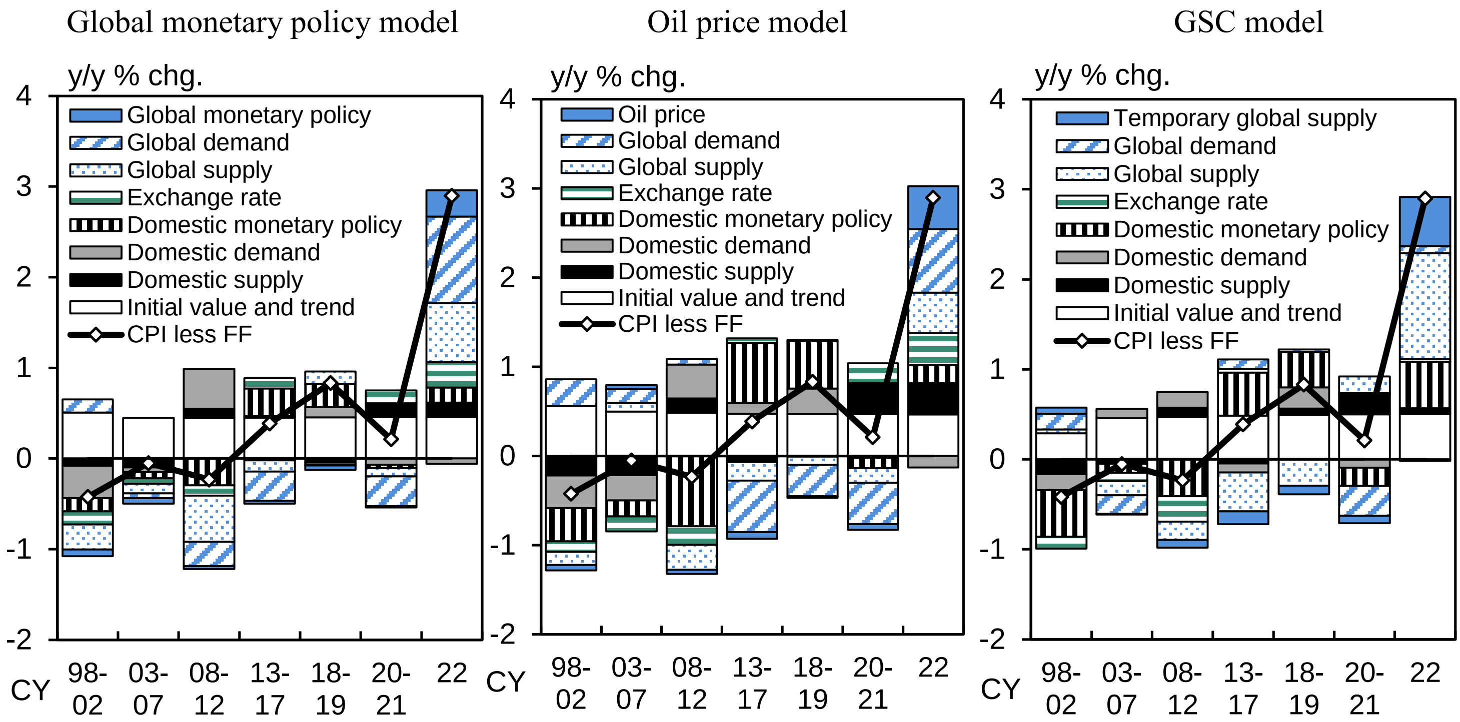
Variables / Shocks			Domestic				Global		
			Supply	Demand	Monetary policy	Exchange rate	Supply	Demand	Supply (temporary)
Short-run restrictions	Domestic	1. Real GDP	+	+	-				
		2. Consumer prices	-	+	-				
		3. Nominal interest rate		+	+				
		4. Nominal effective exchange rate		+	+	+			
	Foreign	5. Share of Japan's real GDP in world real GDP	+	+	-		-	-	-
		6. Consumer prices	0	0	0		-	+	-
		7. GSC pressure index	0	0	0	0	-		-
Long-run restrictions	Domestic	1. Real GDP		0	0			0	0
		2. Consumer prices							
		3. Nominal interest rate							
		4. Nominal effective exchange rate							
	Foreign	5. Share of Japan's real GDP in world real GDP	0	0	0			0	0
		6. Consumer prices	0	0	0				
		7. GSC pressure index	0	0	0	0			

+	Sign restriction (+)
-	Sign restriction (-)
0	Long-run restriction
0	Small open economy assumption

In the following, we present historical decompositions of Japanese CPI from three different models: the baseline (global monetary policy) model, the oil price model, and the GSC model. To conserve space and compare the results side by side, we use five-year average decompositions up to 2017 and one- to two-year average decompositions from 2018 onward (all converted to year-on-year changes) instead of quarterly decompositions.

The historical decompositions of CPI less FF (including energy prices) are shown in Figure 11. In the oil price model, the positive contribution of domestic monetary policy shocks after the introduction of QQE in 2013 was relatively large, while the negative contributions of global shocks (especially global demand shocks) during the same period were also significant. Meanwhile, the contribution of oil price shocks is hardly noticeable, except during the recent high-inflation period, suggesting that the fluctuations of oil prices are explained mostly by the other shocks (especially global demand shocks). In the GSC model, on the other hand, the contribution of (persistent) global supply shocks is larger than that of global demand shocks. The contribution of temporary global supply shocks is small except for the recent high-inflation period, and even in that period, their positive contribution is smaller than that of persistent global supply shocks. While there are some differences among the three models in the relative contributions among the three types of global shocks, the relative contributions between domestic and global shocks in each period are similar across these models.

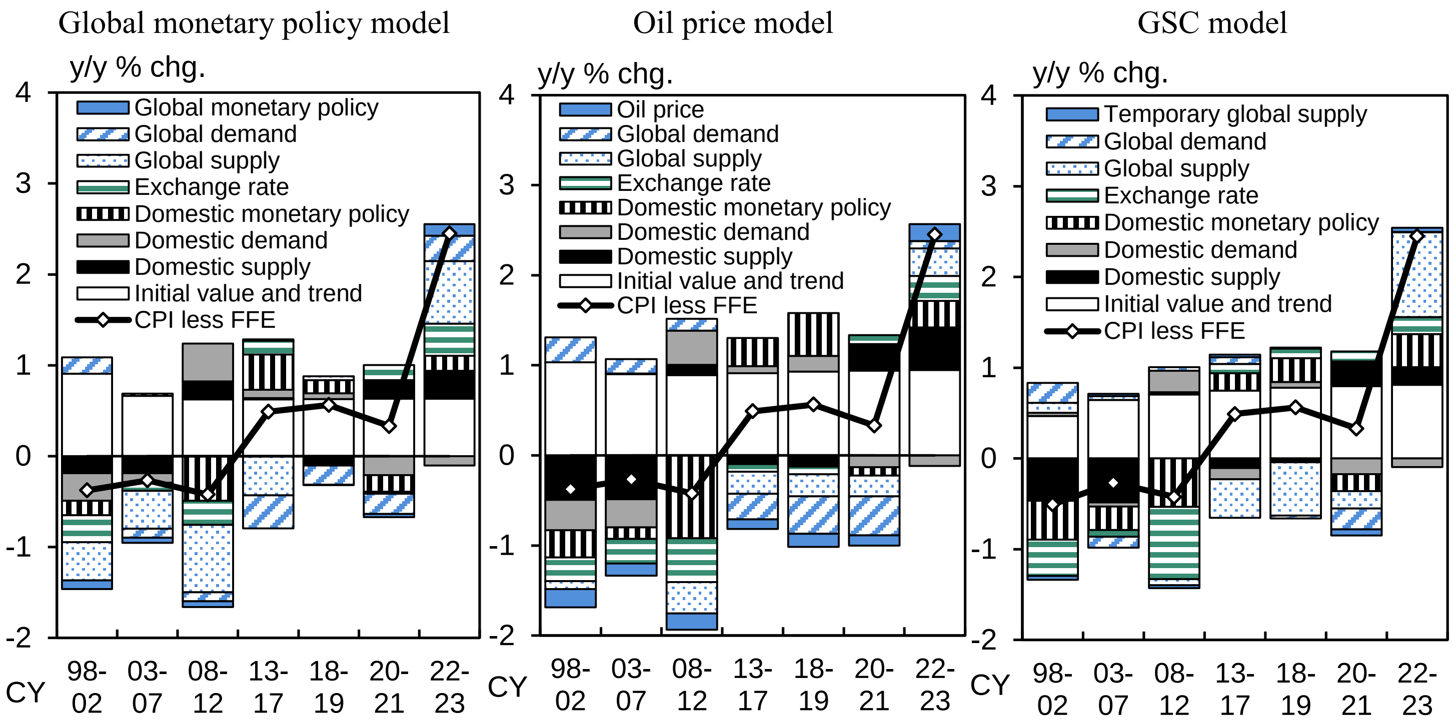
(Figure 11) Historical decompositions of Japanese CPI less FF: alternative models



Note: Estimation period is 1995/Q4 (1998/Q3 for GSC model) - 2022/Q4.

The historical decompositions of CPI less FFE (excluding energy prices) are shown in Figure 12. As in the case of CPI less FF, the oil price model shows a slightly larger negative contributions of global shocks after the introduction of QQE, but in the recent high-inflation period, the positive contributions of global shocks are smaller than in the other models, and not much different from those of domestic shocks (excluding exchange rate shocks). In the GSC model, on the other hand, the contribution of (persistent) global supply shock is relatively large after the introduction of QQE and after the pandemic, while the contributions of temporary global supply and global demand shocks are limited. Despite the above differences between these models, all models show that the inflationary effects of QQE were partly offset by global shocks.

(Figure 12) Historical decompositions of Japanese CPI less FFE: alternative models



Note: Estimation period is 1995/Q4 (1998/Q3 for GSC model) - 2023/Q2.

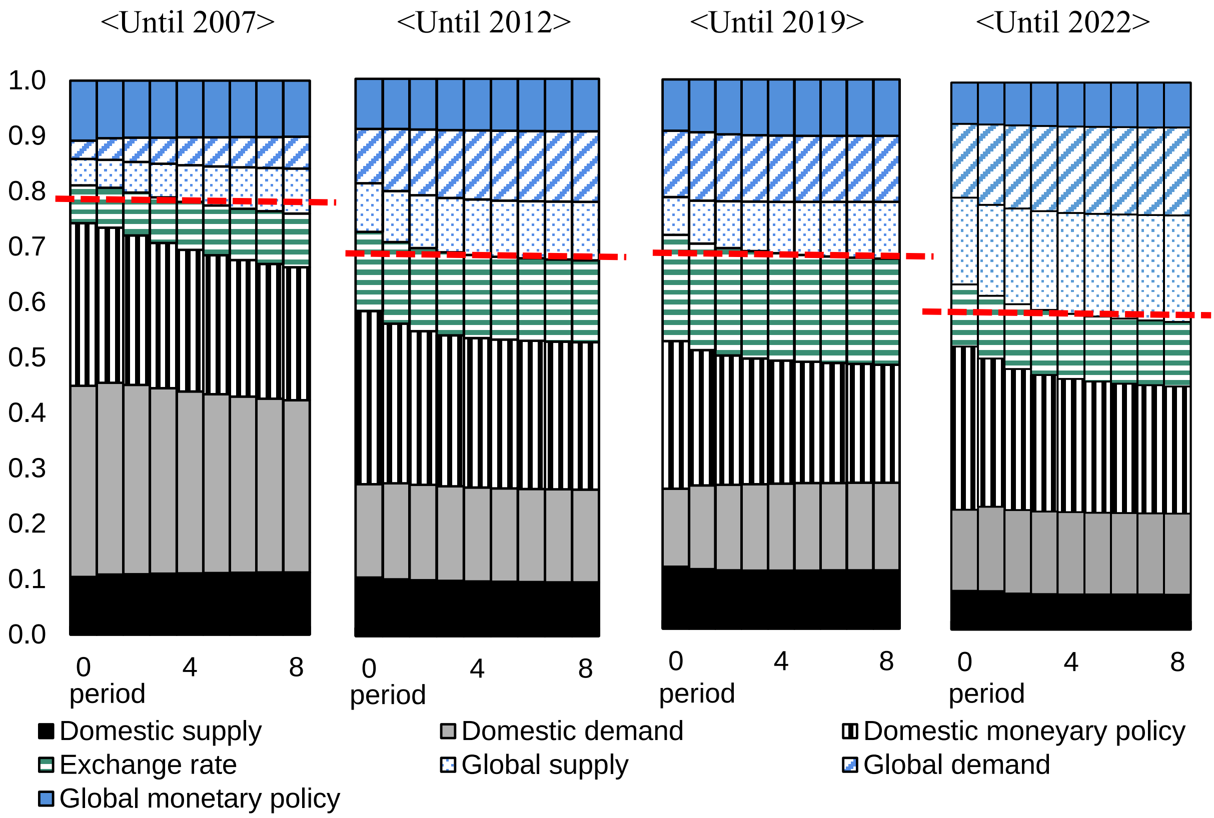
4-4. Forecast Error Variance Decomposition

In addition to the above historical decompositions, another set of important results of our SVAR models is the variance decompositions of forecast errors. While the historical decompositions assumed that the time-series relationship between variables remained unchanged throughout the estimation period (full-sample estimation), here we estimate the model for some sub-periods (sub-sample estimations) to see how the contributions of the identified shocks to Japanese CPI (less FF and less FFE) changed in each estimation period. The estimation period is divided in the same way as in the Phillips curve estimation in Section 3, with a fixed starting period (1995/Q4) to the period before the global financial crisis (2007/Q4), then extended to the period before the introduction of

QQE (2012/Q4), before the pandemic (2019/Q4), and at the end of the full sample (2022/Q4 for CPI less FF, 2023/Q2 for CPI less FFE). Since there are no major differences in the forecast error variance decompositions among alternative models (although there are similar differences to the historical decompositions above), the results only from the baseline (global monetary policy) model are presented below.

The forecast error variance decompositions for CPI less FF (including energy prices) are shown in Figure 13. The contributions of the three types of global shocks (excluding the exchange rate shock) were around 20 percent before the global financial crisis, but have increased to around 40 percent over the entire sample period until recently. A closer look shows that the contributions of global shocks increased to about 30 percent after the global financial crisis, and then the contributions of domestic and exchange rate shocks increased slightly after the introduction of QQE, followed by a further increase in the contributions of global shocks after the pandemic.

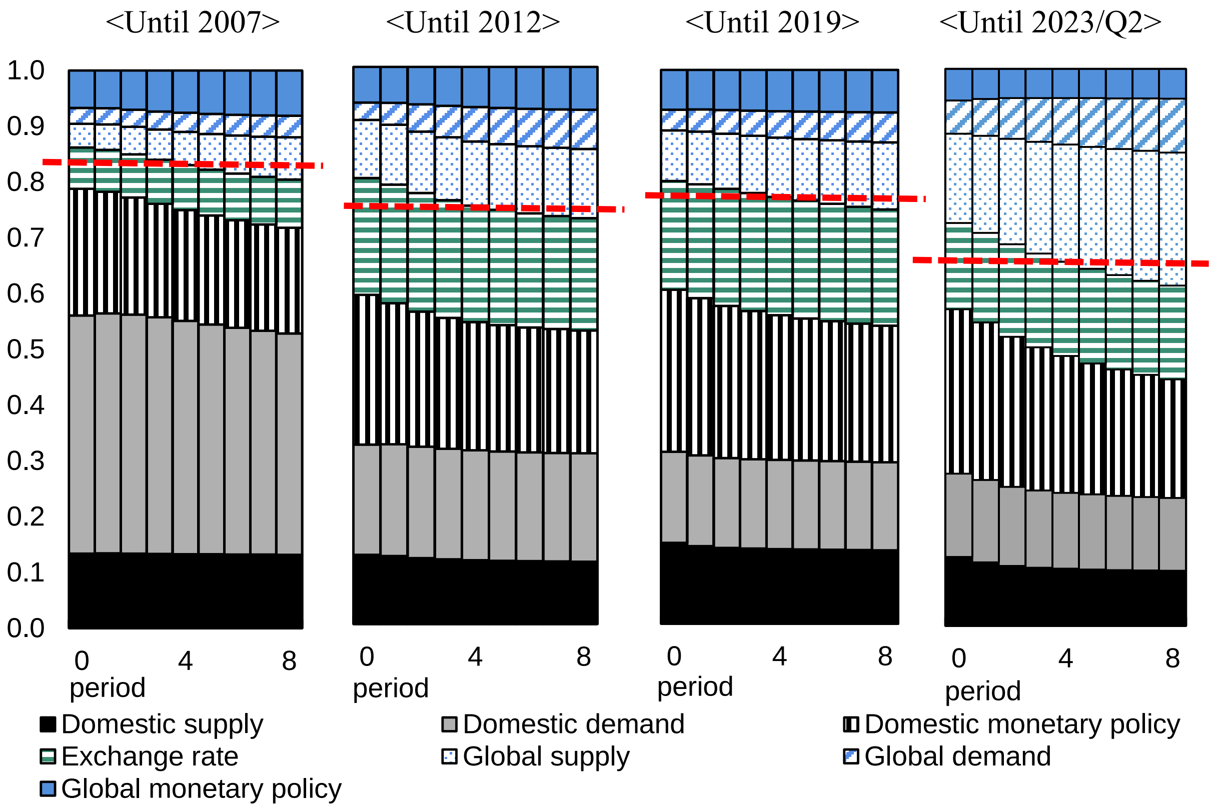
(Figure 13) Forecast error variance decompositions of Japanese CPI less FF



Note: The results from the baseline (global monetary policy) model using CPI for all items less fresh food. Estimation starting period is fixed at 1995/Q4. The red dotted line indicates the boundary between the contributions of global (global supply, global demand, and global monetary policy) shocks and those of the other shocks in the four-period-ahead forecast error variance decompositions.

The forecast error variance decompositions for CPI less FFE (excluding energy prices) shown in Figure 14 are similar to those for CPI less FF in that the contributions of global shocks gradually increase as the estimation period is extended, with an increase from over 10 percent in the pre-global financial crisis sub-sample to around 30 percent over the full sample period. The difference between the above results for CPI less FF and less FFE is in the contribution of foreign demand shocks, which is smaller in the results for CPI less FFE, confirming that energy price fluctuations, which corresponds to the difference between the two, were mainly explained by global demand shocks, as suggested by the historical decompositions. The contribution of domestic demand shocks declined significantly after the global financial crisis (similar for CPI less FF, but more so for CPI less FFE), suggesting that the relationship between the domestic output gap and inflation weakened as the contributions of global shocks increased.

(Figure 14) Forecast error variance decompositions of Japanese CPI less FFE



Note: The results from the baseline (global monetary policy) model using CPI for all items less fresh food and energy. Estimation starting period is fixed at 1995/Q4. The red dotted line indicates the boundary between the contributions of global (global supply, global demand, and global monetary policy) shocks and those of the other shocks in the four-period-ahead forecast error variance decompositions.

4-5. Sub-sample Estimation of Trend Inflation[27]

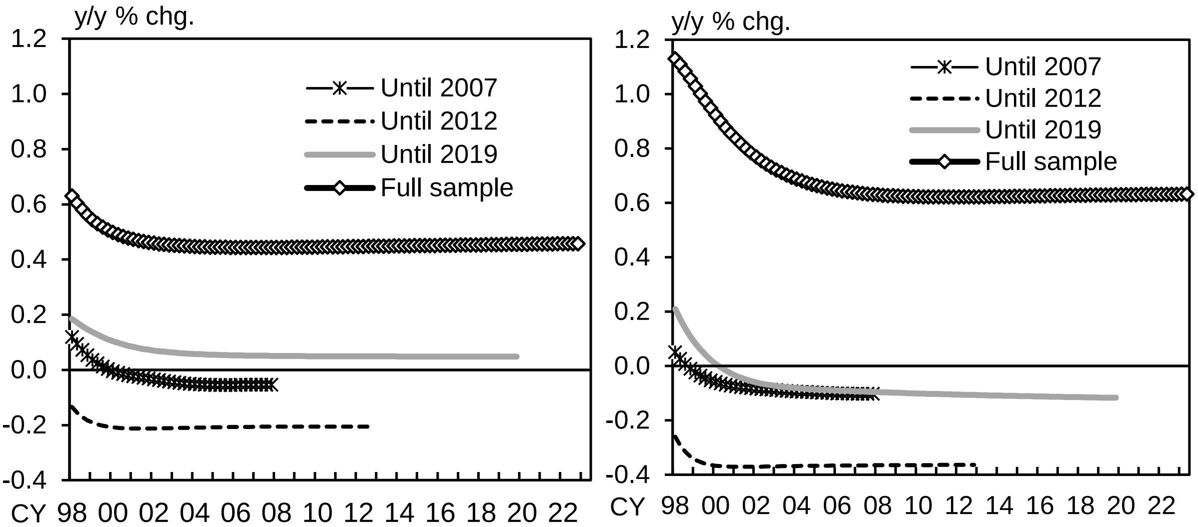
In the forecast error variance decomposition presented above, the contribution of the "initial value and trend" in the historical decomposition (most of which, excluding the effect of the initial value, was a constant term) was not taken into account. In the last part of this section, we check whether this component corresponding to a constant term differs from period to period in the sub-sample estimation, in which the estimation period is divided in the same way as in the forecast error variance decomposition. The component corresponding to a constant term represents a kind of trend inflation that is unaffected by the seven structural shocks. If the estimated constant term differs from period to period in the sub-sample estimation, it can be interpreted that the trend inflation has fluctuated. In that case, the results of historical decompositions presented in Section 4-2 may be biased by not taking into account the fluctuations in the trend inflation.

Figure 15 shows the contribution of "initial value and trend" in the historical decompositions in the sub-sample estimation with a fixed starting period (1995/Q4) to the period before the global financial crisis (2007/Q4), then extended to the period before the introduction of QQE (2012/Q4), before the pandemic (2019/Q4), and at the end of the full sample (2022/Q4 for CPI less FF, 2023/Q2 for CPI less FFE). For CPI less FF (Figure 15, left), the "initial value and trend" changed significantly from period to period: slightly below zero in the sub-sample until 2007, about minus 0.2 percent until 2012, and slightly above zero until 2019, and about 0.4 percent in the full sample (until 2022). Similar results are obtained for CPI less FFE (Figure 15, right), with even greater volatility than the results for CPI less FF, from nearly minus 0.4 percent until 2012 to about 0.6 percent in the full sample (until 2023/Q2). These results may suggest that the trend inflation fluctuated widely above and below zero, falling into the negative territory until about 2012 and then rising into the positive territory.

[27] This subsection was added in response to the comments made by Toshitaka Sekine, our discussant at the 10th Joint Conference co-hosted by the Center for Advanced Research in Finance at the University of Tokyo and the Research and Statistics Department of the Bank of Japan.

(Figure 15) Sub-sample estimation of trend inflation

CPI less FF (including energy prices) CPI less FFE (excluding energy prices)



Note: The results from the baseline (global monetary policy) model. Estimation starting period is fixed at 1995/Q4. The contribution of "initial value and trend" in the historical decomposition for each estimation period.

However, it is questionable whether the level of "initial value and trend" estimated here can be taken at face value as the level of the trend inflation rate. The data on medium- and long-term inflation expectations, which are conceptually similar to the trend inflation and will be introduced into our SVAR models in the next section, had not fluctuated as much since the late 1990s as the above results suggest, nor had they fallen to negative levels. In this regard, one possibility is that some of the global shocks (especially global supply shocks) that had continuously contributed to downward pressure on inflation before the pandemic may have been erroneously captured as part of the declining trend inflation in the sub-sample estimation. If that is the case, the result in the full-sample estimation that global shocks have turned into upward pressure in recent years has also revealed the fact that they had continuously pushed down inflation in the past. Such a possibility could be examined more clearly by treating the constant term as a time-varying parameter, but we would like to leave it for future work as it would make our estimation procedure further complicated.[28]

[28] Nishizaki, Sekine, and Ueno (2014) estimate a Philips curve model with a time-varying trend inflation, and their results suggest that factors corresponding to global shocks had continuously contributed to downward pressure on Japanese CPI inflation from the 1980s to 2000s.

5. Analysis of Price-Related Variables in Japan Using SVAR Models

In the previous section, we used SVAR models with seven variables (three domestic, three foreign, and the exchange rate) to identify structural shocks that have affected fluctuations in Japanese consumer prices. In this section, to delve into the domestic propagation mechanisms of these structural shocks, we modify the SVAR models in the previous section by adding a new domestic variable closely related to consumer prices (inflation expectation or nominal wage), or by breaking down consumer prices into goods and services prices, and analyze the effect of global shocks on these variables. If these domestic variables are strongly affected by global shocks, domestic propagation mechanisms through these variables may have been important even though the fundamental causes of CPI fluctuations are global shocks. To avoid complicating the model by increasing the number of domestic variables, we use only foreign consumer prices as a foreign variable in the SVAR models in this section.[29] The domestic real GDP, consumer prices, nominal interest rate, and nominal effective exchange rate used in the models in the previous section are also used in the models in this section.

5-1. Inflation Expectations

First, we consider SVAR models augmented with inflation expectations as a domestic price-related variable. There are various types of indictors on inflation expectations, with a variety of agents forming expectations and the horizon of expectations. We use the following four indicators of inflation expectation. For firms' inflation expectations, we use the data of 1-year- and 10-year-ahead inflation expectations from Nakajima (2023) which are based on the Bank of Japan's Tankan business survey data. In addition, we use economists' 1-year-ahead inflation expectations from Consensus Forecast by Consensus Economics and the medium- to long-term inflation expectations used in the Phillips curve estimation in Section 3 (an average of inflation expectations of economists, market participants, households, and firms <2-11 years ahead>; See footnote 12 for details).

The other variables are Japan's real GDP, CPI less FFE (excluding energy prices),[30]

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[29] While there are a wide variety of variables that could primarily capture global factors affecting domestic prices, Kabukçuoğlu and Martínez-García (2018) argue that global inflation is a strong candidate, both in theory and in terms of forecasting power for domestic inflation.

[30] We use only CPI less FFE for Japanese consumer prices in this section because the data are stable until recently (2023/Q2) and have a closer relationship with inflation expectations (and nominal wages) more than CPI less FF. The results are largely unchanged, however, when CPI less FF is used instead.

nominal interest rates (2-year interest rates), the nominal effective exchange rate of the Japanese yen, and foreign consumer prices (headline). Together with one of the above four indicators of inflation expectations, each SVAR model has a total of six variables. The estimation period is from 1995/Q4 to 2023/Q2, as in the models using CPI less FFE in the previous section. We consider six types of structural shocks to be identified: domestic supply, domestic demand, domestic monetary policy, and exchange rate shocks, as well as an idiosyncratic shock to inflation expectations and only one type of global shock. The identification restrictions are summarized in Figure 16. We assume that an inflation expectations shock has no long-run effect on the level of real GDP, and no contemporaneous and long-run effects on foreign consumer prices (the small open economy assumption), and moves inflation expectations, consumer prices, and the nominal interest rate in the same direction (imposed as sign restrictions). The restrictions for identifying other domestic shocks remain the same as in the models in the previous section, and no sign restrictions are imposed on the impacts on inflation expectations.[31] For identifying the exchange rate and global shocks, we impose sign restrictions only on the exchange rate and foreign consumer prices, respectively. In the following, we present the results of historical decompositions and how these shocks have affected the changes in inflation expectations. As in the previous section, historical decompositions of Japanese CPI can also be shown from the models in this section, but we do not present them because the results are basically the same as in the previous section.

[31] Neri (2023) imposes no sign restrictions on the effect of various shocks on inflation expectations in his sign-restricted SVAR model (the analysis is for the euro area) that includes inflation expectations as an endogenous variable.

(Figure 16) Identification restrictions for the inflation expectations models

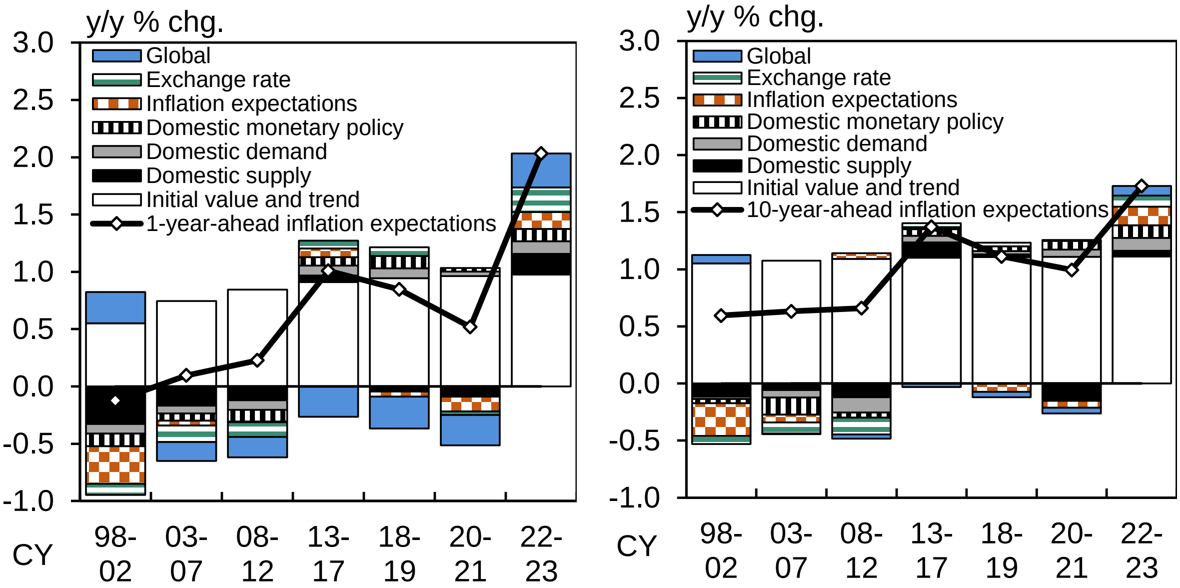
Variables / Shocks			Domestic				Exchange rate	Global
			Supply	Demand	Monetary policy	Inflation expectations		
Short-run restrictions	Domestic	1. Real GDP	+	+	-			
		2. Consumer prices	-	+	-	+		
		3. Nominal interest rate		+	+	+		
		4. Inflation expectations				+		
		5. Nominal effective exchange rate		+	+		+	
	Foreign	6. Consumer prices	0	0	0	0		+
Long-run restrictions	Domestic	1. Real GDP		0	0	0		
		2. Consumer prices						
		3. Nominal interest rate						
		4. Inflation expectations						
		5. Nominal effective exchange rate						
	Foreign	6. Consumer prices	0	0	0	0		

+	Sign restriction (+)
-	Sign restriction (-)
0	Long-run restriction
0	Small open economy assumption

The historical decompositions of firms' inflation expectations are shown in Figure 17. The global shock had some impact on 1-year-ahead inflation expectations throughout the estimation period, including in the recent period of upswing. While the global shock made a negative contribution during the inflationary period after the introduction of QQE, it has contributed to pushing up inflation expectations in the recent period, together with other domestic shocks and the exchange rate shock. By contrast, the fluctuations of firms' 10-year-ahead inflation expectations are largely explained by the trend (corresponding to the constant term), and the fluctuations around the trend driven by various shocks were small. The contribution of global shock was also limited, and the recent increase in 10-year-ahead inflation expectations were mainly driven by expectations-specific shocks and other domestic shocks.

(Figure 17) Historical decompositions of firms' inflation expectations

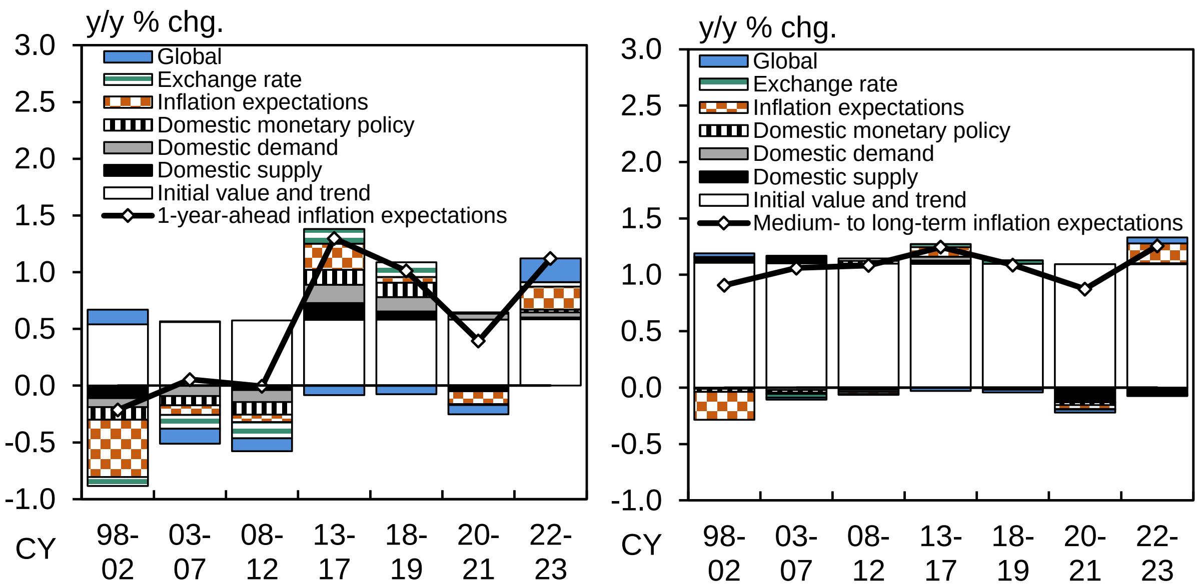
1-year-ahead inflation expectations | 10-year-ahead inflation expectations



Note: Firms' inflation expectations data are from Nakajima (2023). Estimation period is 1995/Q4 - 2023/Q2.

(Figure 18) Historical decompositions of economists' and others' inflation expectations

1-year-ahead inflation expectations | Medium- to long-term inflation expectations



Note: Economists' inflation expectations are based on Consensus Forecast by Consensus Economics. For medium- and long-term inflation expectations, see footnote 12 in Section 3. Estimation period is 1995/Q4 - 2023/Q2.

A similar pattern can be seen in the historical decompositions of economists' inflation expectations (Figure 18). While the global shock had some impact on 1-year-ahead inflation expectations, the fluctuations of medium- to long-term inflation expectations around the trend have been even smaller than those of firms' expectations, and the contributions of shocks other than expectations-specific shock, including global shock, were very limited.

The above situation of stable medium- to long-term inflation expectations and their low sensitivity to global and other shocks may be desirable in other advanced economies, but that would not necessarily be the case in the context of Japan, which has been seeking to raise the trend of inflation. This may have something to do with the fact that, as has been pointed out, decades of low inflation or deflation have entrenched the social norm that prices are unlikely to rise. However, if short-term inflation expectations and nominal wages continue to rise in response to a large shock as in the recent phase of high inflation, the norm may eventually change over time, possibly affecting medium- to long-term inflation expectations as well. At this point, the implications that can be drawn from the above results are limited, but we will continue the analysis of price-related variables including nominal wages in the rest of this section.

5-2. Nominal Wages

In this subsection, we consider SVAR models that incorporate nominal wages instead of inflation expectations as a domestic price-related variable. We use the seasonally adjusted quarterly changes in nominal wages per employee and nominal hourly wages per employee, calculated from data on total cash earnings and total hours worked in the Monthly Labor Survey (for establishments with five or more employees). Both wages per employee and hourly wages are closely related to consumer prices, the former through its relationship with private consumption and the latter through business costs. In Japan, the share of part-time workers has been increasing and the number of hours worked per employee has been decreasing, so the divergence between the two wage indicators is large (wages per employee has grown more slowly than hourly wages). We use these two indicators of nominal wages alternately in the SVAR models below.

The other variables are the same as in the models with inflation expectations in the previous subsection, so each model has a total of six variables. Accordingly, we consider six types of shocks, in which an idiosyncratic shock to nominal wages is included instead of the inflation expectation shock. The identification restrictions are summarized in Figure 19. We assume that a nominal wage shock has no long-run effect on the level of real GDP, and no contemporaneous and long-run effects on foreign consumer prices (the small open economy assumption), and moves nominal wages and consumer prices in the same direction (imposed as sign restrictions). The restrictions for identifying the other shocks remain the same as in the inflation expectations model in the previous subsection, and no sign restrictions are imposed on the impact on nominal wages.

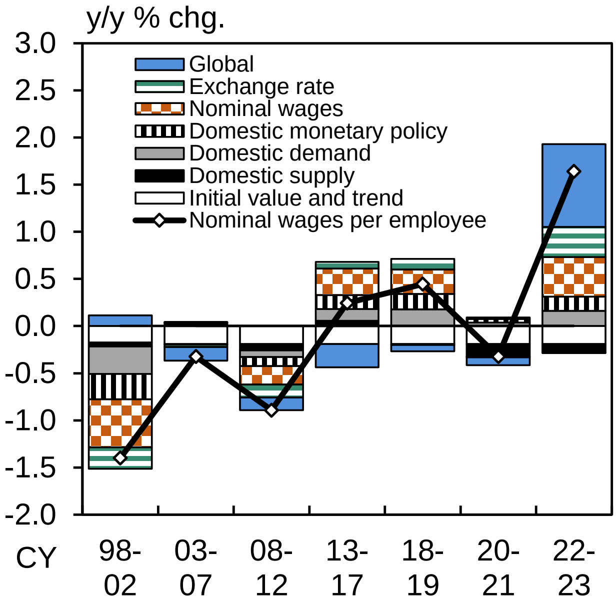
(Figure 19) Identification restrictions for the nominal wage models

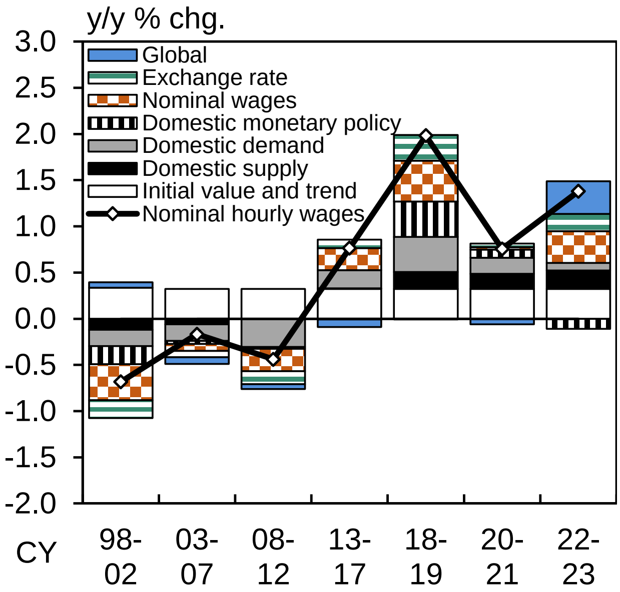
Variables / Shocks			Domestic					Global
			Supply	Demand	Monetary policy	Nominl wages	Exchange rate	
Short-run restrictions	Domestic	1. Real GDP	+	+	-			
		2. Consumer prices	-	+	-	+		
		3. Nominal interest rate		+	+			
		4. Nominal wages				+		
		5. Nominal effective exchange rate		+	+		+	
	Foreign	6. Consumer prices	0	0	0	0		+
Long-run restrictions	Domestic	1. Real GDP		0	0	0		
		2. Consumer prices						
		3. Nominal interest rate						
		4. Nominal wages						
		5. Nominal effective exchange rate						
	Foreign	6. Consumer prices	0	0	0	0		

+	Sign restriction (+)
-	Sign restriction (-)
0	Long-run restriction
0	Small open economy assumption

Figure 20 shows the historical decompositions of the two indicators of nominal wages. The left panel shows that the global shock has made a large positive contribution to recent increases in nominal wages per employee. Before the pandemic, the global shock had depressed wages, albeit with a small contribution, but the recent acceleration in wage growth is largely explained by the reversal of the global shock. As for nominal hourly wages shown on the right panel, the contribution of the global shock is generally smaller than that to nominal wages per employee, but it has made a clear positive contribution in the recent phase of wage growth. This is a very different from the post-QQE phase of wage growth, in which the main positive contributions came from domestic demand and monetary policy shocks.

(Figure 20) Historical decompositions of nominal wages





Note: Nominal wages are based on the "Monthly Labor Statistics" of the Ministry of Health, Labor and Welfare. Estimation period is 1995/4Q - 2023/2Q.

As described above, the propagation of global shocks to domestic nominal wages, which was not clear in the past, has been clearly observed in the recent phase of wage growth. Even if a shock originates abroad, once it spills over to domestic wages through prices, the effects of the shock may persist through the interrelationship between prices and nominal wages and eventually may spill over into medium- to long-term inflation expectations. Given this possibility, the spillover channel through nominal wages would be crucial for the persistence of the effects of global shocks on domestic prices.

5-3. Goods and Services Prices

Finally, we use consumer goods prices and consumer services prices separately, and analyze the effect of the global shock on each of them. Specifically, we consider an SVAR model that includes seasonally adjusted quarterly changes in two consumer prices: CPI for goods less fresh food and energy (hereafter simply "goods"), and CPI for general services less mobile phone charges (not including administered prices, hereafter simply "services"). The other variables are Japan's real GDP, nominal interest rate (2-year interest rate), nominal effective exchange rate, and foreign consumer prices (headline), so the model has a total of six variables. Accordingly, we consider six types of shocks, in which an idiosyncratic shock to services prices is included. The restrictions for identifying these shocks are summarized in Figure 21. We assume that a services prices shock has no contemporaneous and long-run effect on foreign consumer prices (the small open economy assumption), but do not impose a long-run restriction on domestic real GDP because the shock may have a long-run effect domestically through changes in relative prices. Indeed, the estimated impulse responses show that a services prices shock move service and goods prices in opposite directions despite no sign restriction imposed, which implies a significant change in relative prices. The restrictions for identifying the other shocks are basically the same as in other models in this section. We impose the same sign restrictions on the effects of domestic supply, demand, and monetary policy shocks on goods and services prices, as we do on consumer prices in the other models.

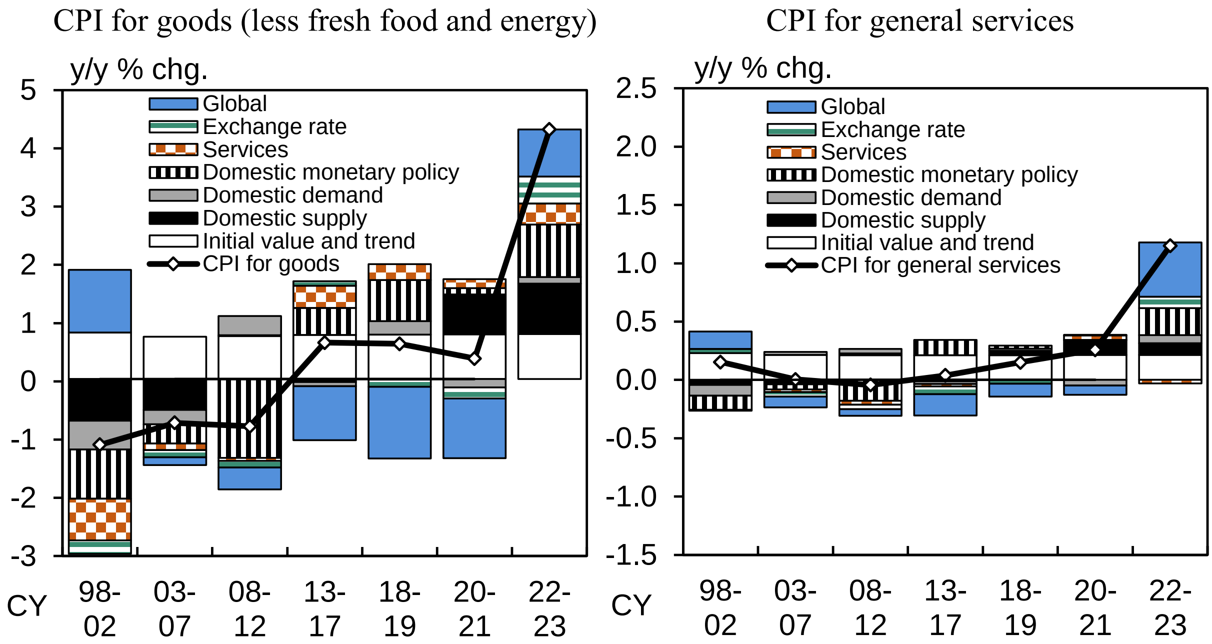
(Figure 21) Identification restrictions for the goods and services prices model

Variables / Shocks			Domestic				Exchange rate	Global
			Supply	Demand	Monetary policy	Services prices		
Short-run restrictions	Domestic	1. Real GDP	+	+	-			
		2. CPI for goods	-	+	-			
		3. CPI for services	-	+	-	+		
		4. Nominal interest rate		+	+			
		5. Nominal effective exchange rate		+	+		+	
	Foreign	6. Consumer prices	0	0	0	0		+
Long-run restrictions	Domestic	1. Real GDP		0	0			
		2. CPI for goods						
		3. CPI for services						
		4. Nominal interest rate						
		5. Nominal effective exchange rate						
	Foreign	6. Consumer prices	0	0	0	0		

+	Sign restriction (+)
-	Sign restriction (-)
0	Long-run restriction
0	Small open economy assumption

Figure 22 shows the historical decompositions of goods and services prices. As can be seen immediately, the difference in the range of fluctuations between the two is very large. Even though the vertical axis of the graph of goods prices on the left is set twice as high as that of services prices on the right, the fluctuation in goods prices is overwhelmingly larger. Taking this into account, we can see that goods prices declined continuously during the 2000s mainly due to domestic shocks (domestic supply shocks reflecting technological progress, etc. in the first half, and then mainly domestic monetary policy shocks after the global financial crisis). After the introduction of QQE, domestic monetary policy shocks turned into a positive contribution, causing goods prices to rise, but the negative contribution of the global shock expanded to offset the effects of QQE. In the meantime, services prices barely declined except for a period after the global financial crisis, but the negative contribution of the global shock expanded slightly after the introduction of QQE. Thereafter, in the recent inflationary period, the contribution of the global shock turned positive to both goods and services prices. While the contribution of global shocks to goods prices has been smaller than that of domestic shocks, its contribution to services prices has been more pronounced. As the latter includes some specific services prices (e.g., meals outside the home) that are sensitive to import prices, there are some uncertainty about the persistence and spillover effects across a wide range of service prices. That said, as with the results of the analysis of nominal wages in the previous subsection, the propagation of global shocks to service prices, which was not clear in the past, has become more pronounced in the recent period.

(Figure 22) Historical decompositions of goods and services prices

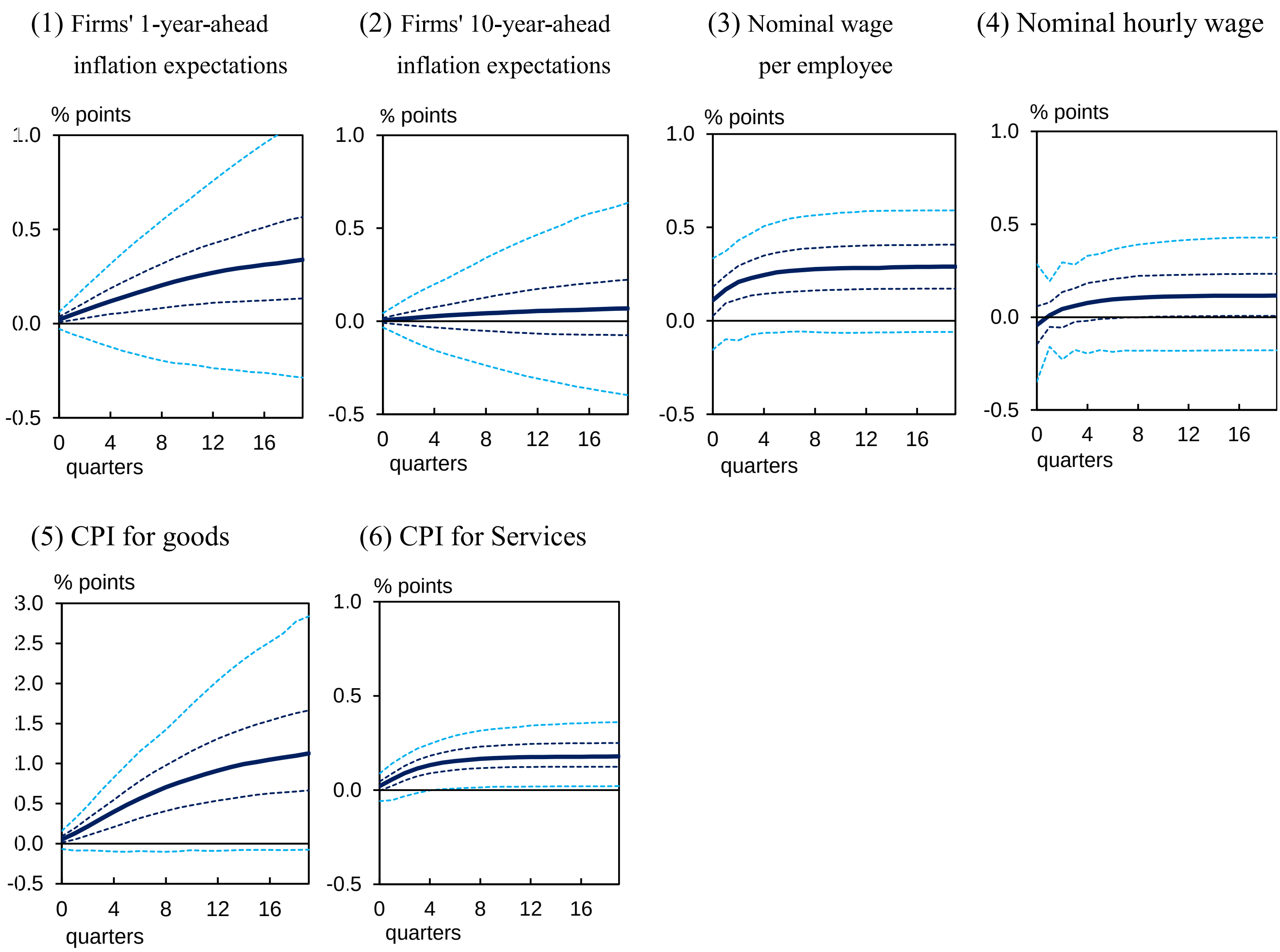


Note: Estimated period is 1995/4Q - 2023/2Q.

5-4. Effects of Global Shocks on Price-Related Variables

To sum up, the analysis in this section shows that the effects of global shocks on medium- and long-term inflation expectations have so far been limited, but those on 1-year-ahead inflation expectations and goods prices have been clearly observed, and services prices and nominal wages, which had not been much affected by global shocks in the past, have been significantly pushed up by global shocks in the recent inflationary phase. Comparing the impulse responses of these price-related variables to the global shock after standardizing the size of the shock across different models (Figure 23), we can see that all the responses of these variables except the medium- to long-term (firms' 10-year-ahead) inflation expectations are clearly positive, although their magnitudes are different. As the global inflation synchronization increases and the effects of global factors on consumer prices become larger, the propagation mechanism of global shocks on these domestic price-related variables warrants more attention.

(Figure 23) Impulse Responses of Price-Related Variables to Global Shocks



Notes: 1. Cumulative impulse responses of various price-related variables to a global shock.
2. The shock is standardized so that the initial responses of foreign consumer prices can be equal across different models.
3. Thick lines represent the median response. Inner dotted lines represent 25 and 75 percentiles, and outer dotted lines represent 5 and 95 percentiles.

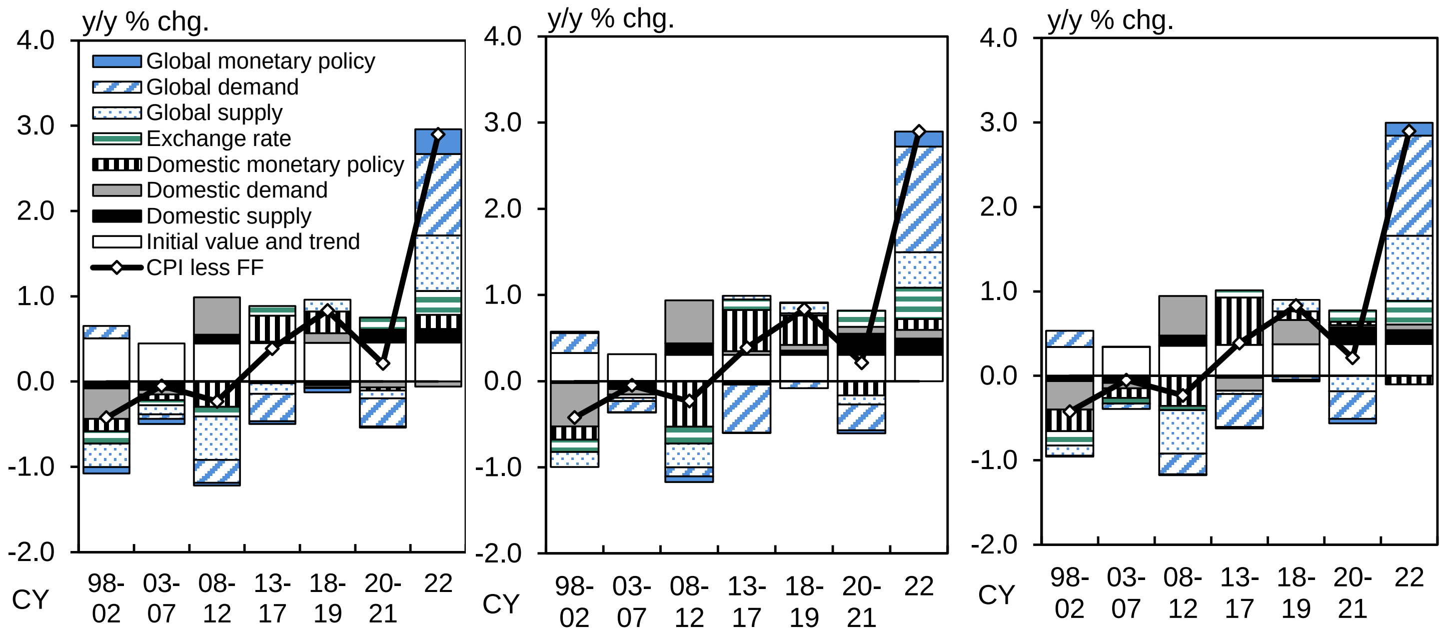
6. Conclusion

With a brief examination of the global inflation synchronization, this paper analyzes the effects of domestic and global factors on Japanese consumer price inflation and related variables since the late 1990s, when Japan fell into deflation, mainly using SVAR models with short- and long-run zero and sign restrictions. Historical decompositions show that various types of global shocks, including downward cost pressure due to globalization, had continuously pushed down Japanese consumer prices until the late 2010s, and then their contributions reversed, significantly pushing up prices especially during the high-inflation phase after the pandemic. In addition, we find that service prices and nominal wages, which had not been much affected by global shocks, have also been significantly pushed up by global shocks in the recent period.

The recent increase in the global inflation synchronization across countries has reminded us of the important role of global factors in inflation. The discussions among central banks and others about their implications for monetary policy, as summarized in Section 1, may be revisited at some point. A deeper understanding of domestic propagation mechanisms as well as the persistence of global shocks themselves is needed to forecast future price developments. We look forward to further research and discussion in these areas, both in Japan and abroad.

(Supplementary Figure 1) Historical decomposition of Japanese CPI less FF: alternative interest rates

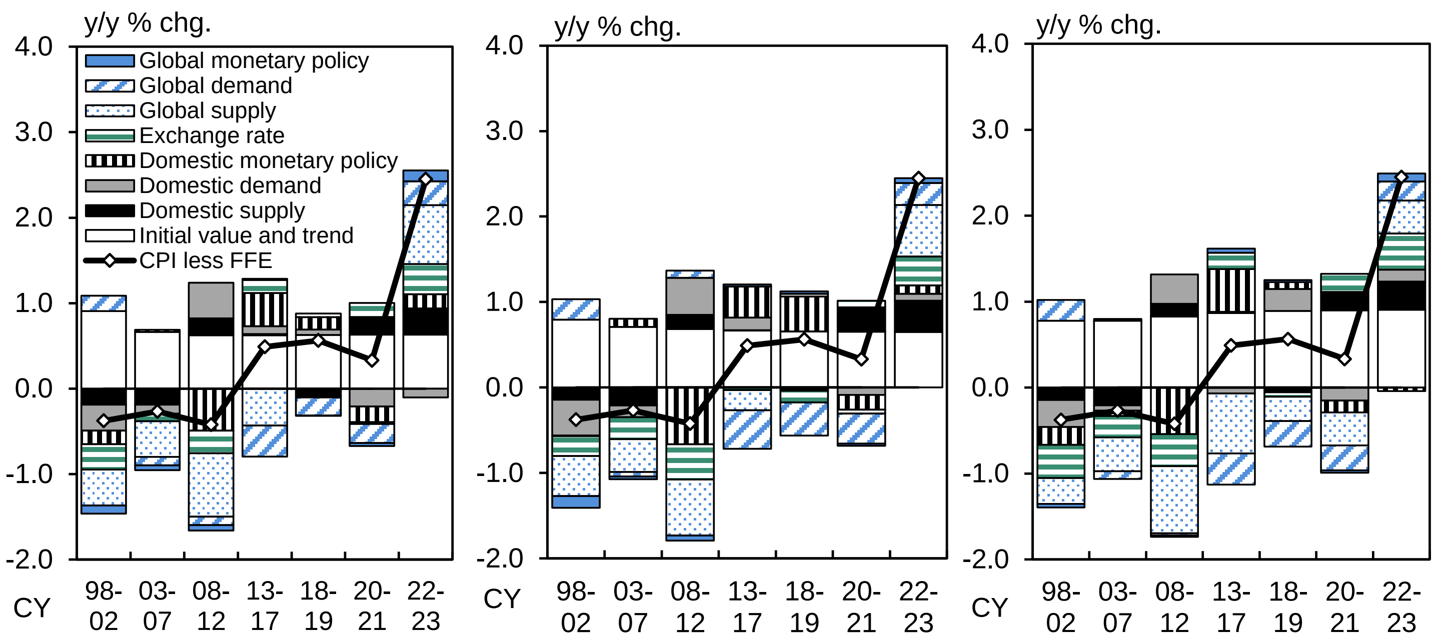
2-year interest rate | 10-year interest rate | Shadow rate



Note: The results from the baseline (global monetary policy) model using CPI for all items less fresh food. Estimation period is 1995/Q4 - 2022/Q4.

(Supplementary Figure 2) Historical decomposition of Japanese CPI less FFE: alternative interest rates

2-year interest rate | 10-year interest rate | Shadow rate



Note: The results from the baseline (global monetary policy) model using CPI for all items less fresh and energy. Estimation period is 1995/Q4 - 2023/Q2.

Appendix 1: Data used for estimation

This appendix provides details on the data used to estimate the SVAR models in Section 4 of the main text (Figure A1). For both the CPI for all items less fresh food and the CPI for all items less fresh food and energy, we use Bank of Japan staff estimates, which exclude mobile phone charges and the effects of the consumption tax rate hikes, policies concerning the provision of free education, and travel subsidy programs. Foreign CPI and GDP are based on G20 data, which include China and other emerging economies. Data compiled by the OECD are used for foreign CPI from 1996/Q2 onwards and for foreign real GDP from 1998/Q1 onwards; before that, data available for G20 countries and regions have been averaged with GDP weights.[32] For interest rates, all results presented in the main text are based on 2-year rates, but for robustness analysis, we also analyze using 10-year rates and shadow rates (as estimated by Krippner, 2020). Foreign interest rates are a weighted average of U.S., Germany (for shadow rates, euro area data are used), and the U.K., averaged with GDP weights. GDP, CPI, exchange rates, and oil prices (GDP and CPI are seasonally adjusted) are log-differenced, and linear trends are removed from interest rates and the global supply chain pressure index.

[32] China is not included in foreign GDP before 1998/Q1 due to data availability, but its share of the world economy at that time was much smaller (about 6 percent) than the present (nearly 20 percent), and its influence should be limited.

(Figure A1) List of Data

Variables		Notes	Reference
Real GDP (SA, Log-difference)	Japan	-	Cabinet Office, OECD, Haver
	Foreign	The aggregate of G20 countries and regions excluding Japan. (Prior to 98Q1) Calculated as the weighted average of available G20 countries and regions excluding Japan.	
CPI (SA, Log-difference)	Japan	All items less fresh food or less fresh food and energy. Mobile phone charges and the effects of the consumption tax rate hikes, policies concerning the provision of free education, and travel subsidy programs are excluded from both series.	Ministry of Internal Affairs and Communications, Bank of Japan
	Foreign	The aggregate of G20 countries and regions excluding Japan. (Prior to 96Q1) Calculated as the weighted average of available G20 countries and regions excluding Japan.	OECD, Haver
Interest Rate (Detrended, %)	Japan	2-year rate, 10-year rate, and shadow rate.	Refinitiv, LJKmfa, Haver
	Foreign	2-year rate, 10-year rate, and shadow rate. Calculated as the weighted average of the U.S., euro area, and the U.K.	
Nominal Effective Exchange Rate (Log-difference)		-	Bank of Japan
Oil Prices (Log-difference)		West Texas Intermediate	EIA, CME, Haver
Global Suupy Chain Pressure Index (Detrended)		Estimates by New York Fed	New York Fed

Note: The aggregate or average is caluculated usng PPP-based GDP weights published by IMF.

Appendix 2: Estimation Methodology for SVAR Models

This appendix describes the estimation methodology for the SVAR models in Section 4 of the main text. In order to apply the combination of short- and long-run zero and sign restrictions described in the main text, we conduct Bayesian estimation as in Forbes, Hjortsoe, and Nenova (2020),[33] which consists of the following steps.

1). The standard Minnesota priors are used and a reduced-form model is estimated. The prior means of the coefficients are assumed to follow random walk processes, and the variance-covariance matrix of the error term is replaced by the OLS estimates. The hyper-parameters defining the shape of the prior distributions are set to the same values as in Forbes, Hjortsoe, and Nenova (2020). The lag order is set to 2 quarters based on the Akaike Information Criterion (AIC).

2). A variance-covariance matrix and a residual covariance matrix are randomly generated from the obtained posterior distributions.

3). Following Binning (2013)'s method, an orthogonal decomposition satisfying the long-run and short-run zero restrictions are randomly generated.

4). Steps 2) and 3) above are conducted 10,000 times as a burn-in, and then repeated until we obtain 1,000 samples which satisfies the sign restrictions.

We presented in the main text the distribution of the above 1,000 samples for impulse responses, and the mean of the 1,000 samples for historical decompositions and forecast error variance decompositions.

[33] The Matlab code used in Forbes, Hjortsoe, and Nenova (2020) is available at Kristin Forbes' website linked below.
https://mitsloan.mit.edu/faculty/directory/kristin-j-forbes

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