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Estimating Effects of Expansionary Monetary Policy since the Introduction of Quantitative and Qualitative Monetary Easing (QQE) Using the Macroeconomic Model (Q-JEM)

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Estimating Effects of Expansionary Monetary Policy since the Introduction of Quantitative and Qualitative Monetary Easing (QQE) Using the Macroeconomic Model (Q-JEM)*

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Abstract

This paper estimates the macroeconomic effects of the Bank of Japan's expansionary monetary policies since the introduction of Quantitative and Qualitative Monetary Easing (QQE) using the Bank of Japan's large-scale macroeconomic model, Q-JEM (Quarterly Japanese Economic Model). We consider counterfactual paths of major financial variables, such as real interest rates, constructing hypothetical scenarios where the QQE and subsequent easing measures had not been introduced. We then conduct counterfactual simulations to examine how Japan's macroeconomic variables such as real GDP and CPI would have evolved under those hypothetical scenarios. In this setting, we estimate the policy effects on the macroeconomic variables as the difference between actual values and the counterfactual. Estimation results show that, on average during the period from the introduction of QQE to the July-September quarter of 2020, the policy effect on the level of real GDP is between around +0.9 and +1.3 percent and that on the year-on-year rate of change in the CPI (all items less fresh food and energy) is between around +0.6 and +0.7 percentage points.

JEL classification: C53, E37, E47, E52, E58.

Key words: Monetary policy, Policy effect, Large-scale macroeconomic model, Simulation.

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1. Introduction

This paper estimates the macroeconomic effects of the Bank of Japan (BoJ)'s monetary easing measures since the introduction of Quantitative and Qualitative Monetary Easing (QQE) using the BoJ's large-scale macroeconomic model, Q-JEM (Quarterly Japanese Economic Model). Q-JEM is a macro-econometric model for Japan's economy that consists of hundreds of equations, maintained by the Research and Statistics Department at the BoJ. Each equation is estimated using a quarterly series of macroeconomic variables ranging two to three decades, which are updated every quarter. Specifications of the model are also often updated reflecting changes in economic circumstances. As Q-JEM is the econometric model which estimates the historical relationships among Japan's major macroeconomic variables, it is utilized for policy evaluation and various risk simulations at the BoJ (see Fukunaga et al., 2011; Hirakata et al., 2019).

In the BoJ's "Comprehensive Assessment" (Bank of Japan, 2016), released in September 2016, Q-JEM is used to estimate the policy effects of the BoJ's monetary easing measures from the introduction of QQE to the end of FY2015 (see the assessment's supplementary paper, Kan et al., 2016). The assessment considers counterfactual paths of major financial variables, constructing hypothetical scenarios where the BoJ's monetary easing measures had not been introduced, and conducts counterfactual simulations. In this setting, the policy effects of the monetary easing measures on the macroeconomic variables such as real GDP and CPI are estimated as the difference between the actual values and the counterfactual. Following this idea, the current paper estimates the policy effects of the monetary easing measures from the introduction of QQE to the July-September quarter of 2020 (see Chart 1).

We set the counterfactual paths for the financial variables using several approaches. One approach is to regress economic variables which are not likely to be directly affected by monetary policy onto each financial variable and regard an extrapolated estimate as the counterfactual path implied by the hypothetical scenario without monetary easing measures. Another approach is an event study approach that assumes the level of each financial variable prior to a policy change would have continued as the counterfactual in the hypothetical scenario without monetary easing measures. Because the counterfactual paths are not observable, the way to set them can be arbitrary as there is inevitably room for researcher discretion. With this in mind, this paper considers several counterfactual paths for each variable to examine the robustness of the simulation result.

Studies on monetary policy effectiveness have been rigorously developed among central bankers and macroeconomics researchers, in particular, since the period of Global

Financial Crisis when unconventional monetary policies were successively implemented in major countries. As a study using a large-scale macroeconomic model like Q-JEM, Engen et al. (2015) use FRB/US, the large-scale macroeconomic model of the Federal Reserve Board (FRB) to estimate the policy effects of FRB's unconventional monetary easing from 2008 to 2013. Mouabbi and Sahuc (2019) evaluate the macroeconomic effects of the European Central Bank's unconventional monetary policies from 2008 to 2017 using a dynamic general equilibrium model and show that the euro area would have had experienced severe deflation if these policies had not been introduced. As a study using a small-scale time series model, Kim et al. (2020) estimate effects of FRB's asset purchases and forward guidance from 2008 to 2015 using a vector autoregressive (VAR) model and monetary policy shocks identified by an event study. They show that these policies contributed considerably to increase inflation and lower unemployment rates in the United States.

The remainder of the paper is organized as follows. Section 2 provides an overview of the influences of BoJ's monetary easing measures on developments of financial markets and discusses the transmission mechanism of monetary policy specified in Q-JEM. In Section 3, we set the counterfactual paths of financial variables for simulation. Section 4 provides simulation results. Finally, Section 5 concludes.

2. Transmission mechanism of monetary policy specified in Q-JEM

2-1. Monetary policies and developments of financial markets since the introduction of QQE

The BoJ has implemented aggressive monetary easing measures since the introduction of QQE in April 2013 to achieve the price stability target of 2 percent. Before explaining the transmission mechanism of monetary policy specified in Q-JEM, we provide an overview of major monetary policy changes since the introduction of QQE and their influence on developments of the financial market (see Chart 2).

In April 2013, the BoJ introduced QQE, which focused on the large-scale purchases of assets, primarily long-term Japanese Government Bonds (JGBs) and Exchange Traded Funds (ETFs). Consequently, the JGB long-term (10-year) nominal interest rates significantly declined as shown in Chart 5. While an increase of U.S. interest rates during "Taper tantrum" led to upward pressure on the JGB nominal long-term interest rates to some extent, they followed their declining trend under downward pressure through the stock effect of the BoJ's large-scale JGB purchases.[1] Meanwhile, the yen depreciated partly due to the

[1] For the stock effect of the BoJ's JGB purchases on JGB yields, see Sudo and Tanaka (2018).

widening of the interest rate differential between Japan and the United States, and improvement of firm's profits along with the depreciation of the yen pushed up stock prices (see Charts 11 and 12). In October 2014, the BoJ expanded QQE when weak demand after a consumption tax rate hike and a large decline in oil price led to a downward pressure on prices. Afterward, the nominal long-term interest rates declined, the yen depreciated, and stock prices increased, further.

In the beginning of 2016, these developments were wound rapidly back, with the yen appreciation and stock prices falling, reflecting the economic slowdown in emerging economies. Against this background, in January 2016, the BoJ introduced "QQE with a Negative Interest Rate," which applied a negative interest rate of minus 0.1 percent to the Policy-Rate Balance. In response to this policy change, the nominal long-term interest rates further declined. Against the backdrop of the United Kingdom's vote to leave the European Union, which led to volatile developments in the global financial markets, the BoJ doubled the amount of ETF purchases in July 2016. In September 2016, given its "Comprehensive Assessment," it introduced "QQE with Yield Curve Control (YCC)," and decided to purchase long-term JGBs so that 10-year JGB yields remain around zero percent. Since the introduction of QQE with YCC up to recent periods, the nominal long-term interest rate has remained at around zero percent. While the yen appreciated against U.S. dollar slightly lower than 100 yen/dollar in the first half of 2016, this development was reversed after September 2016. Afterward, the rate stayed between about 105 and 115 yen. The stock price bottomed out after September 2016 and kept a high level until 2019.

In 2020, due to the impact of the COVID-19 outbreak, the financial market became unstable, as stock prices plunged. Given this development, the BoJ introduced "Enhancement of Monetary Easing in Light of the Impact of the Outbreak of the Novel Coronavirus (COVID-19)." Namely, the BoJ decided to actively purchase ETFs and introduced several measures to ease funding conditions of firms such as the Special Funds-Supplying Operations to Facilitate Corporate Financing regarding the Novel Coronavirus (COVID-19). Against the backdrop of COVID-19, firms were suffering from suppressed economic activity and corporate financing was under stress. However, the measures easing corporate financing by the government and the BoJ as well as enhancements by financial institutions mitigated financial stress and consequently firm's availability in the corporate financing market has remained accommodative (see Chart 8). The stock price bottomed out on the day of the BoJ's policy announcement stated above and turned to follow an increasing trend.

2-2. Transmission channels of monetary policy specified in Q-JEM

As stated above, the BoJ's monetary easing measures have largely affected major financial variables such as long-term interest rates, foreign exchange rates, stock prices, and the financial condition of firms. Here, we explain how Q-JEM specifies effects of such changes in financial conditions on the real economy and prices (see Chart 3)[2]. In general, Q-JEM has four transmission channels of monetary policy.

The first channel is that a decline in real interest rates leads to a positive effect on the real economy by reducing financing cost. The real interest rates are decreased by lowering nominal long-term interest rates under measures such as the JGB purchases and by raising inflation expectations under a commitment to achieving the price stability target of 2 percent. In Q-JEM, firms increase fixed investment due to lowered cost of capital reflecting the decline in real interest rates. On the household side, the decline in real interest rates pushes up private consumption through intertemporal substitution effects. In addition, households increase residential investment benefiting from lowered mortgage rates.

The second channel is that a rise in stock price raises "Tobin's Q," which is the ratio of a firm's market value evaluated by stock market relative to its replacement value, which increases business fixed investment. The stock price increase also expands private consumption by raising the value of households' financial assets (i.e., wealth effect).

Third, the decline in real interest rates and the rise in stock prices also stimulate the economy through a depreciation of the yen. The decline in real interest rates can lead to depreciation of the yen through widening of spread between domestic and foreign interest rates. In addition, the rise in stock prices allows investors to take additional risk through increasing value of their net asset and consequently increases selling pressure on the yen, which is perceived as a safe-haven currency in the global financial market. The yen depreciation expands exports and firm's profits and thus induces investment demand. On the household side, the expansion of firm's profits pushes up private consumption through the increase in labor income.

The fourth channel is that an improvement in the availability of loans to firms in the loan market has a positive effect on business fixed investment by facilitating corporate financing. In Q-JEM, we include the lending attitude DI of *Tankan* (BoJ's Short-Term Economic Survey of Enterprises in Japan) in a function of business fixed investment to

[2] References 1, 2, and 3 show key equations in Q-JEM.

describe a lending stance of financial institutions that is not explained by lending rates.[3] For instance, the BoJ's measures of facilitating corporate financing in response to the outbreak of COVID-19 support the economy through a channel of improved lending attitude DI that is separated from the real interest rate channel. In Q-JEM, this channel is explicitly addressed by the above specification of the business fixed investment.

In Q-JEM, consumer prices are formulated by a hybrid Phillips curve. In its specification, the consumer price is a function of output gap and inflation expectations. The latter includes two elements of (i) forward-looking expectations formation on the pace of inflation approaching toward the price stability target of 2 percent and (ii) backward-looking (i.e., adaptive) expectations formation that is formed based on realized values of consumer prices. An increase in the forward-looking inflation expectations, led by a strengthened commitment to achieving the price stability target, directly contributes to increase consumer prices. If an improvement of output gap pushes up the realized inflation rates and consequently raises the adaptive inflation expectations, the inflation rates are further levered up.

3. Simulation scenarios

In this section, we consider counterfactual paths, constructing hypothetical scenarios where the QQE and subsequent easing measures had not been introduced, for the following four financial variables that play important roles in the transmission channels of monetary policy in Q-JEM: (i) real interest rates, (ii) lending attitude DI, (iii) exchange rate, and (iv) stock prices. Setting counterfactual paths for these variables requires some assumptions since these paths are not observable. Such assumptions can be arbitrary as there is inevitably room for researcher discretion. With this in mind, this paper considers several different assumptions and sets corresponding counterfactual paths for each of the financial variables to examine the robustness of the simulation result. Specifically, we estimate counterfactual paths for financial variables using the following three approaches (see Chart 4).

3-1. Estimation approach

In the first approach, we regress each of the financial variables on the economic variables that are not likely to be directly affected by the monetary policy, and define the estimated value from those regression results as a counterfactual path. We call it the "estimation

[3] In Q-JEM, the lending attitude DI is formulated by a function of stock price and firm's profits. Therefore, a rise in stock prices and an increase in firm's profits (for example, caused by declining real interest rates or a depreciation of the yen) move the lending attitude DI toward a more accommodative direction.

approach," in this paper.

Regarding the nominal long-term interest rates, we regress several economic variables using data before the introduction of QQE. With its regression result, we compute an estimated value of the nominal long-term interest rate by extrapolating based on realized values of the explanatory variables after the introduction of QQE. We set this estimated value as the counterfactual path for the nominal long-term interest rate. This calculation means that the monetary easing measures since QQE have lowered nominal long-term interest rate significantly, relative to the counterfactual computed with the historical relationships among the variables. In this consideration, the policy effect on the nominal long-term interest rate (or an effect of lowering the interest rate) is defined as the difference between the actual and the counterfactual path. Expressed by technical terms of regression analysis, the counterfactual path for nominal long-term interest rate corresponds to the "fitted value," i.e., the estimated value obtained by extrapolating with the realized values of explanatory variables after the introduction of QQE, and the policy effect corresponds to the "residual," the difference between the fitted and the actual. A counterfactual path for real interest rates is calculated by subtracting a counterfactual path for medium- to long-term inflation expectations, which is explained below, from that of the nominal long-term interest rate. We set the counterfactual path for the lending attitude DI in the same way.

For the exchange rate and the stock prices, we compute their values in Q-JEM given counterfactual paths of the real interest rates and lending attitude DI. We define the resulting values of the exchange rate and the stock prices as their counterfactual paths. The equations in Q-JEM indicate historical relationships among the economic variables estimated using data up to the latest period. Therefore, the counterfactual paths for exchange rate and stock prices after the introduction of QQE correspond to the level implied by the counterfactual paths of real interest rate and lending attitude DI with the historical relationship among the economic variables.

We explain details of the counterfactual path for each financial variable as follows.

(1) Real interest rates

In Q-JEM, real interest rate is defined as long-term (10-year) JGB nominal interest rate minus medium- to long-term inflation expectations. Our counterfactual path for real interest rate is defined as the difference between the counterfactual paths for the nominal long-term interest rate and medium- to long-term inflation expectations.

We consider the counterfactual path for the nominal long-term interest rate. Following the analysis in "Comprehensive Assessment," we regress the following three variables onto the nominal long-term interest rate: (a) active job openings-to-applicants ratio, (b) CPI (less fresh food, year-on-year), and (c) 10-year U.S. Treasury bond yields. The estimation period is from January 1997 to March 2013 (i.e., the period before the introduction of QQE). The estimation result is as follows.

Nominal long-term interest rates (10-year) (1)

$$
\begin{aligned}
&= \underset{[0.09]}{0.22} + \underset{[0.09]}{0.26} \times \text{Active job openings-to-applicants ratio} \\
&\quad + \underset{[0.02]}{0.10} \times \text{CPI} \\
&\quad + \underset{[0.01]}{0.25} \times \text{U.S. Treasury bond yields}
\end{aligned}
$$

The values in brackets are the standard errors of coefficients.
Estimation period: From Jan. 1997 to Mar. 2013
Adjusted R^2 : 0.71, Standard error of regression : 0.21
Active job openings-to-applicants ratio and CPI are lagged by one month.

The adjusted R-squared is quite high as 0.71, which implies about 70 percent of the variation in the nominal long-term interest rates before the introduction of QQE is explained by the variations of the explanatory variables. The actual and the fitted values plotted in Chart 5(1) show the good fitting of the regression during the in-sample period. We estimate fitted values from April 2013 by extrapolation based on the regression result. The Chart shows that the fitted values are between around 1.0 and 1.5 percent until around 2019 and then decline down to about 0.5 percent reflecting the decline in the U.S. Treasury bond yields (see also Chart 5(2)). We define this fitted value as the counterfactual path for nominal long-term interest rate from the introduction of QQE (April 2013).

In this approach, the residual of regression, i.e., the difference between actual and counterfactual values of nominal long-term interest rate corresponds to the policy effect. The Chart shows that the policy effect gradually gets larger from the introduction of QQE to around 2016. The average size of policy effect is about minus 1.0 percent for this period. After the introduction of YCC (in the second half of 2016), the nominal long-term interest rate stayed around zero percent under the YCC despite circumstances where the upward pressure on the nominal long-term interest rate could be materialized due to an increase in Japan's active job openings-to-applicants ratio and in the U.S. Treasury bond yields. The policy effect of monetary easing on the nominal long-term interest rate increases from about minus 1.0 to minus 1.5 percent. From the beginning of 2019, the U.S. Treasury bond yields started to decline partly reflecting the trade issues between the United States and China. In

2020, the U.S. Treasury bond yields declined further due to the policy rate cut by the FRB in response to the outbreak of COVID-19. Meanwhile, the Japan's nominal long-term interest rates have been around zero percent, thus the policy effect implied by the regression result reduced to about minus 0.5 percent.

In such a regression analysis, we expect that the BoJ's monetary policy does not affect explanatory variables. However, the active job openings-to-applicants ratio and the CPI in the above regression can be (indirectly) affected by the BoJ's monetary policy. On this point, the above regression may not accurately address the hypothetical scenario without the monetary easing measures. To check the robustness of the estimated policy effect, we examine another estimation approach focusing on the outstanding of BoJ's JGB holdings to capture its direct effect of lowering the nominal long-term interest rates.

The BoJ has conducted large-scale purchases of the JGBs since the introduction of QQE to reduce the nominal long-term interest rates. To estimate its effect, the analysis in "Comprehensive Assessment" regressed the following variables onto the nominal long-term interest rates: (a) the BoJ's share of JGB holdings, (b) the expected real GDP growth rate, and (c) the U.S. Treasury bond yields. Its regression result shows that an increase in the BoJ's share of JGB holdings significantly lowers the nominal long-term interest rates. In the current paper, we estimate the same regression using the data updated to October 2020. The estimation result is as follows.

$$\begin{aligned}\text{Nominal long-term interest rates (10-year)} \quad & \quad (2)\\ = \underset{[0.12]}{0.26} - \underset{[0.002]}{0.02} & \times \text{the BoJ's share of JGB holdings}\\ + \underset{[0.21]}{0.40} & \times \text{Expected real GDP growth rate}\\ + \underset{[0.07]}{0.18} & \times \text{U.S. Treasury bond yields}\end{aligned}$$

The values in brackets are the Newey-West standard errors of coefficients.
Estimation period: From Jan. 2005 to Oct. 2020
Adjusted R^2 : 0.95, Standard error of regression : 0.14
The expected real GDP growth rate is obtained from Consensus Forecasts (average real GDP for 6-10 years ahead). The U.S. Treasury bond yields are 10-year maturity.

The coefficient of the BoJ's share of JGB holdings is significantly negative, which is consistent with "Comprehensive Assessment." Using this result, Chart 6(1) plots a decomposition of the variation of nominal long-term interest rates into the contribution of each explanatory variable. The Chart shows that after the introduction of QQE, the effect of increasing the BoJ's share of JGB holdings rises to about minus 1 percent, and remain at almost the same level until 2020. We set an alternative counterfactual path for the nominal long-term interest rates by subtracting the direct effect of JGB purchasing since the introduction of QQE from the actual values as in Chart 6(2), and use it to check the robustness of simulation results.

Next, following the analysis in "Comprehensive Assessment," we define the counterfactual path for medium- to long-term inflation expectations using the value in the October-December quarter of 2012, just before the introduction of the price stability target of 2 percent (in January 2013). Under the strong commitment to achieving the price stability target, the BoJ implemented large-scale monetary easing measures, in order to convert the deflationary mindset and raise inflation expectations. In this paper, we assume that the medium- to long-term inflation expectations would have remained the same level right before the introduction of the price stability target if the monetary easing measures after the introduction of QQE had not been introduced. Thus, we set the counterfactual path for medium- to long-term inflation expectations as the same level after the October-December quarter of 2012 as in Chart 7(1).[4]

The counterfactual path for real interest rate is estimated as the difference between the counterfactual path for nominal long-term interest rate and medium- to long-term inflation expectations derived above, which is plotted in Chart 7(2). The counterfactual path for real interest rate from equation (1) stays between around 0 and 0.5 percent. In contrast, the counterfactual path from equation (2) focusing on the JGB purchasing by the BoJ, stays between around minus 0.5 and 0 percent, relatively lower than that from equation (1). After the introduction of QQE, the actual real interest rates declined to between around minus 1.5 and minus 1.0 percent. The estimated size of policy effect on real interest rate is between around minus 1.5 and minus 1.0 percent, though it partly depends on the specification of regression.

(2) Lending attitude DI

We simply regress the business conditions DI (from *Tankan*, all enterprises and all industries)

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[4] In Q-JEM, figures for the medium- to long-term inflation expectations before 2014 are from the "Consensus Forecasts" (average CPI for 6-10 years ahead). Figures from 2014 onward are estimated using principal component analysis of figures in the *Tankan* for 5-year ahead expectations of output prices by industry and enterprise size. The two time series are linked by fitting the level of latter series to the level of former series. In order to create the time series of inflation expectations based on *Tankan,* we examined first principal components from various sets of inflation expectation dataset (the expectations of output prices and general prices by the time span of outlook, industry and enterprise size), and selected the principal component that yields the best prediction power for the realized CPI.

onto the lending attitude DI, and define the fitted value of the regression as the counterfactual path. The estimation period is up to the January-March quarter of 2013, right before the introduction of QQE. The estimation result is as follows.

Lending attitude DI (3)

$$= \underset{[0.71]}{11.70} + \underset{[0.03]}{0.56} \times \text{Business conditions DI}$$

The values in brackets are the standard errors of coefficients.
Estimation period: From Jan.−Mar. 1997 to Jan.−Mar. 2013
Adjusted R^2 : 0.84, Standard error of regression : 4.05

The coefficient of business conditions DI is significantly positive. This result indicates that the lending attitude DI, which is a proxy for loan availability in lending markets, has a significantly positive correlation with firm's business conditions. The adjusted R-squared is high as 0.84, and the actual and the fitted values plotted in Chart 8 show a good fitting of the regression. We obtain the estimated value after the introduction of QQE by an extrapolation. There is little difference between estimated and actual value in early part of this out-of-sample period. From the July-September quarter of 2014, in contrast, actual values are significantly higher than the estimated values, partly reflecting the expansion of QQE introduced in October 2014. This finding implies that the monetary easing measures improved the loan availability in lending markets. In particular, the actual value of lending attitude DI indicates it was significantly accommodative even in 2020, when business conditions declined drastically due to COVID-19 and the fitted value of lending attitude DI dropped sharply, as in the Chart. This indicates that the BoJ's monetary easing measures to support firm's financing, together with the government measures and enhancements by financial institutions, had significant effects on the lending market. In the following simulation, we set the fitted value from the July-September quarter of 2014 as the counterfactual path for the lending attitude DI.[5]

(3) Exchange rate

We use the following long-run equilibrium equation of U.S. dollar/yen exchange rate in Q-JEM to estimate its counterfactual path.

[5] For this counterfactual path, we use the fitted value only from the July-September quarter of 2014, when the actual and fitted values started to deviate. Even if we use the fitted value since the April-June quarter of 2013, when QQE was introduced, there is little difference in estimated results.

$$\log(\text{Real U.S. dollar/yen exchange rate}) \quad (4)$$
$$= \underset{[0.02]}{5.24} + 10 \times (\text{Real U.S. interest rate} - \text{Real Japan's interest rate})$$

The value in bracket is the standard error of coefficient.
Estimation period: From Apr.−Jun. 1980 to Jul.−Sep. 2020
R^2 : 0.30, Standard error of regression : 0.22

The real U.S. dollar/yen exchange rate is calculated by dividing nominal U.S. dollar/yen exchange rate by the ratio of CPI (excluding food and energy) of Japan to that of the United States. In this equation, because the real interest rates of Japan and the United States are 10-year yields in an annual basis, the coefficient of the real interest rate differential is fixed at 10. This specification relies on two economic theories for long-run equilibrium of exchange rates, the relative purchasing power parity and the uncovered interest rate parity.

Using this equation, we derive the counterfactual path for U.S. dollar/yen rate from that of Japan's real interest rate. Specifically, under the assumption that BoJ's monetary policy does not affect the U.S. real interest rate, we substitute actual value of the U.S. real interest rate and the counterfactual path for Japan's real interest rate into equation (4), and compute the fitted value as the counterfactual path for U.S. dollar/yen rate. Chart 9(1) shows that this counterfactual path is more appreciated than the actual by about 10 yen on average.

(4) Stock prices

We consider the counterfactual path for stock prices (TOPIX) in a similar way to the exchange rate using the equations in Q-JEM. The stock price in Q-JEM is formulated by an error correction model that consists of its long-run equilibrium and short-run dynamics. The former is given by the following.

$$\log(\text{TOPIX / Firm's profit}) \quad (5)$$
$$= \underset{[0.03]}{-8.68} + \underset{[0.29]}{1.02} \times \text{Dummy for 2008/Oct.−Dec.}$$
$$+ \underset{[0.29]}{1.20} \times \text{Dummy for 2009/Jan.−Mar.}$$

The values in brackets are the standard errors of coefficients.
Estimation period: From Jan.−Mar. 2000 to Jul.−Sep. 2020
Adjusted R^2: 0.25, Standard error of regression : 0.28

This equation assumes that the overall price-earnings ratios (PER) is converged to a certain level in the long run. The equation of short-run dynamics is given as follows.

$$\text{dlog(TOPIX)} \qquad (6)$$

$$= -0.001 - 0.08 \times \text{log(Error correction term)}$$
$$\quad [0.008] \qquad [0.03]$$
$$+ 1.08 \times \text{dlog(Nominal U.S. dollar/yen rate)}$$
$$\quad [0.20]$$

The values in brackets are the standard errors of coefficients.
"dlog" stands for log-difference.
Estimation period: From Apr.−Jun. 2000 to Jul.−Sep. 2020
Adjusted R^2 : 0.34, Standard error of regression : 0.07

The error-correction term in equation (6) is a deviation rate of the actual value to the long-run equilibrium in the previous quarter. This equation captures short-run fluctuation of stock prices with the following two mechanisms: (a) the convergence to the long-run equilibrium, and (b) a correlation between the stock price and the exchange rate as a depreciation (appreciation) of the yen is likely to be accompanied by a rise (decline) in stock price.

Using equation (5) and (6), we compute our counterfactual path for stock prices with that of real interest rate, lending attitude DI, and exchange rates. Specifically, we substitute the counterfactual paths of these three variables into Q-JEM equations, and set a simulated path of the stock price as the counterfactual. This counterfactual path can be interpreted as the hypothetical path if the expansionary monetary policy measures since the introduction of QQE had not been introduced, given the historical relationships among the economic variables. Chart 9(2) shows that the counterfactual path is lower than the actual since the introduction of QQE, and implies that the policy effect pushes up the stock price by 27 percent on average during this period.

3-2. Event study approach

The "estimation approach" allows us to identify the policy effect for each financial variable by excluding factors other than monetary policy based on economic theories. However, it has the disadvantage that it largely depends on specifications of regression equations. In particular, regarding the exchange rate and stock prices, existing literature has suggested various specifications and there is no consensus on them among academia and central bank economists. Regarding this concern, in setting counterfactual paths for the exchange rate and stock prices, we examine an alternative approach that identifies the policy effects relying only on movements of these variables before and after the date of the policy announcement in a spirit of event study methodology. In this paper, we call it the "event study approach."

We apply the event study methodology to the following five expansionary monetary policy actions: (I) "The Introduction of QQE" (April 2013), (II) "The Expansion of QQE" (October 2014), (III) "QQE with a Negative Interest Rate" (January 2016), (IV) "QQE with YCC" (September 2016), and (V) "Enhancement of Monetary Easing in Light of the Impact of the Outbreak of the Novel Coronavirus (COVID-19)" (March 2020). Our key assumption is that the levels of the exchange rate and stock prices at the day before the announcement on policy changes would have continued through the following quarter.[6]

To illustrate our event-study method, we take the exchange rate development after the expansion of QQE as an example. As illustrated in Chart 10(1), the yen sharply depreciated against U.S. dollar responding to the policy announcement on October 31, 2014. The size of its impact reached 12 yen/U.S. dollar at the most through the end of March 2015. The average size of impact during the October-December quarter of 2014 is about 6 yen/U.S. dollar, and that during the January-March quarter of 2015 is about 10 yen/U.S. dollar. In the event study approach, we define the change from the level before the policy action as "policy shock."

As for the five policy actions, Charts 11 and 12 summarize the estimated policy effects of the exchange rate and stock prices, respectively. Except when QQE with a Negative Interest Rate was introduced in early 2016, our estimates indicate that the expansionary monetary policy action depreciated the yen against U.S. dollar and increased stock prices.[7] We input these identified policy shocks with their signs reversed into Q-JEM and simulate the model to obtain counterfactual paths of the exchange rate and stock prices. Note that for the quarters in which these shocks are absent, each financial variable follows according to Q-JEM functions.

3-3. "Comprehensive Assessment" approach

The final approach is exactly the same as that employed in "Comprehensive Assessment." This approach, which we call the "Comprehensive Assessment approach," regards the

[6] The measured impact of policy action depends on the length of time window with which we measure the changes after the policy announcement. A shorter window (for example 30 minutes) can reduce the effects from factors other than the policy action. However, the policy actions may be digested in the financial market only gradually, and it may take some duration of time after the announcement for the policy effects to materialize. A longer window can be an alternative, though we allow the resulting size of impact to contain some possible noises. Given these considerations, we set around one to two quarters to identify the shock in this paper. Specifically, we compute the changes in the levels of exchange rate and stock prices from the policy announcement to the end of the following quarter as policy effects.

[7] In early 2016, risk-averse investor behavior induced by the economic slowdown in emerging economies and the sharp decline in crude oil prices significantly contributed to the appreciation of the yen and the fall in stock prices following the introduction of QQE with a Negative Interest Rate. As mentioned earlier, estimated policy effects may include various factors other than monetary policy actions when we adopt a relatively long time window as in our analysis.

decline in the real interest rates (decline in nominal interest rates and increase in inflation expectations) as the most relevant transmission channel of monetary policy. Specifically, in this approach we assume that all the changes in real interest rates since the introduction of the price stability target in the January-March quarter of 2013 were due to the expansionary monetary policy measures. Based on this assumption, counterfactual paths for nominal interest rates and inflation expectations are constant at their level in the October-December quarter of 2012. Given this counterfactual path for real interest rates, we simulate Q-JEM and set trajectories of the other three financial variables (lending attitude DI, exchange rate, and stock prices) as their counterfactual paths. In this approach, we assume that the monetary policy actions transmit only through the real interest rates and subsequent endogenous reactions of other variables. Therefore, estimated policy effects do not include factors that cannot be explained by the declines in real interest rate, such as the improvement of lending attitude DI reflecting the measures that ease corporate financing and the rise in stock prices reflecting the BoJ's ETF purchases.

4. Simulation results

In this section, we conduct counterfactual simulations by Q-JEM given the counterfactual paths for financial variables discussed in the previous section. Our simulation period is from the January-March quarter of 2013 to the July-September quarter of 2020. We use Q-JEM whose equations are estimated based on a dataset up to the July-September quarter of 2020.

We run five counterfactual simulations (A-E) in the following table, which differ in the setting of counterfactual paths for financial variables.

<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th></tr>
<tr><td>(1) Real interest rates</td><td colspan="2">Estimation approach
(based on variables such as the active job openings-to-applicants ratio)</td><td colspan="2">Estimation approach
(based on the share of the BoJ's JGB holdings)</td><td rowspan="4">"Comprehensive Assessment" approach</td></tr>
<tr><td>(2) Lending attitude DI</td><td colspan="4">Estimation approach</td></tr>
<tr><td>(3) Foreign exchange rates</td><td rowspan="2">Estimation approach</td><td rowspan="2">Event study approach</td><td rowspan="2">Estimation approach</td><td rowspan="2">Event study approach</td></tr>
<tr><td>(4) Stock prices</td></tr>
</table>

Table: Settings of counterfactual paths for each simulation

Charts 13 and 14 present results of Simulation A. We interpret the policy effects of the real GDP and CPI as the difference between their actual and simulated values. As shown in Chart 13(1), after the introduction of QQE, the impact of the policy effect on real GDP gradually increases as it ranges from about +1.0 to +1.5 percent around 2016, when QQE with YCC was introduced, and then reaches around +2.0 percent around 2019, right before the spread of COVID-19. During the period from the introduction of QQE (the April-June quarter of 2013) to the July-September quarter of 2020, the average policy effect on real GDP is +1.3 percent on an annualized basis.

Among transmission channels of each financial variable, the channel through a decline in real interest rates contributes the most to push up real GDP. In addition, the channels through a rise in stock prices and through a depreciation of the exchange rate also have significant positive impacts on real GDP. The contribution of the real interest rate channel significantly expands right after the introduction of QQE. Around 2016, when the BoJ doubled its ETF purchases and introduced YCC, the contribution of real interest rate channel slows to moderate, while the contribution of the stock price channel gradually increases. The contribution of lending market channel is relatively modest until around 2019, but then starts increasing when the BoJ introduced policy measures in response to the outbreak of COVID-19 in 2020.

Chart 13(2) plots contributions of each demand component of real GDP, which shows that real GDP is pushed up by private non-residential and residential investments significantly reflecting declines in real interest rates. The expansion of exports and of firm's profits induced by a depreciation of the yen also contributes through the private non-residential investment. Furthermore, a rise in stock prices also increases private non-residential investment according to increased Tobin's Q. Private consumption expands reflecting improvement in the employment and income situation. The wealth effect in the stock price increase and the intertemporal substitution effect in the decline in real interest rate also push up private consumption, although these effects are only modest in Q-JEM, and therefore the contribution of private consumption to the real GDP is smaller than that of the investments. Note that because imports increase along with the increase in demand, the contribution of imports appears to be negative during the whole sample period.

Chart 14(1) plots the policy effect on the year-on-year rate of change in the CPI (all items less fresh food and energy), which increases since the introduction of QQE and remains between +0.6 and +0.8 percentage points since 2015. Decomposing this policy effect into contributions of explanatory variables in Phillips curve, we find that both the contributions of inflation expectations and output gap increase immediately after the introduction of QQE. Since around 2015, the largest contribution of CPI is the lagged inflation indicating the adaptive expectations formation. Chart 14(2) plots a decomposition using backward iteration which sequentially substitutes the contribution of the output gap and the inflation expectations into the lagged inflation. The result shows that the contribution of inflation expectations dominates during the first half of the period in simulation. During the second half of the simulation period, the improvement of output gap pushed up the CPI relatively more.[8]

Chart 15 summarizes the estimation results of policy effects for five simulations (A-E). In all simulations, the policy effect of output gap suggests that if QQE had not been introduced, the output gap would have likely stayed in a negative territory, except for a few periods, as shown in Chart 15(2). In Chart 15(3), the estimation result of CPI indicates that while the year-on-year rate of change in CPI would have once turned to be positive from 2014 to 2015 due to a rapid depreciation of the yen, it would have likely remained in negative territory afterward to the end of the sample period. After the outbreak of COVID-19 in 2020, actual values for both output gap and CPI are significantly higher than the counterfactual paths, which implies that the monetary easing measures have appeared to be effective.

The five simulation results above show that the BoJ's monetary easing measures since the introduction of QQE have had positive effects to push up output gap and CPI through the declines in real interest rates, rises in stock prices, depreciations of exchange rates, and improvements of loan availability in lending markets. During the period from the introduction of QQE to the July-September quarter of 2020, the average policy effects on the level of real GDP range from +0.9 to +1.3 percent. Similarly, the estimated impacts on the year-on-year rate of change in the CPI range from +0.6 to +0.7 percentage points, as reported in Chart 15(4).

5. Concluding remarks

We estimate the policy effects of the BoJ's monetary easing measures using the large-scale macroeconomic model, Q-JEM. We consider counterfactual paths of major financial variables such as real interest rates, constructing hypothetical scenarios where the QQE and

---

[8] Note that in the formulation of inflation in Q-JEM, exchange rates affect CPI (all items less fresh food) directly through energy prices (exchange rates times oil prices), though there is no mechanism of direct exchange rates path-through on CPI (all items less fresh food and energy). Still, the formulation contains an indirect effect of exchange rates to raise CPI (all items less fresh food and energy) through output gap improvement arising from the increase in exports and expansion of firm's profits. The specification also includes a mechanism that the realization of CPI increase pushes up itself according to a rise of inflation expectations through adaptive expectations formulation.

subsequent easing measures had not been introduced. We run counterfactual simulations to examine how the Japan's macroeconomic variables such as real GDP and CPI would have evolved under those hypothetical scenarios and obtain estimates of policy effects by comparing the simulated paths and actual values. Estimation results based on several different counterfactual paths show that, on average during the period since the introduction of QQE, the policy effects on the level of real GDP are between around +0.9 and +1.3 percent and those on the year-on-year rate of change in the CPI (all items less fresh food and energy) are between around +0.6 and +0.7 percentage points. Moreover, the simulation results also show that monetary easing measures have been effective in supporting economic activity and prices even since 2020, when the economy faced a major negative shock due to the outbreak of COVID-19.

Although the results of policy effects depend on the setting of the counterfactual path, it is clear that QQE (and QQE with YCC) has had positive effects on Japan's economic activity and prices. Besides, note that this kind of policy effect estimation has possibilities of both overestimation and underestimation. For instance, the estimated policy effects could include the effects of government fiscal policy and expansionary monetary policy of other central banks overseas, which may overestimate the policy effects. On the other hand, although the BoJ implemented asset purchases of CP, corporate bonds, and J-REIT as a part of its monetary easing measures, our analysis does not explicitly address policy effects of these asset purchases, which may underestimate the policy effects. From these considerations, we have to bear in mind that there is some uncertainty in the estimated policy effects in this paper.

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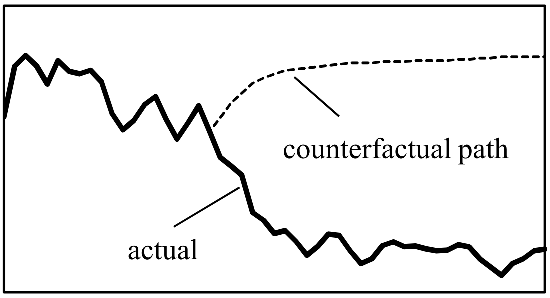
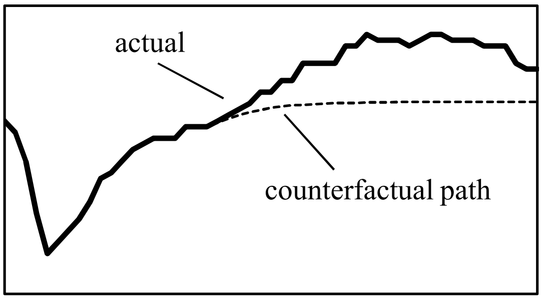
Estimation of the Policy Effects

1. Set counterfactual paths for four financial variables based on hypothetical scenario where the QQE and subsequent easing measures had not been introduced.

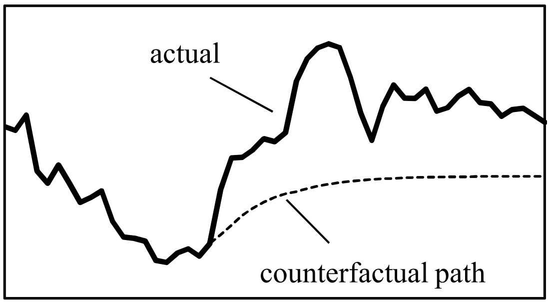
Real Interest Rates



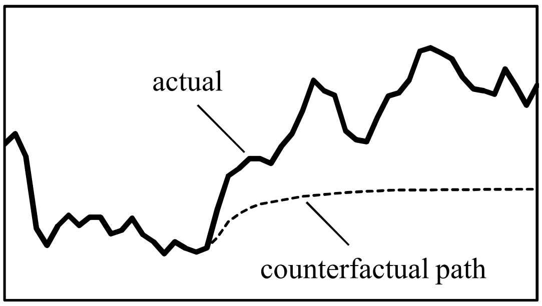
Lending Attitude DI



Exchange Rate (U.S. dollar/yen)

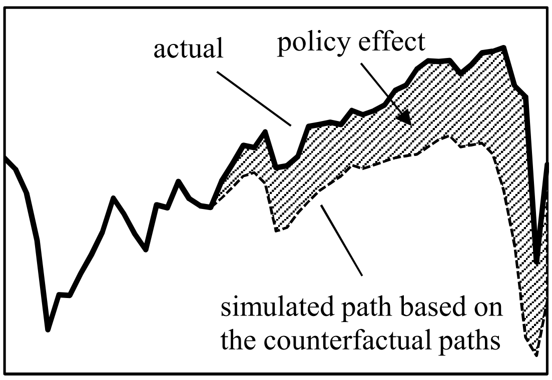


Stock Prices (TOPIX)

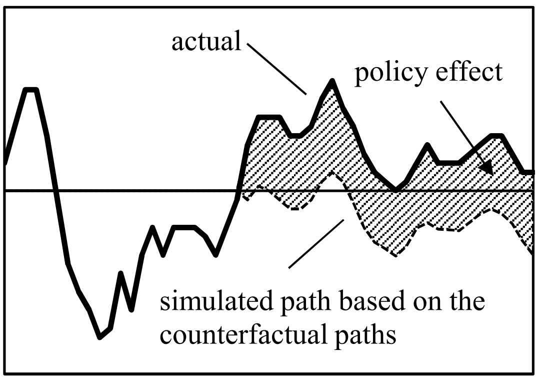


2. Simulate the Q-JEM and obtain a path of the economy based on counterfactual paths of four financial variables.

Real GDP



CPI (less fresh food and energy)



3. Define the difference between the actual and simulated paths as the policy effects.

Chart 2

Overview of Monetary Policy Actions since the Introduction of QQE

Release date	Summary of monetary policy actions
Apr. 4, 2013 (I)	**Introduction of QQE** Monetary base: Annual increase of about 60-70 tril. yen JGBs: Annual increase of about 50 tril. yen ETFs: Annual increase of about 1 tril. yen
Oct. 31, 2014 (II)	**Expansion of QQE** Monetary base: Accelerating the annual pace of increase to about 80 tril. yen (about 10-20 tril. yen additional) JGBs: Increasing the amount outstanding at an annual pace of about 80 tril. yen (about 30 tril. yen additional) ETFs: Increasing the amount outstanding at an annual pace of about 3 tril. yen (tripled)
Jan. 29, 2016 (III)	**Introduction of QQE with a Negative Interest Rate** Applying a negative interest rate of minus 0.1 percent to the Policy-Rate Balance
Jul. 29, 2016	**Enhancement of Monetary Easing** ETFs: Increasing the amount outstanding at an annual pace of about 6 tril. yen (doubled)
Sep. 21, 2016 (IV)	**Introduction of QQE with Yield Curve Control** Introducing yield curve control and inflation-overshooting commitment
Jul. 31, 2018	**Strengthening the Framework for Continuous Powerful Monetary Easing** Introducing forward guidance for policy rates JGBs: Making it clear that the long-term yields might move upward and downward to some extent mainly depending on developments in economic activity and prices ETFs: Making it clear that the BoJ might increase or decrease the amount of purchases depending on market conditions
Mar. 16, 2020 (V)	**Enhancement of Monetary Easing in Light of the Impact of the Outbreak of the Novel Coronavirus (COVID-19)** CP and Corporate Bonds: Increasing the upper limit of purchases by 1 tril. yen for each asset ETFs: Increasing the amount outstanding at an annual pace with the upper limit of 12 tril. yen
Apr. 27, 2020	**Enhancement of Monetary Easing** CP and Corporate Bonds: Increasing the maximum amount of the additional purchases to 7.5 tril. yen (6.5 tril. yen additional) JGBs: Removing "at an annual pace of about 80 trillion yen" from Statement
Dec. 18, 2020	**Extension of the Special Program to Support Financing in Response to the Novel Coronavirus (COVID-19)** CP and Corporate Bonds: Extending the duration of additional purchases by 6 months Combining the maximum amount of additional purchases for each asset

Note: Index (I-V) in Release date indicates the policy action used for the estimation of the policy effects in the event study approach.

Main Transmission Mechanisms of Monetary Policy in Q-JEM

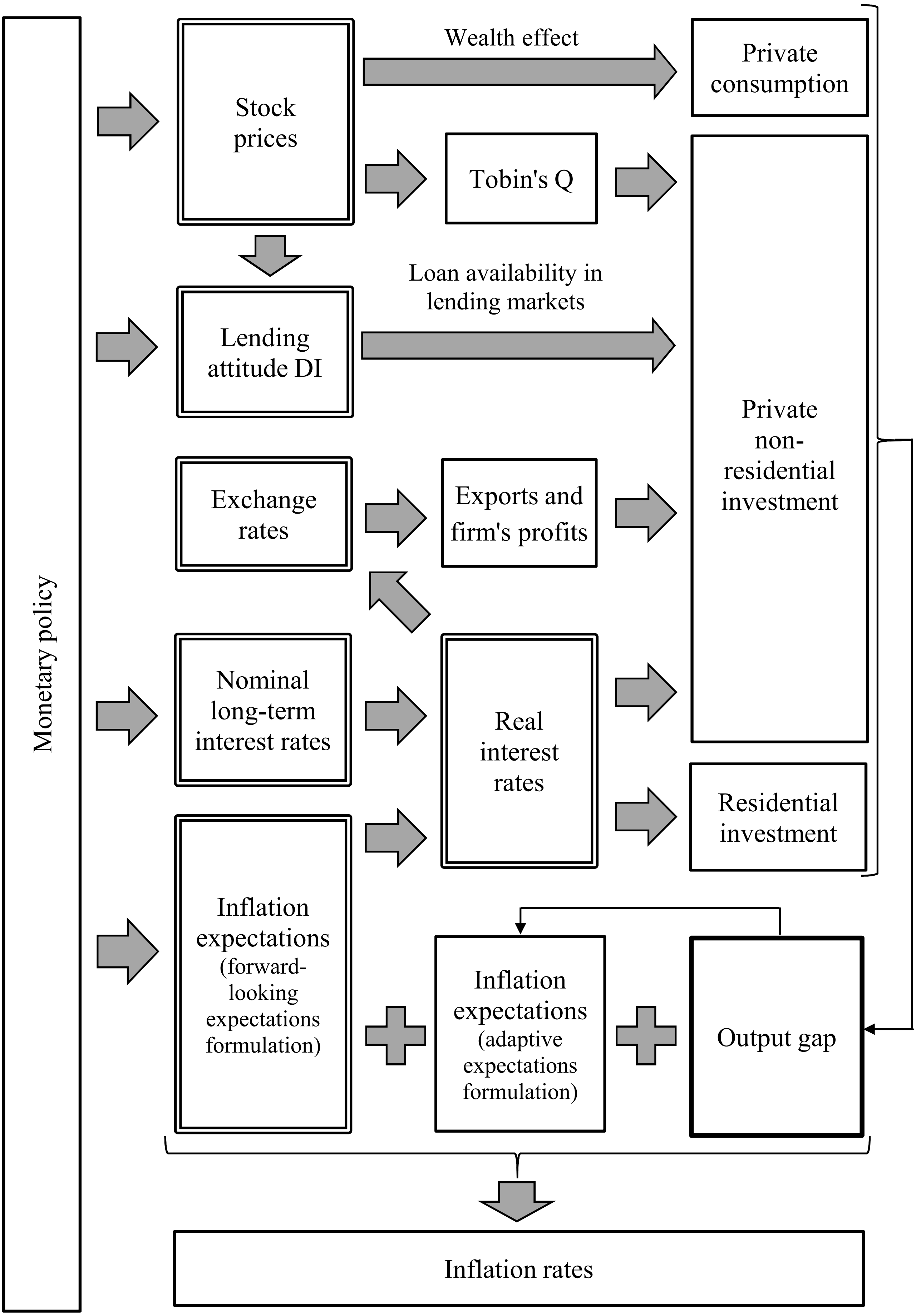


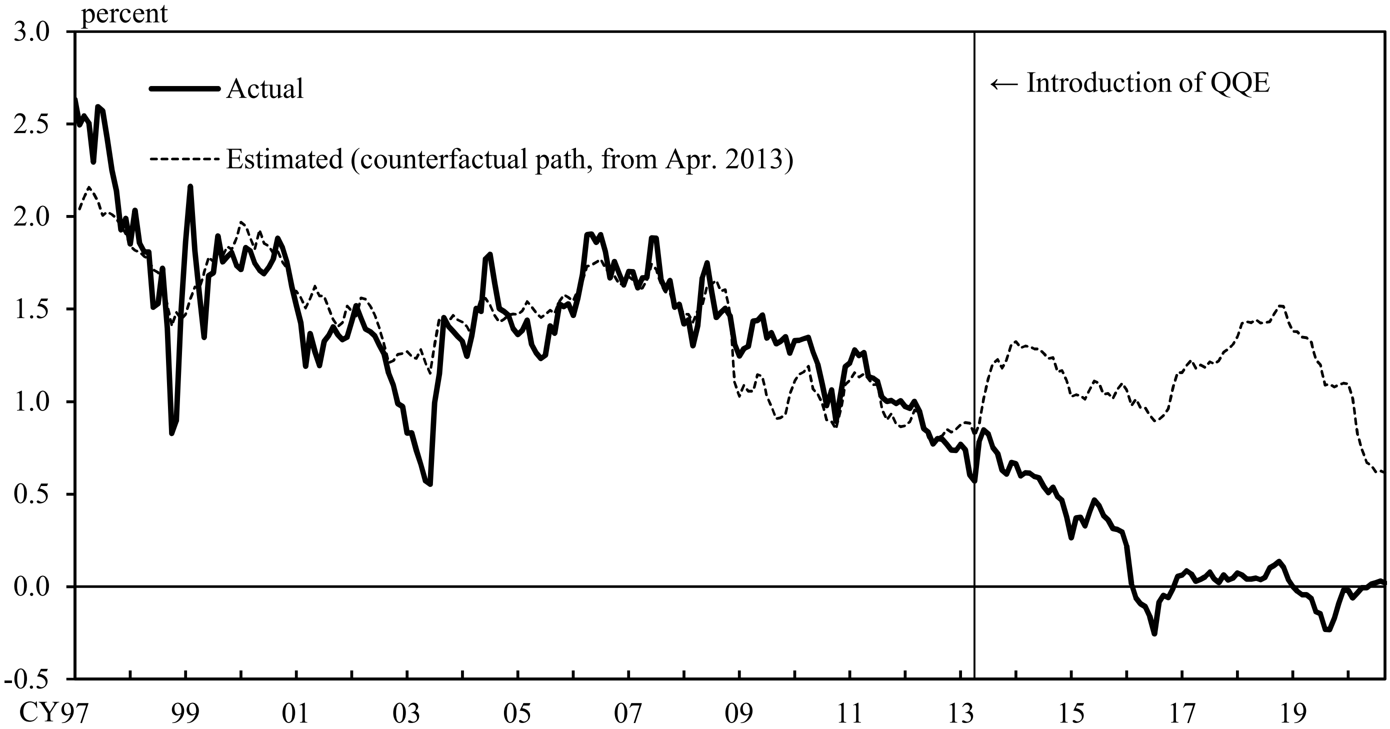
Chart 4

Counterfactual Paths of Financial Variables

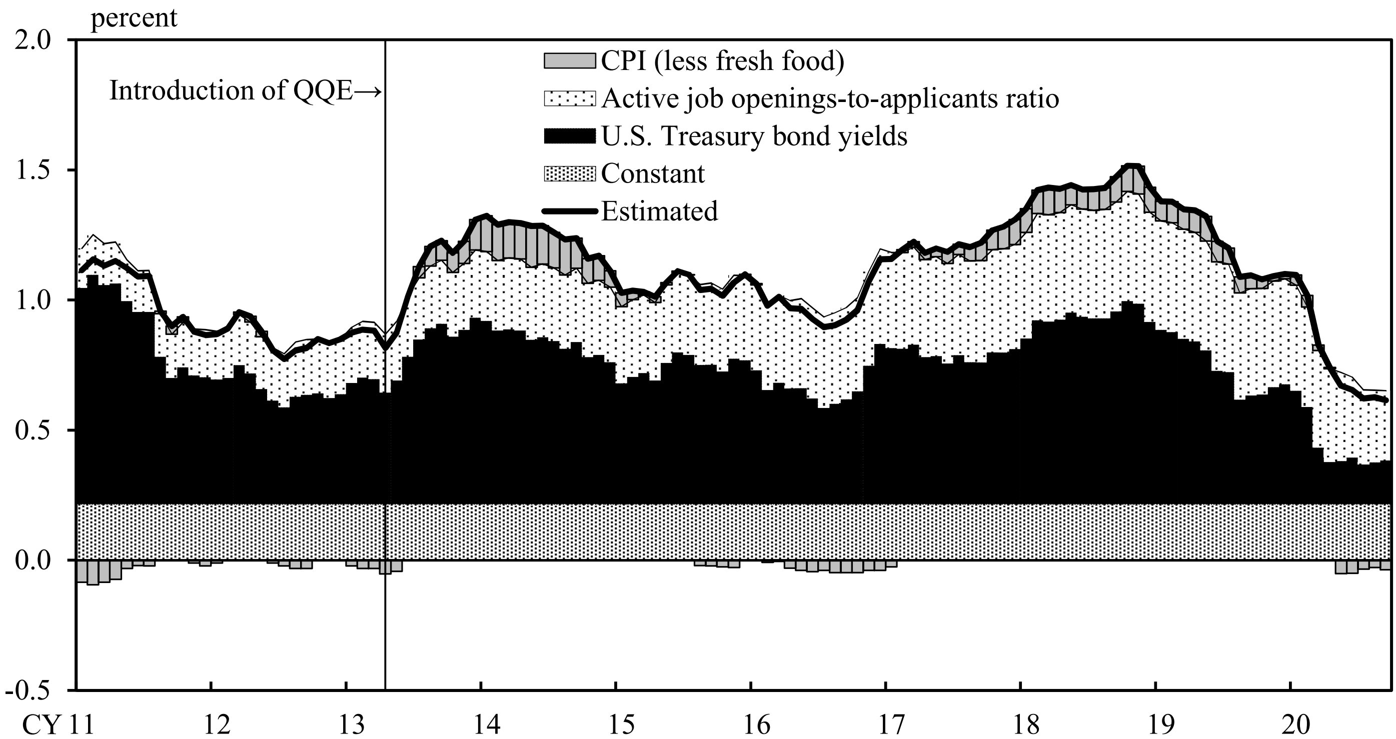
<table>
<tr><th>Financial variables</th><th>Estimation approach</th><th>Event study approach</th><th>"Comprehensive Assessment" approach</th></tr>
<tr><td>Real interest rates</td><td colspan="2" rowspan="2">Estimated by other economic variables</td><td>Assuming unchanged since 2012/Q4</td></tr>
<tr><td>Lending attitude DI</td><td rowspan="3">Simulated values in Q-JEM given the counterfactual path of real interest rates</td></tr>
<tr><td>Foreign exchange rates</td><td rowspan="2">Estimated by other economic variables</td><td rowspan="2">Set by event study</td></tr>
<tr><td>Stock prices</td></tr>
</table>

Nominal Long-Term Interest Rates

(1) Nominal Long-Term Interest Rates



(2) Decomposition of the Estimated Nominal Long-Term Interest Rates

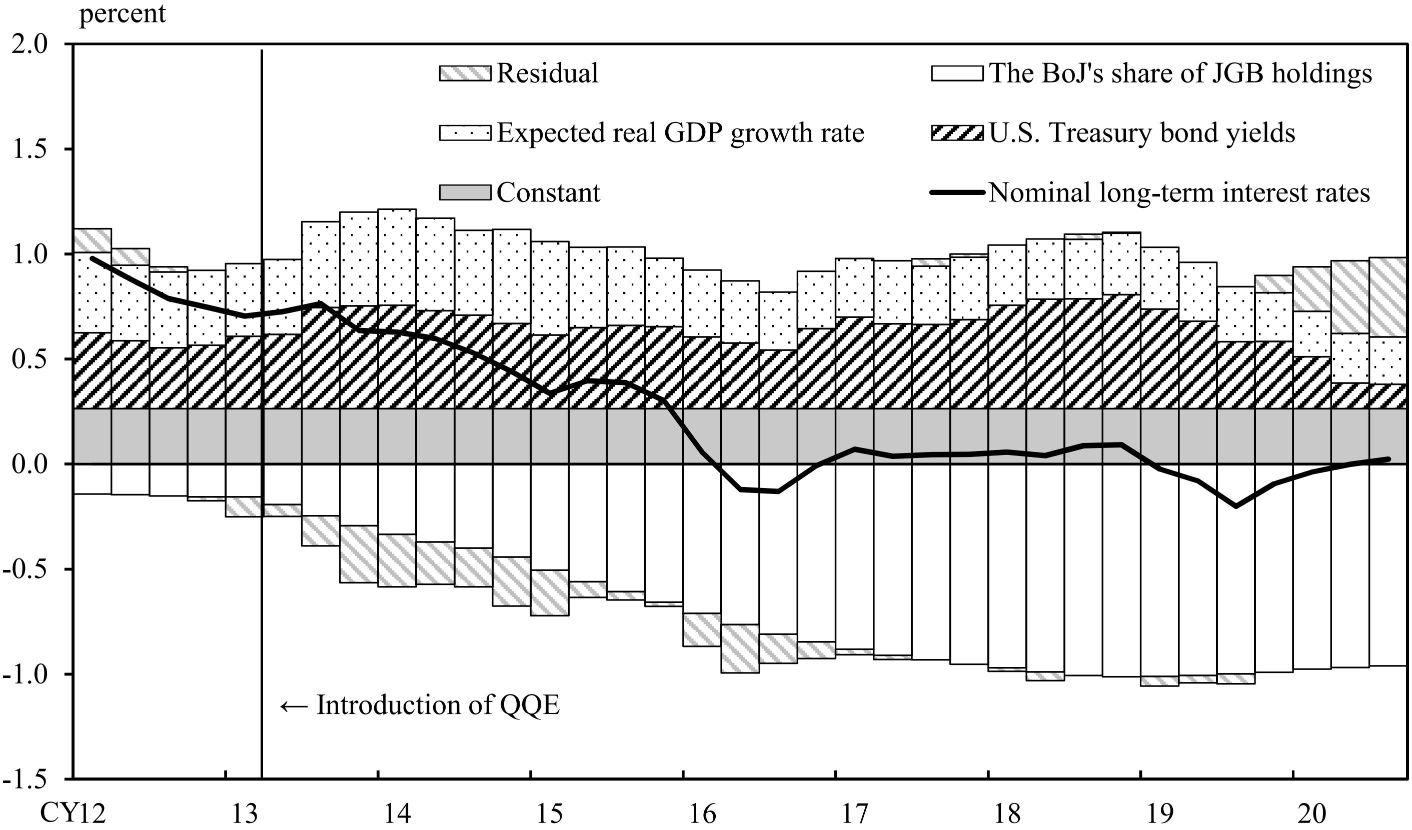


Notes: 1. The estimates of nominal long-term interest rates since April 2013 are obtained by extrapolation.
2. The figures of CPI in (2) exclude the effects of the consumption tax hikes, policies concerning the provision of free education, and the "Go To Travel" campaign, which covers a portion of domestic travel expenses. The figures from April 2020 onward are based on staff estimations, and exclude the effects of measures such as free higher education introduced in April 2020.

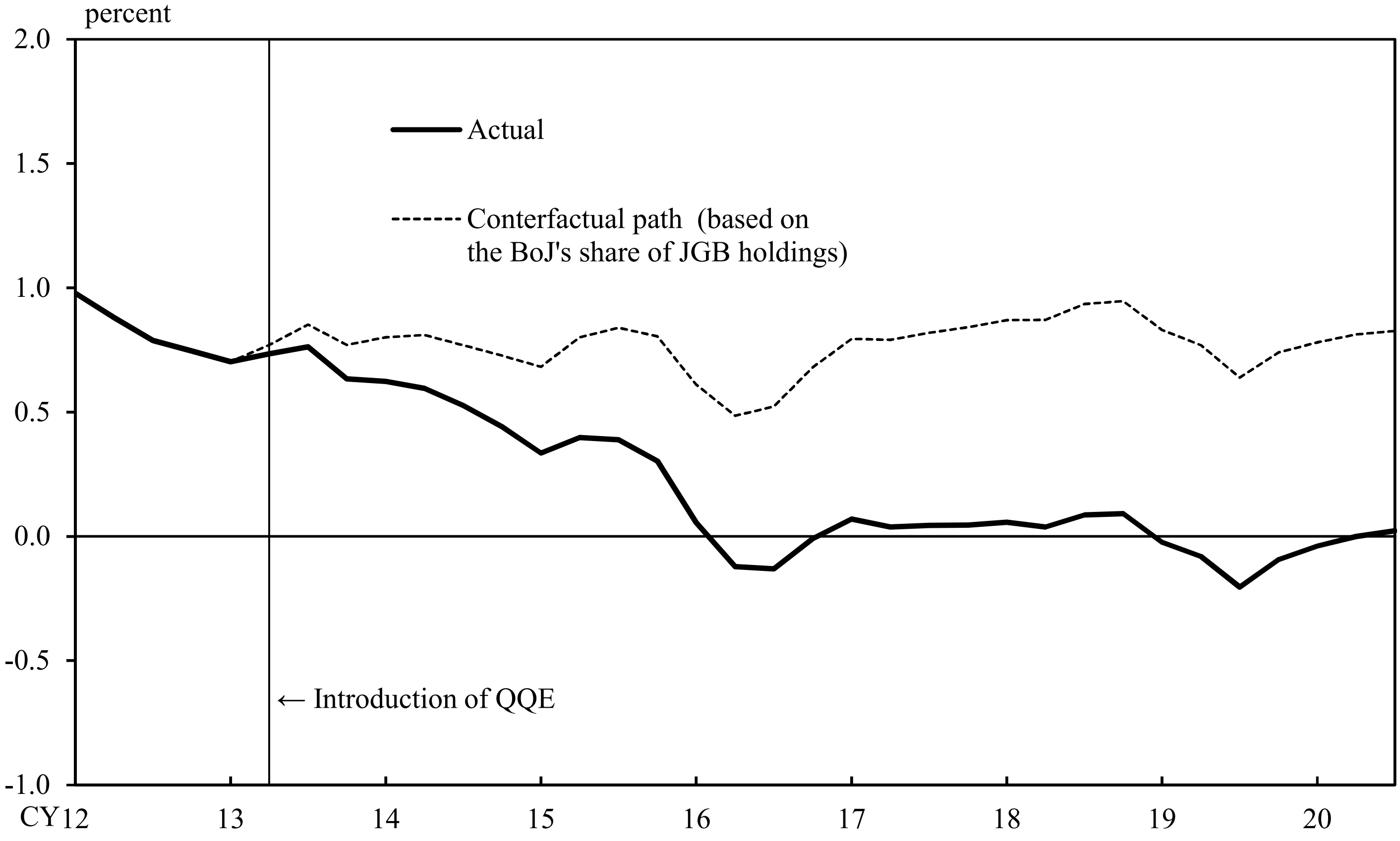
Sources: Ministry of Internal Affairs and Communications; Ministry of Health, Labour and Welfare; Bloomberg.

Effects of JGB Purchases on Nominal Long-Term Interest Rates

(1) Decomposition of Nominal Long-Term Interest Rates



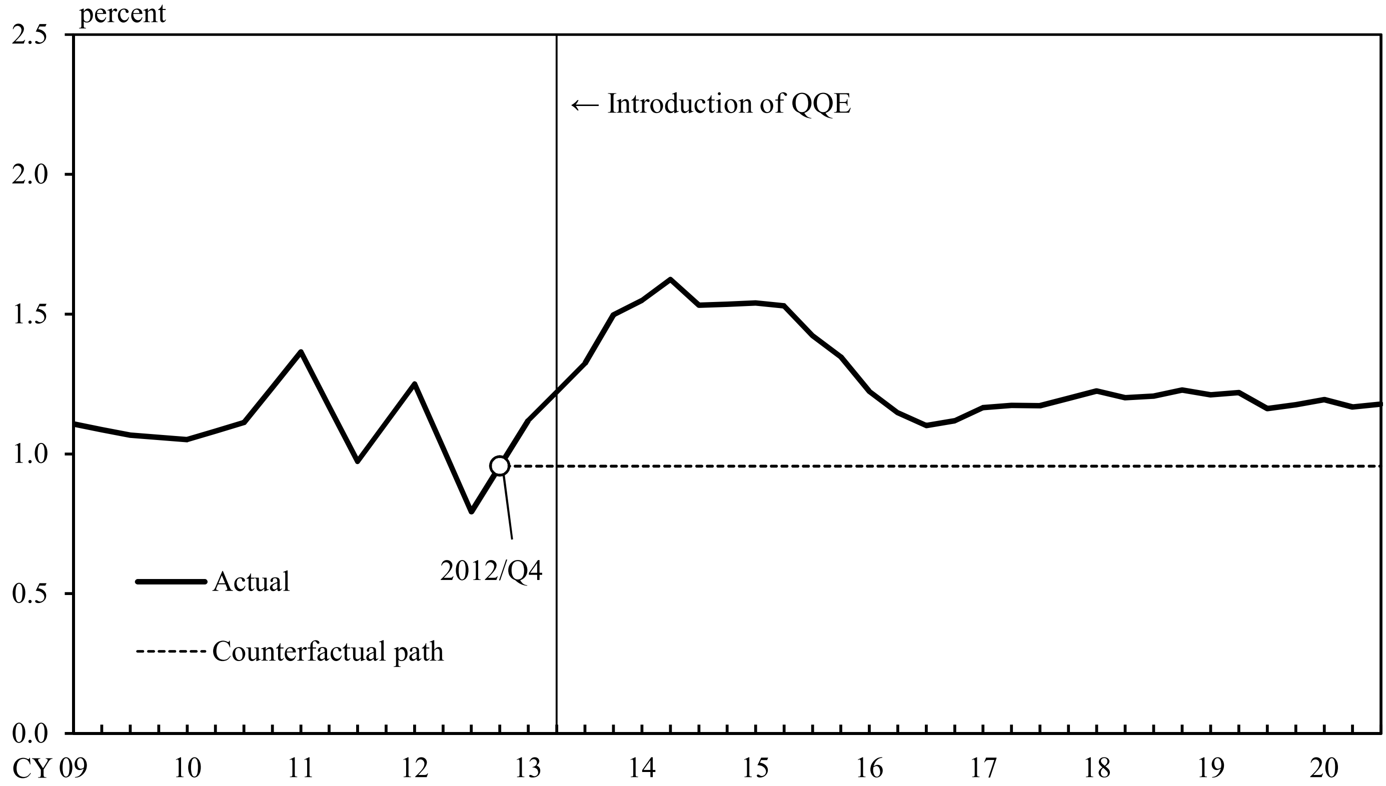
(2) Nominal Long-Term Interest Rates



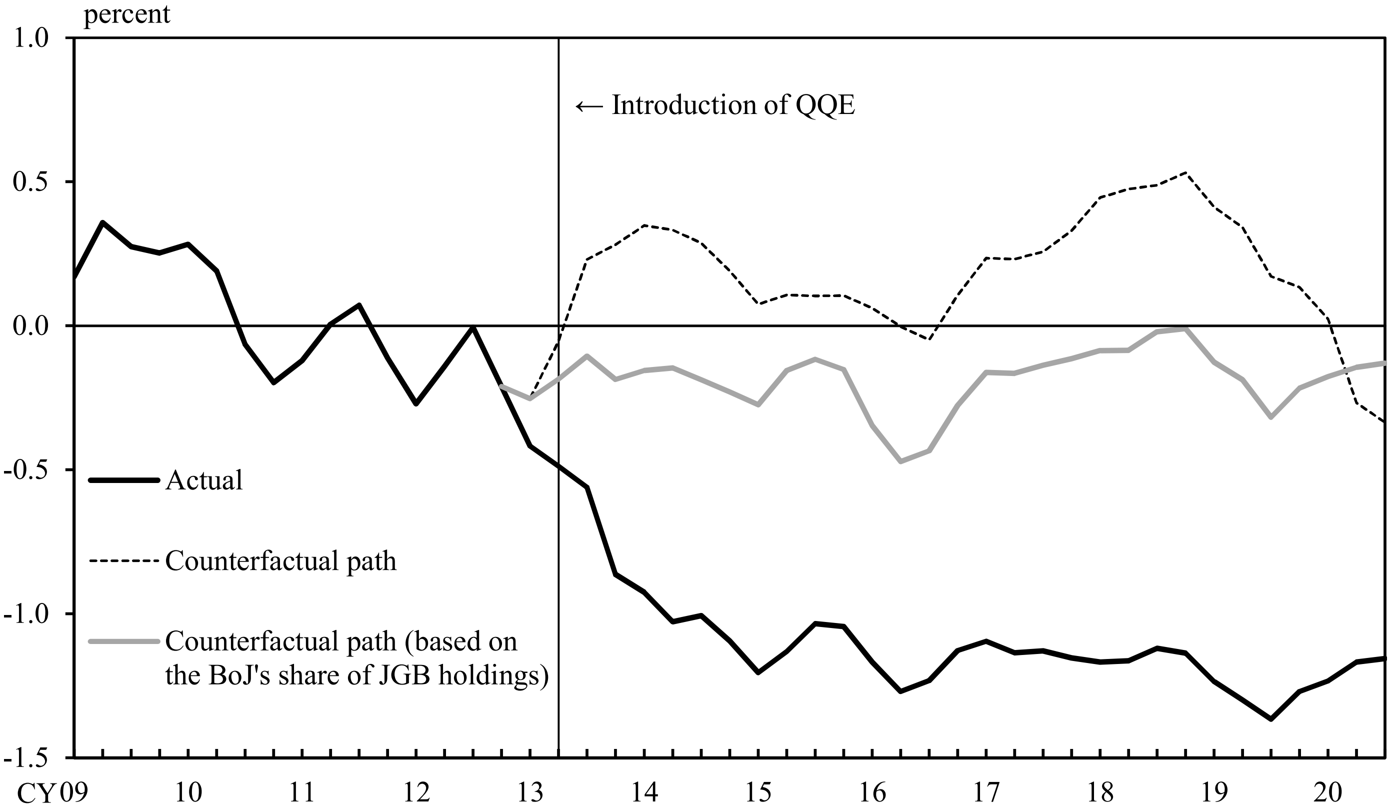
Sources: Bloomberg; Consensus Economics Inc., "Consensus Forecasts"; Bank of Japan; Ministry of Finance.

Inflation Expectations and Real Interest Rates

(1) Medium- to Long-Term Inflation Expectations



(2) Real Interest Rates (Nominal Long-Term Interest Rates minus Inflation Expectations)

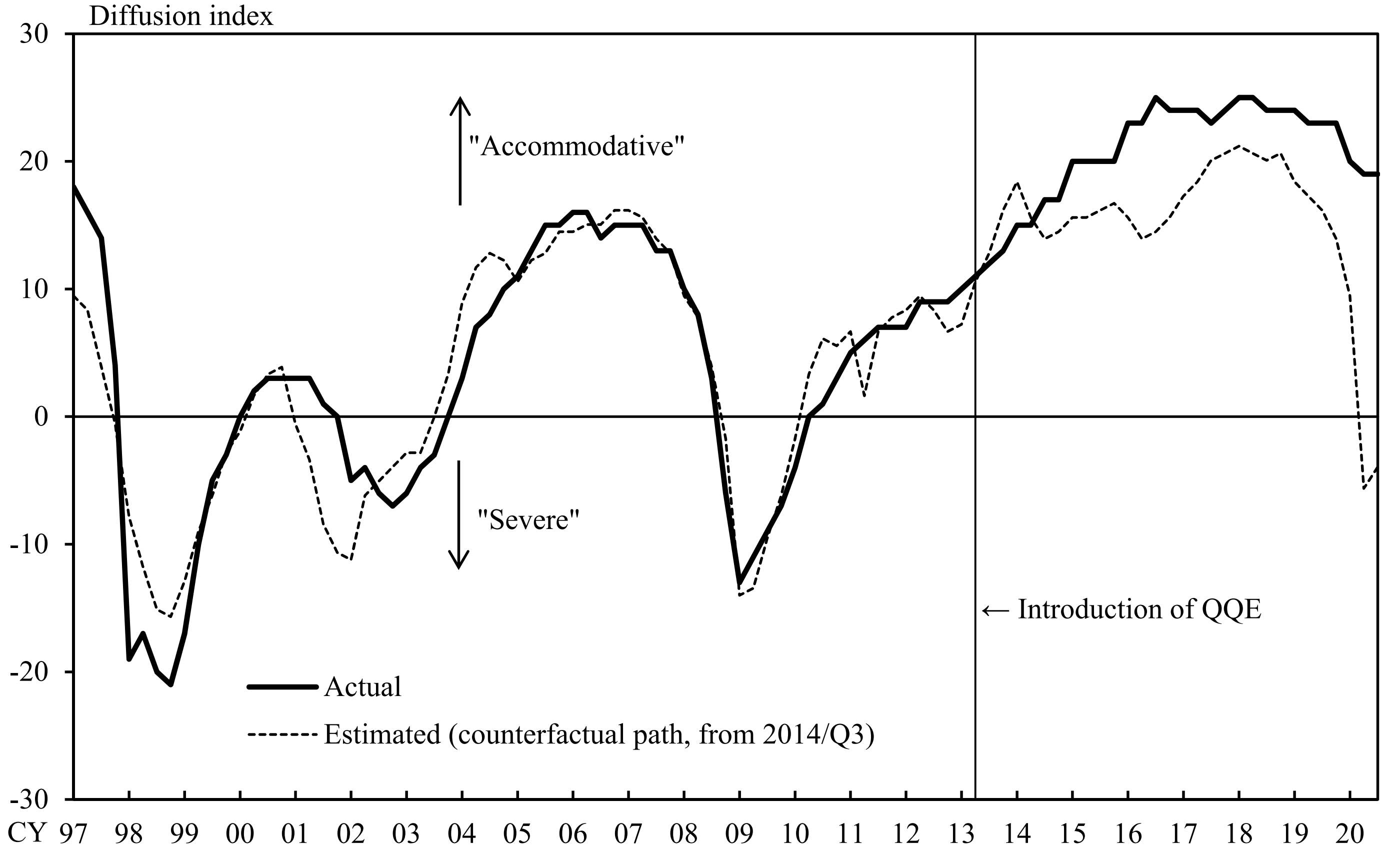


Note: Figures for medium- to long-term inflation expectations from 2014 onward are estimated using principal component analysis of figures in the *Tankan* for 5-year ahead expectations of output prices by industry and enterprise size. Figures before 2014 are from the "Consensus Forecasts" (average for 6-10 years ahead).

Sources: Ministry of Internal Affairs and Communications; Ministry of Health, Labour and Welfare; Bloomberg; Bank of Japan; Ministry of Finance; Consensus Economics Inc., "Consensus Forecasts."

Loan Availability in Lending Markets

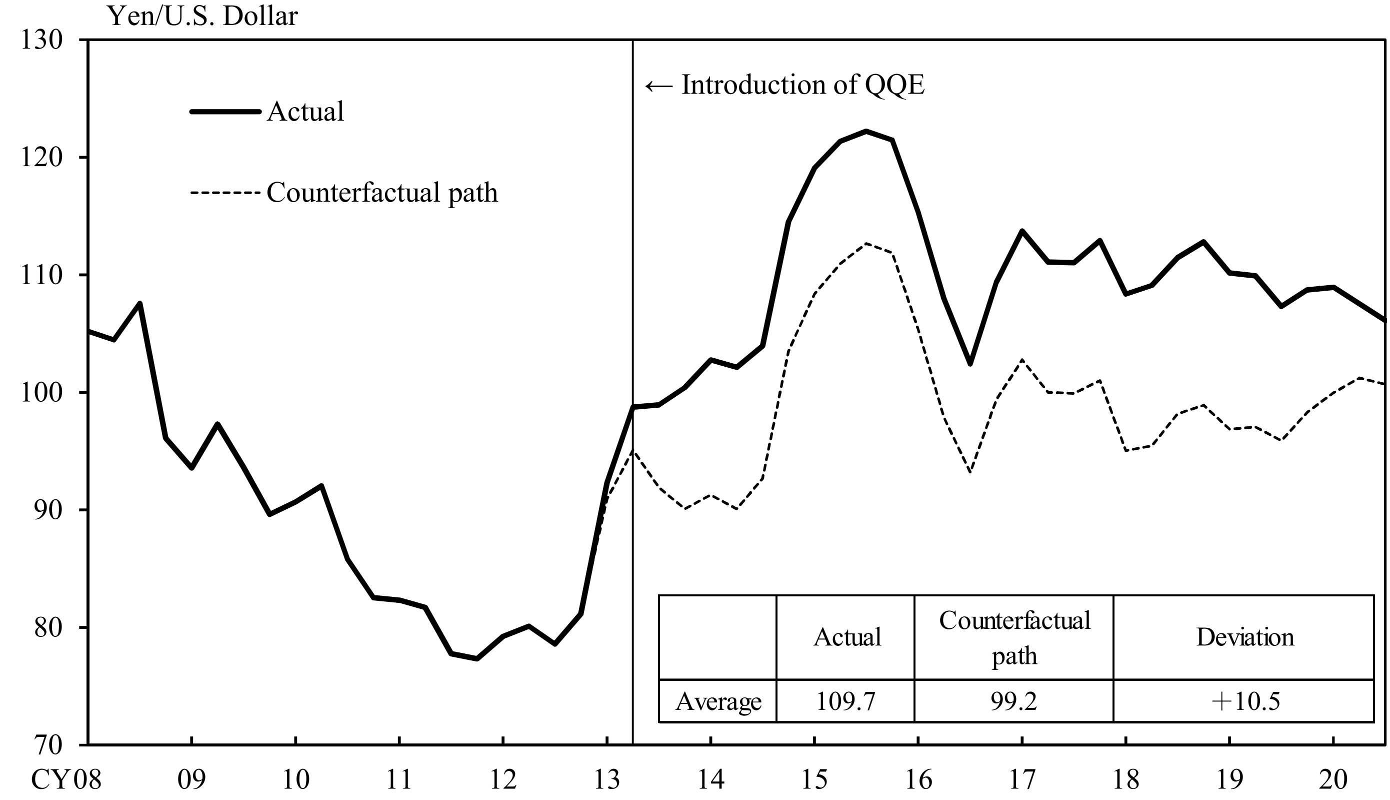
Lending Attitude DI



Note: Based on the *Tankan*. All industries and enterprises.
Source: Bank of Japan.

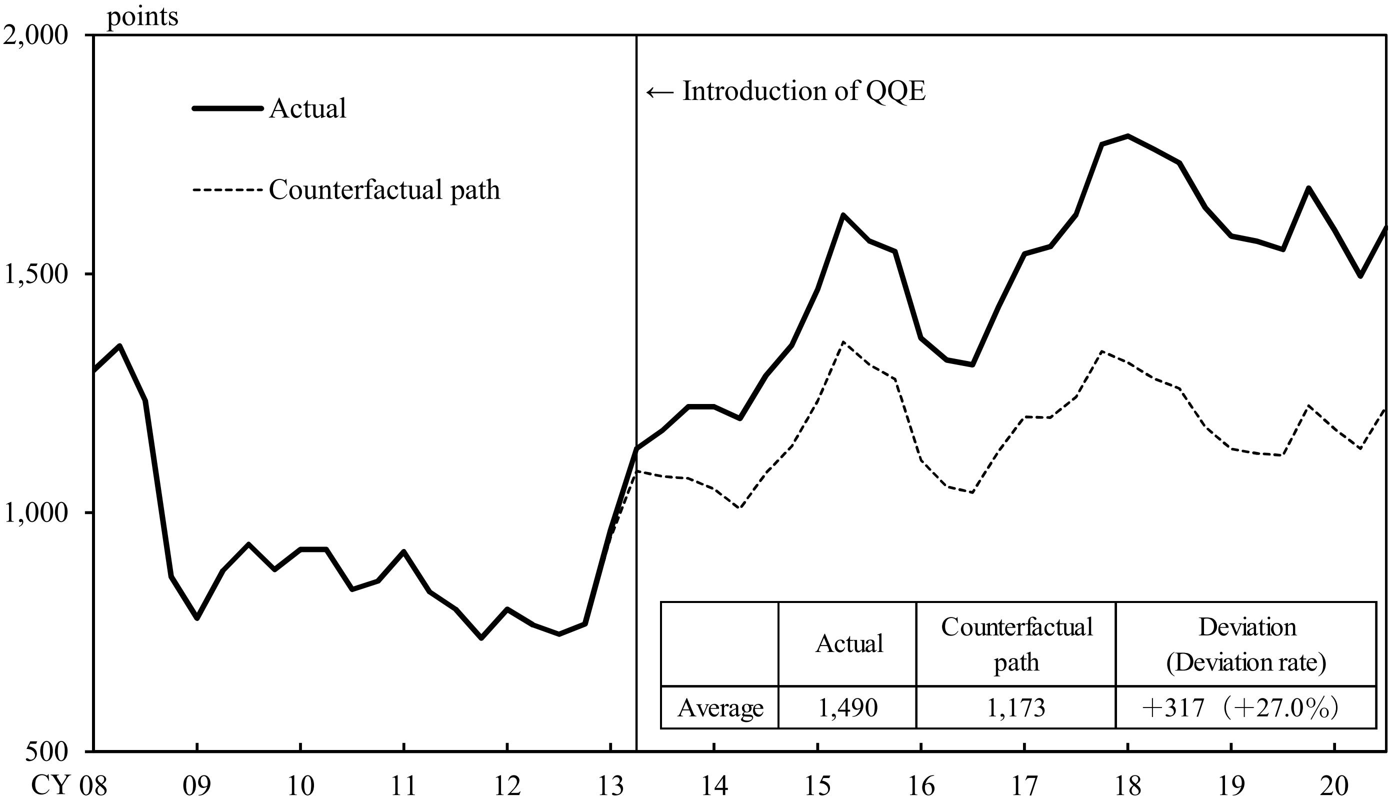
Foreign Exchange Rates and Stock Prices (Estimation Approach)

(1) U.S. Dollar/Yen Rate



	Actual	Counterfactual path	Deviation
Average	109.7	99.2	＋10.5

(2) Stock Prices (TOPIX)

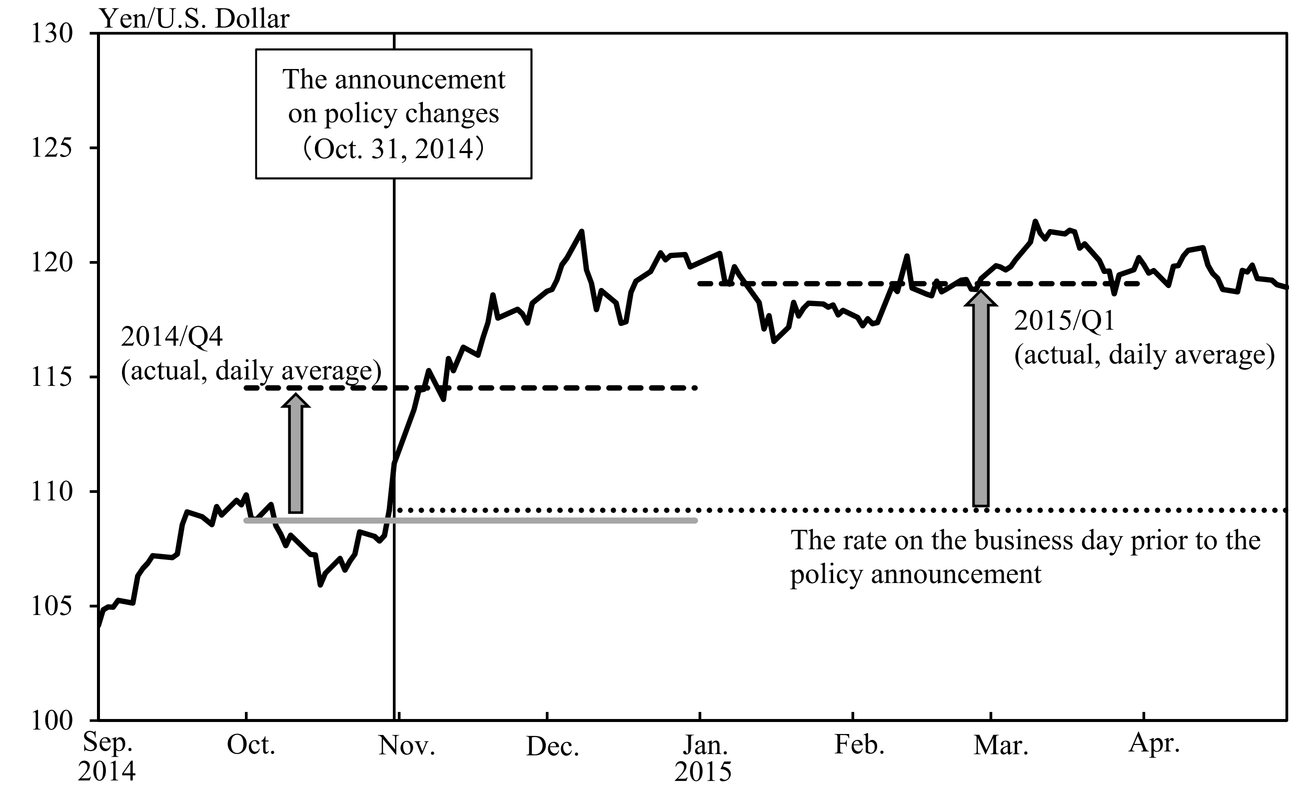


	Actual	Counterfactual path	Deviation (Deviation rate)
Average	1,490	1,173	＋317 （＋27.0%）

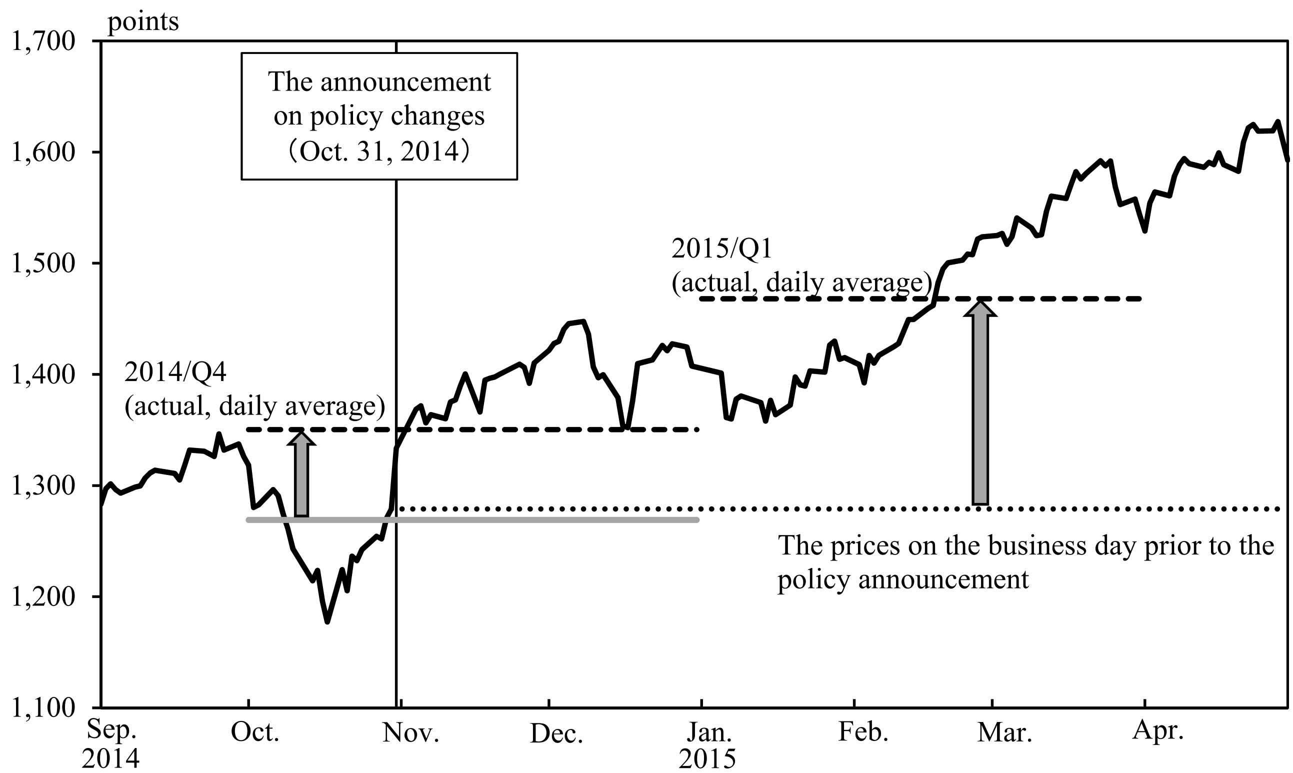
Note: Averages taken from 2013/Q2 to 2020/Q3 in the tables.
Sources: Bank of Japan; Bloomberg.

Illustration of Event Study Approach

(1) U.S. Dollar/Yen Rate



(2) Stock Prices (TOPIX)

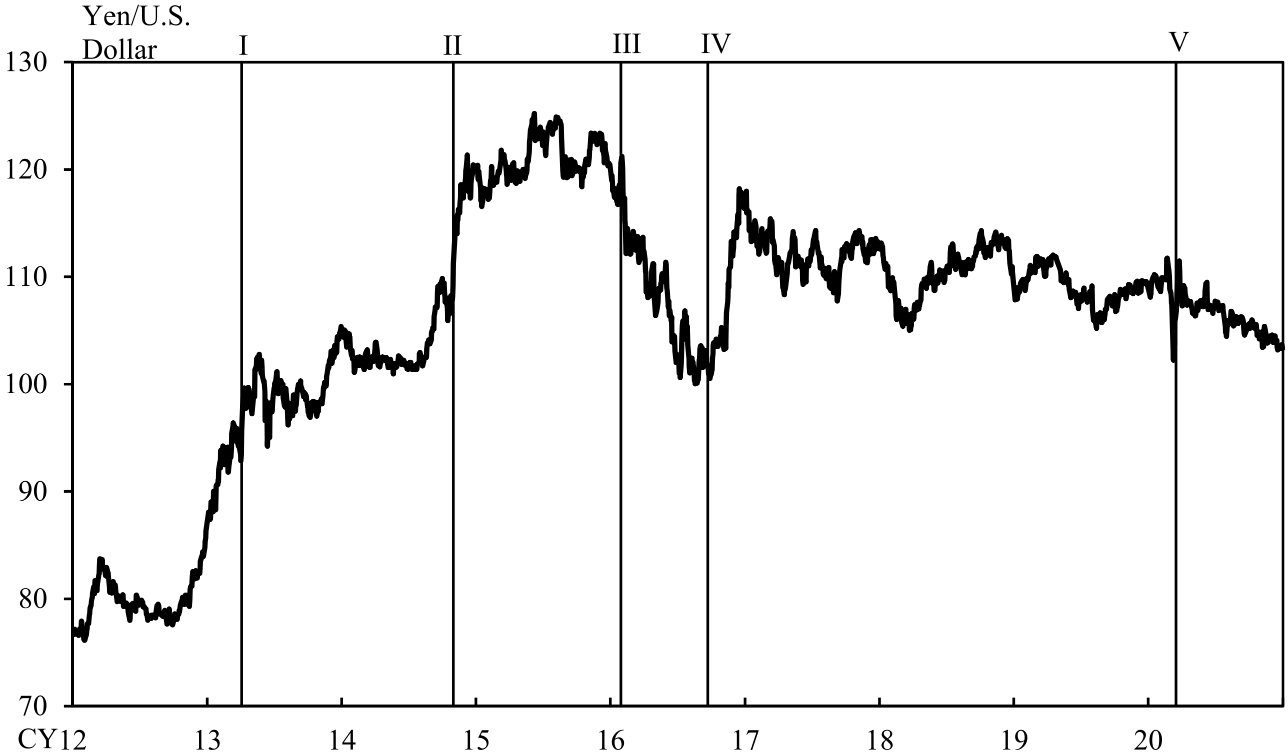


Note: The gray lines show hypothetical levels of each variable in 2014/Q4 without policy effect (hypothetical levels prior to the policy announcement is the actual value on a daily basis).

Sources: Bank of Japan; Bloomberg.

Foreign Exchange Rates (Event study)

(1) Daily U.S. Dollar/Yen Rate and the Dates of Major Policy Change Announcements



(2) Policy Effects on U.S. Dollar/Yen Rate

Yen/ U.S. Dollar

Policy changes	Announcement periods (Quarter T)	The size of policy effects	
		Quarter T	Quarter T+1
I. Introduction of QQE	2013/Q2	＋5.4	＋5.5
II. Expansion of QQE	2014/Q4	＋5.6	＋10.0
III. Introduction of QQE with a Negative Interest Rate	2016/Q1	▲3.3	▲10.8
IV. Doubling the amount of ETF purchases & Introduction of QQE with YCC	2016/Q3	▲0.1	＋7.8
V. Responses to the impact of COVID-19	2020/Q1	＋0.6	＋1.8

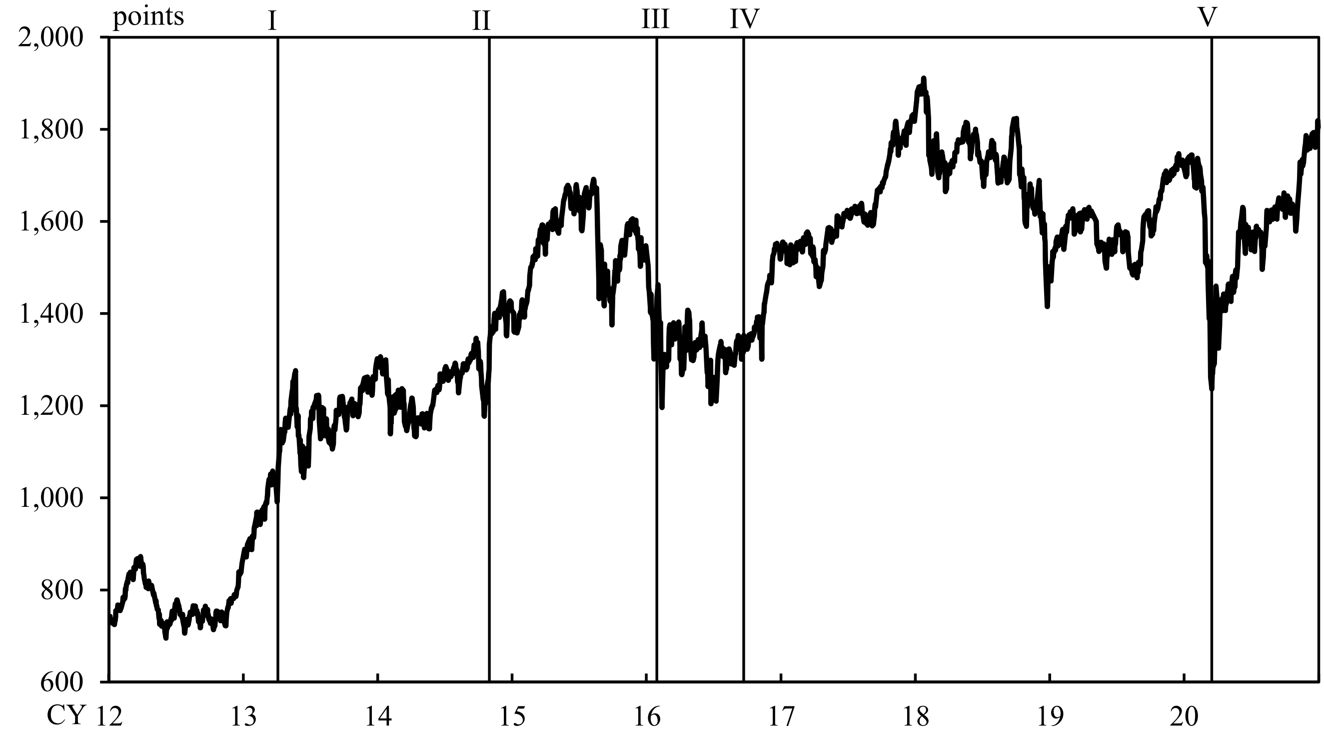
	Actual	Counterfactual path	Deviation
Average	109.7	102.8	＋6.9

Notes: 1. The figures of U.S. dollar/Yen rate are the spot rate at 17:00 JST on each day.
2. The details of policy change announcements are documented in Chart 2.
The policy effects of IV are calculated based on the date when QQE with YCC was announced.
3. Averages taken from 2013/Q2 to 2020/Q3 in the bottom table.

Source: Bank of Japan.

Stock Prices (Event study)

(1) Daily Stock Prices (TOPIX) and Dates of Major Policy Change Announcements



(2) Policy Effects on Stock Prices (TOPIX)

Points

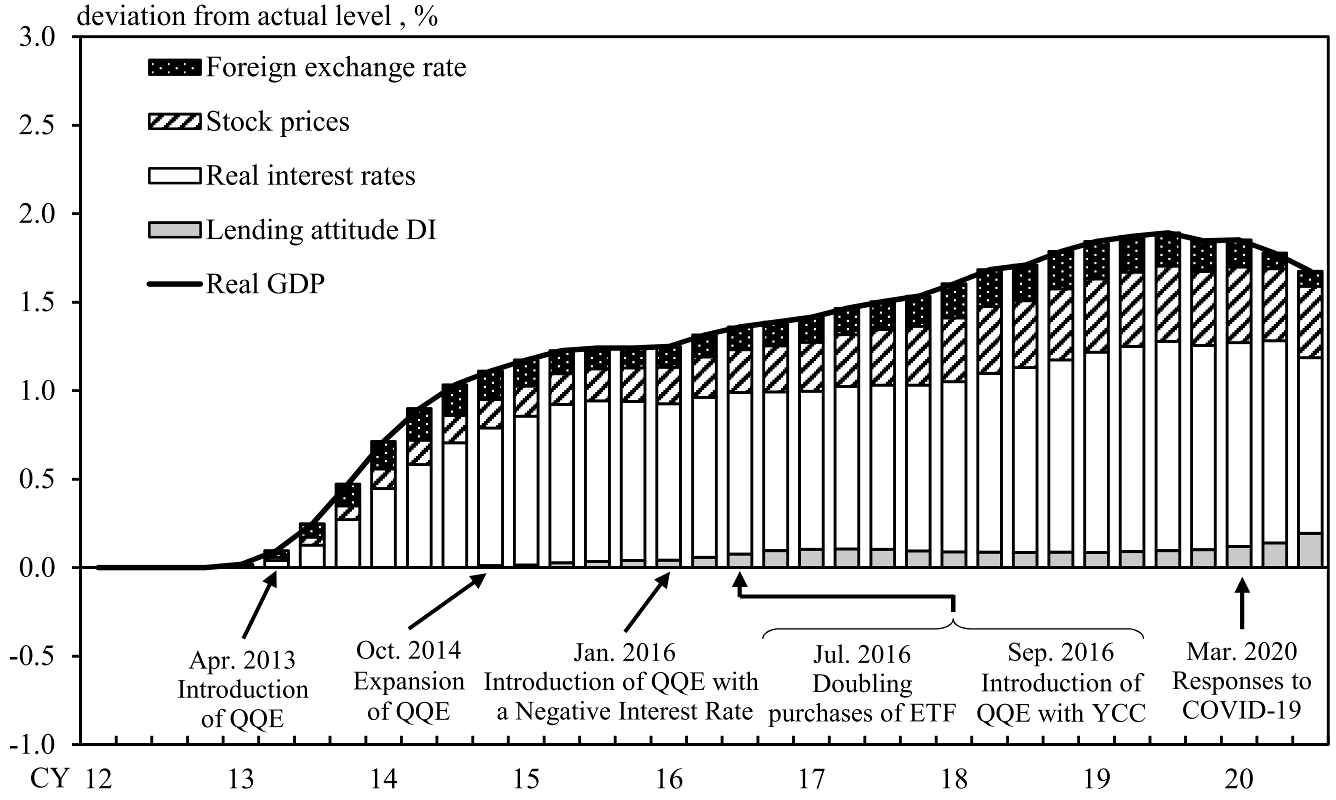
Policy Changes	Announcement periods (Quarter T)	The size of policy effects	
		Quarter T	Quarter T+1
I. Introduction of QQE	2013/Q2	＋125	＋161
II. Expansion of QQE	2014/Q4	＋78	＋193
III. Introduction of QQE with a Negative Interest Rate	2016/Q1	▲34	▲74
IV. Doubling the amount of ETF purchases & Introduction of QQE with YCC	2016/Q3	＋3	＋115
V. Responses to the impact of COVID-19	2020/Q1	＋16	＋236

	Actual	Counterfactual path	Deviation (Deviation rate)
Average	1,490	1,281	+208 (+16.3%)

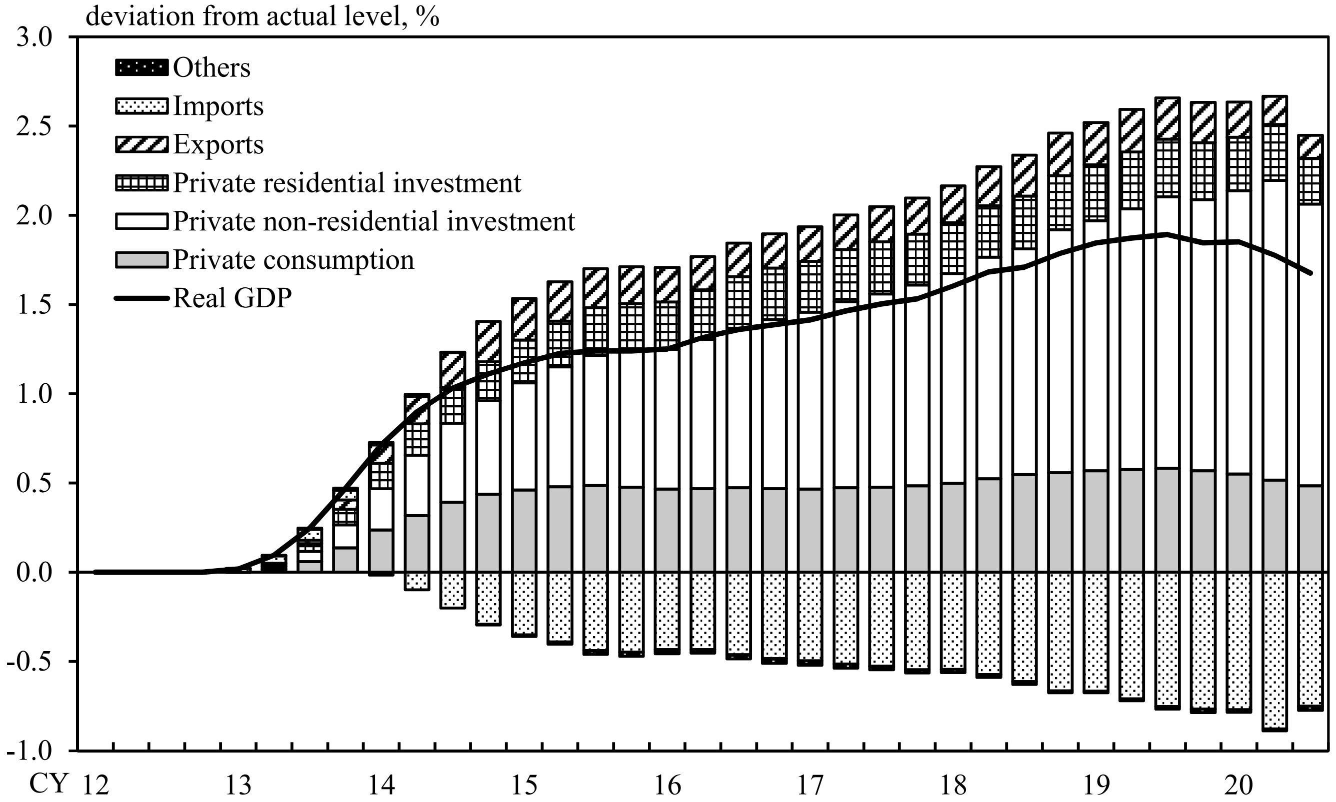
Notes: 1. The details of policy change announcements are documented in Chart 2.
The policy effects of IV are calculated based on the date when QQE with YCC was announced.
2. Averages taken from 2013/Q2 to 2020/Q3 in the bottom table.
Source: Bloomberg.

Simulation Results: Simulation A (1)

(1) Policy Effect on Real GDP and Its Decomposition by Transmission Channels



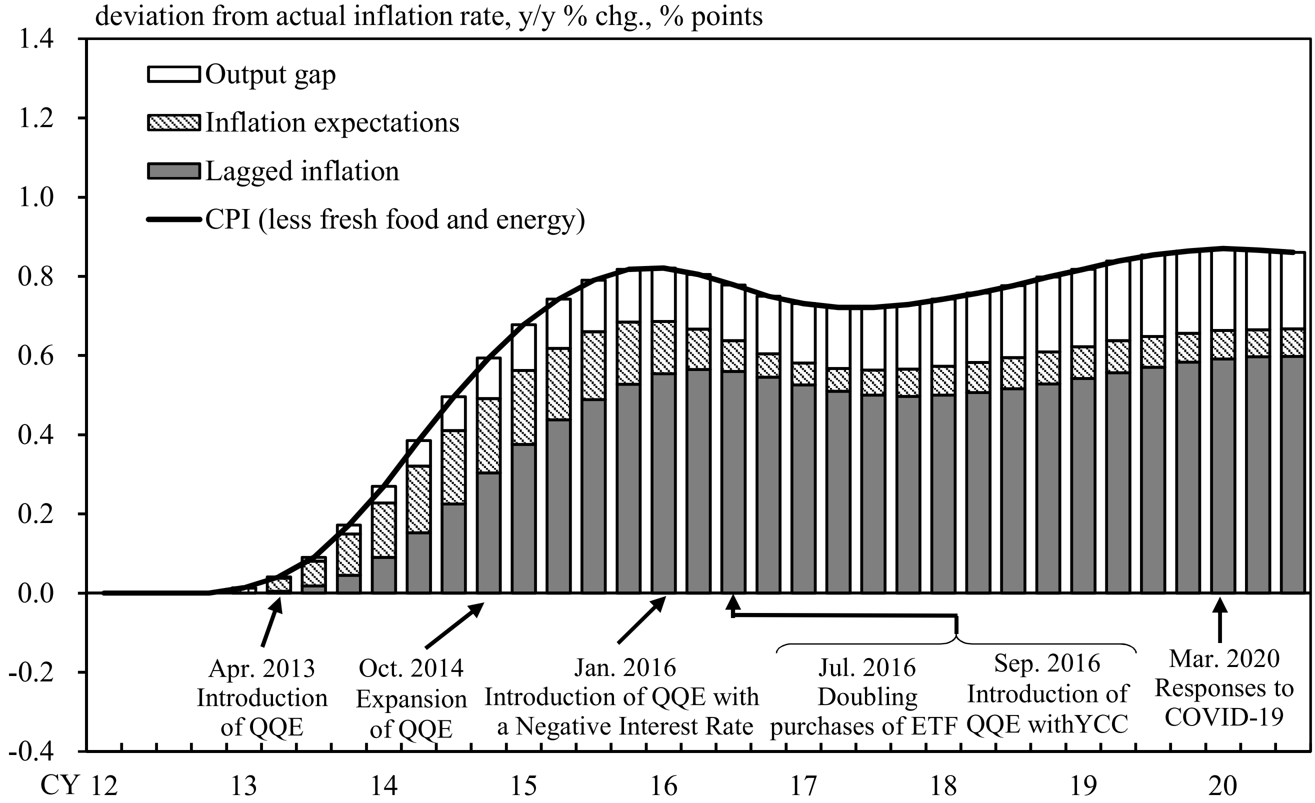
(2) Policy Effect on Real GDP and Its Decomposition by Expenditure Components



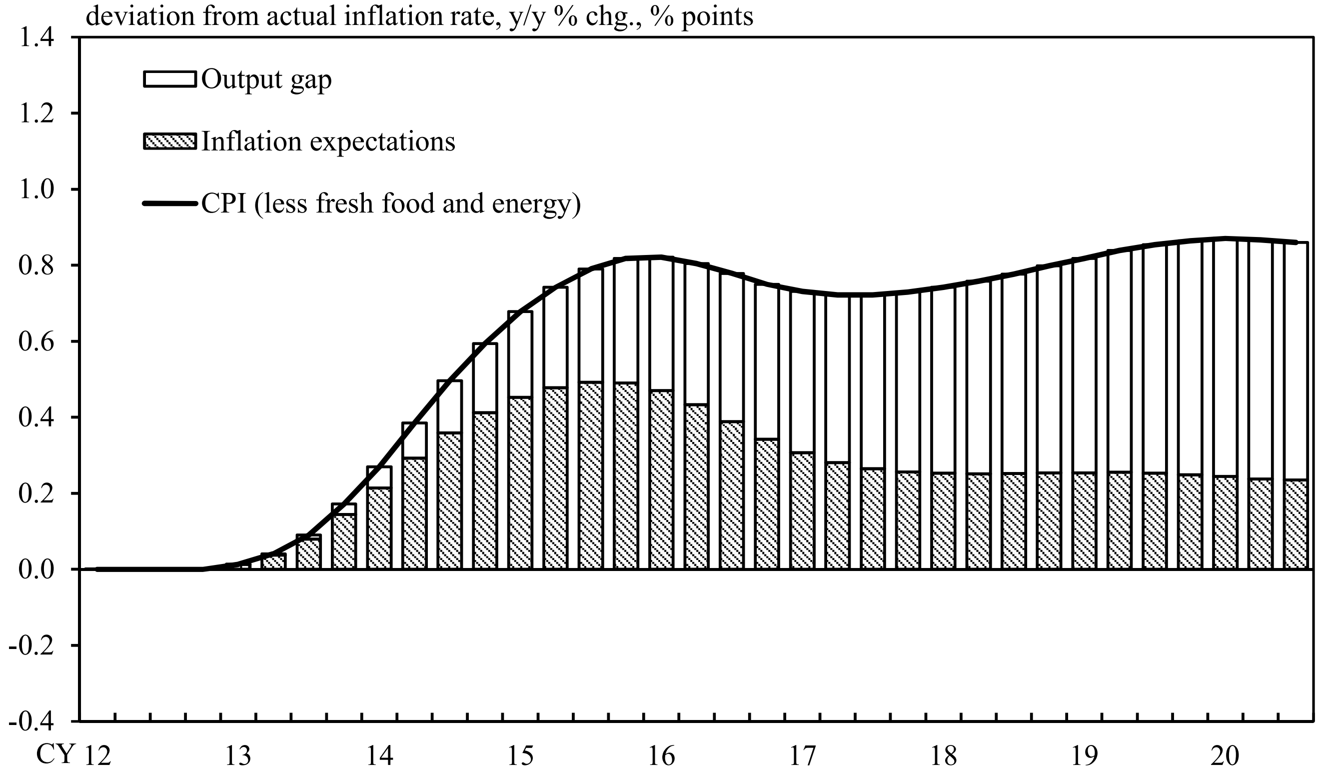
Note: "Others" in (2) includes a discrepancy between real GDP and the sum of its components, which arises from the additive inconsistency in chain-based measures.

Simulation Results: Simulation A (2)

(1) Policy Effect on CPI and Its Decomposition by Phillips Curve



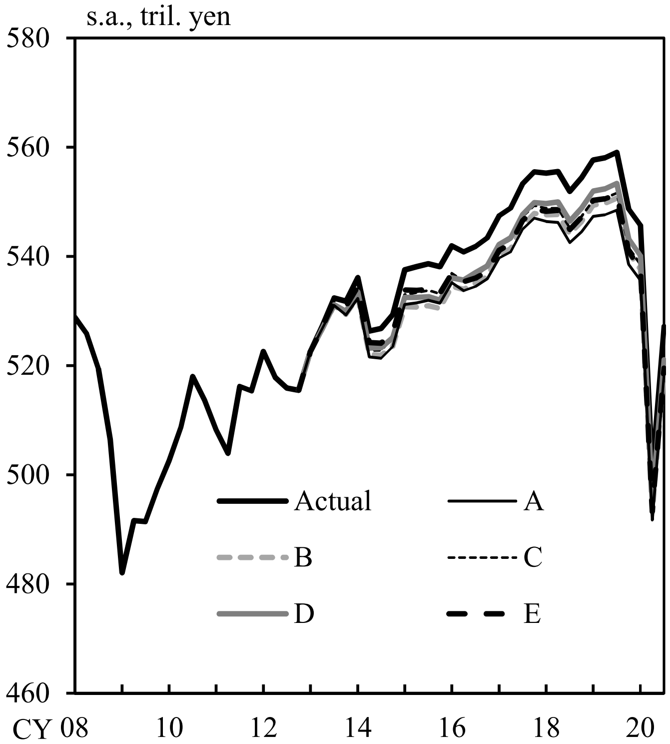
(2) Policy Effect on CPI and Its Decomposition Using Backward Iteration



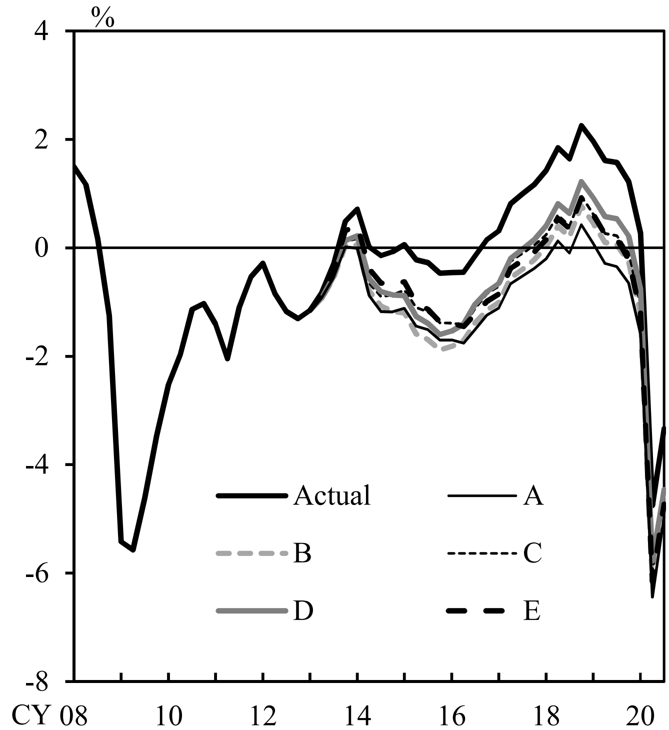
Note: Contributions in (2) are calculated by sequentially substituting the contribution of the output gap and the inflation expectations decomposed in (1) into the lagged inflation.

Summary of Simulation Results

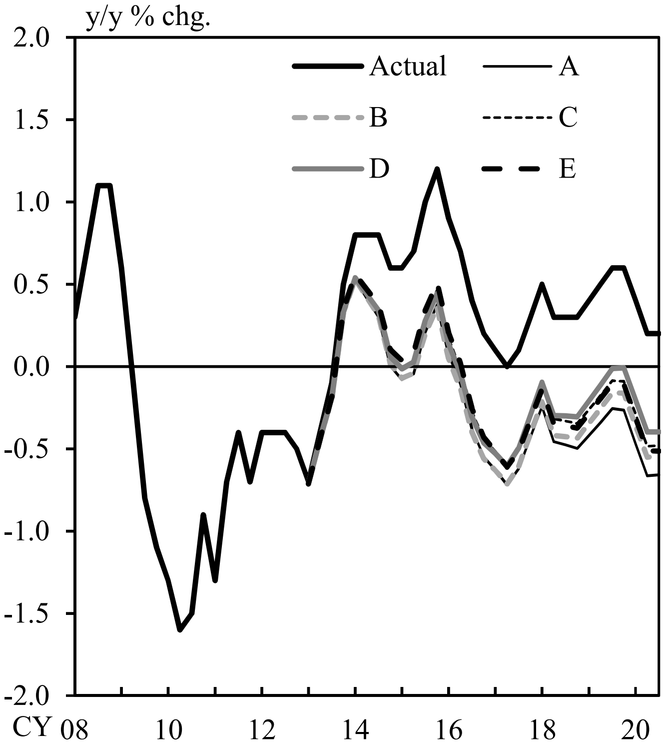
(1) Real GDP



(2) Output Gap



(3) CPI (less fresh food and energy)



(4) Average Policy Effects since the Introduction of QQE

	Simulations				
	A	B	C	D	E
Real GDP (level, %)	+1.3	+1.2	+1.0	+0.9	+1.0
Output Gap (% points)	+1.3	+1.2	+1.0	+0.9	+1.0
CPI (less fresh food and energy, y/y chg., % points)	+0.7	+0.6	+0.6	+0.6	+0.6

Note: Figures in (3) exclude the effects of the consumption tax hikes, policies concerning the provision of free education, and the "Go To Travel" campaign, which covers a portion of domestic travel expenses. The figures from 2020/Q2 onward are based on staff estimations, and exclude the effects of measures such as free higher education introduced in April 2020.

Sources: Cabinet Office; Bank of Japan; Ministry of Internal Affairs and Communications.

Key Equations in Q-JEM (1)

Private consumption (CP)

[Long-run equilibrium]

$$CPN / YDN = Const - 0.01 \times (RIRL - HYGDPQ) + 0.01 \times FASSET / YDN$$

[Short-run dynamics]

$$CP\ (q/q\ chg) = Const - 0.17 \times EC$$

Private non-residential investment (INV)

[Long-run equilibrium]

$$\log(INV / KF) = Const + 0.27 \times \log(TOB) - 0.23 \times \log(RIRLOAN + DEPRATE) + 0.001 \times LOANDI$$

[Short-run dynamics]

$$INV\ (q/q\ chg) = Const - 0.18 \times EC + 0.23 \times EX\ (q/q\ chg) - 0.01 \times \log(VI) + 0.35 \times CF\ (q/q\ chg)$$

Private residential investment (IH)

[Long-run equilibrium]

$$\log(IHN / GDPN) = Const - 1.29 \times \log(SHN / GDPN) - 3.38 \times POP50 / POP15 - 0.05 \times RIRLOAN$$

[Short-run dynamics]

$$IH\ (q/q\ chg) = Const - 0.36 \times EC$$

Notes: 1. EC is the error correction term. For abbreviation of the other variables, see Reference 3.
2. To simplify the equation expressions, some dummy variables are omitted.

Key Equations in Q-JEM (2)

Exports (EX)

[Long-run equilibrium]

$$\log(EX) = Const + 1.02 \times \log(TVOL) - 0.15 \times \log(FXR)$$

[Short-run dynamics]

$$EX\ (q/q\ chg) = Const - 0.29 \times EC + 1.59 \times TVOL\ (q/q\ chg)$$

Lending attitude DI (LOANDI)

$$LOANDI = Const + 1.08 \times PROF / GDPN + 12.06 \times SP\ (y/y\ chg)$$

Nominal compensation of employees (YWN)

$$YWN = WHN \times H \times LW$$

Nominal wage (per capita per hour, WHN)

[Long-run equilibrium]

LS = Const (assumed as constant in the long-run)

[Short-run dynamics]

$$WHN\ (q/q\ chg) = Const - 0.07 \times EC - 0.37 \times U$$

Consumer price index (less fresh food and energy, CPI)

$$\begin{aligned} CPI\ (q/q\ chg) = & \ 0.69 \times \text{Lagged CPI (q/q chg, two-quarter moving average)} \\ & + 0.31 \times ZPIL \\ & + 0.11 \times GAP \\ & - 0.37 \times \text{Period dummy (from 1990 to 2012)} \end{aligned}$$

Notes: 1. EC is the error correction term. For abbreviation of the other variables, see Reference 3.
2. FXR is determined by U.S. dollar/yen exchange rate and the ratio of domestic and foreign general price.
3. LS = YWN/GDPN.
4. To simplify the equation expressions, some dummy variables are omitted.

List of Selected Variables in Q-JEM

Name	Description
CF	Real cash flow of firms
CP	Real private consumption
CPI	Consumer price index (less fresh food and energy)
CPN	Nominal private consumption
DEPRATE	Depreciation rate of fixed capital
EX	Real exports of goods and services
FASSET	Financial assets of households
FXR	Real effective exchange rate
GAP	Output gap
GDPN	Nominal gross domestic product
H	Total hours worked (per capita)
HYGDPQ	Potential growth rate
IH	Real private residential investment
IHN	Nominal private residential investment
INV	Real private non-residential investment
KF	Net real capital stocks of private non-residential fixed assets
LOANDI	Lending attitude DI
LS	Labor share
LW	Employees
POP15	Population of 15 years old or more
POP50	Population of 50 years old or more
PROF	Firm's profits
RIRL	Real interest rates
RIRLOAN	Long-term real interest rates on loans
SHN	Nominal housing stock
SP	Stock prices
TOB	Tobin's Q
TVOL	Global trade volume
U	Unemployment rate
VI	Stock volatility index
WHN	Nominal wage (per capita per hour)
YDN	Nominal disposable income of households
YWN	Nominal compensation of employees
ZPIL	Medium- to long-term inflation expectations

Note: YDN does not include property income.