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## Chronic Deflation in Japan

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# Chronic Deflation in Japan<sup>\*</sup>

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## Abstract

Japan has suffered from long-lasting but mild deflation since the latter half of the 1990s. Estimates of a standard Phillips curve indicate that a decline in inflation expectations, the negative output gap, and other factors such as a decline in import prices and a higher exchange rate, all account for some of this development. These factors, in turn, reflect various underlying structural features of the economy. This paper examines a long list of these structural features that may explain Japan's chronic deflation, including the zero-lower bound on the nominal interest rate, public attitudes toward the price level, central bank communication, weaker growth expectations coupled with declining potential growth or the lower natural rate of interest, risk averse banking behavior, deregulation, and the rise of emerging economies.

**JEL Classification Number:** E31, E58, O53

**Keywords:** deflation, Japan

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# 1 Introduction

Why have price developments in Japan been so weak for such a long time? What can leading-edge economic theory and research tell us about the possible causes behind these developments? Despite the obvious policy importance of these questions, somewhat to our surprise, there have been few serious research attempts made in academia to answer them. Therefore, in order to shed light on these issues, the Research and Statistics Department of the Bank of Japan and the Center for Advanced Research in Finance (CARF) of the University of Tokyo jointly held a conference on the subject by inviting prominent economists in Japan. A decade after the Bank of Japan held a series of workshops on a similar subject (“Bank of Japan Workshops on Price Stability,” held on April 19, June 8, and September 21, 2001), the conference provided a golden opportunity to take stock of subsequent developments in the literature. This paper tries to summarize the main findings presented at the conference, although to some extent the summary reflects our own interpretation.

The paper proceeds as follows. Section 2 presents some stylized facts regarding deflation in Japan. Section 3 then explores the causes of prolonged deflation in Japan based on the now-standard New Keynesian Phillips curve, examining each of the explanatory variables—namely, inflation expectations, the output gap and other factors—in turn. In doing so, we not only describe developments in these variables, but also discuss what the driving forces underlying them are in order to discover the more fundamental reasons for the chronic deflation. Section 4 concludes the paper. Appendix 1 elaborates on technical details of the estimation of the time-varying Phillips curve, while Appendix 2 presents the program of the conference.

## 2 Stylized Facts

### 2.1 Price developments

Japan has suffered from long-lasting but mild deflation since the latter half of the 1990s (Table 1, Figure 1). After reaching 11.6 percent in the first half of the 1970s, annual average CPI inflation rates declined, becoming around zero or slightly negative from the middle of the 1990s. A similar trend can be observed for inflation rates calculated from the GDP deflator, although they tend to be somewhat weaker than CPI inflation. The weakness of these prices from the mid-1990s onward becomes more evident, once the hike of oil prices and the depreciation of the yen against the US dollar are taken into account. Meanwhile, the Domestic Corporate Goods Price Index (DCGPI), which is an equivalent of the Producer Price Index (PPI), shows considerable volatility. It declined sharply around the middle of the 1980s when oil prices fell and the yen appreciated. After the turn of the millennium, the DCGPI increased significantly until 2007, but then decreased sharply in the wake of the Lehman Crisis.

Table 1: Price Developments (annual average, %)

	1971- 1975	1976- 1980	1981- 1985	1986- 1990	1991- 1995	1996- 2000	2001- 2005	2006- 2009
CPI (less fresh food)	11.6	6.5	2.5	1.2	1.3	0.0	-0.4	0.0
GDP deflator	10.4	5.5	1.5	1.2	0.7	-0.9	-1.3	-0.9
DCGPI	10.3	6.1	-0.4	-1.0	-0.9	-1.1	-0.2	0.6
Oil price	53.7	26.7	-4.3	2.6	-4.1	14.5	16.4	7.2
Yen/USD	-3.4	-5.5	0.6	-7.6	-7.3	3.3	0.8	-4.7
Contribution to CPI (less fresh food)								
Energy	0.9	0.7	-0.0	-0.2	-0.0	-0.0	0.1	0.1
Durable goods	0.3	0.1	0.0	-0.1	-0.1	-0.2	-0.2	-0.2
Other goods	6.3	2.3	1.3	0.5	0.4	-0.1	-0.2	0.2
Services	4.3	3.4	1.3	1.0	1.0	0.3	-0.0	0.0

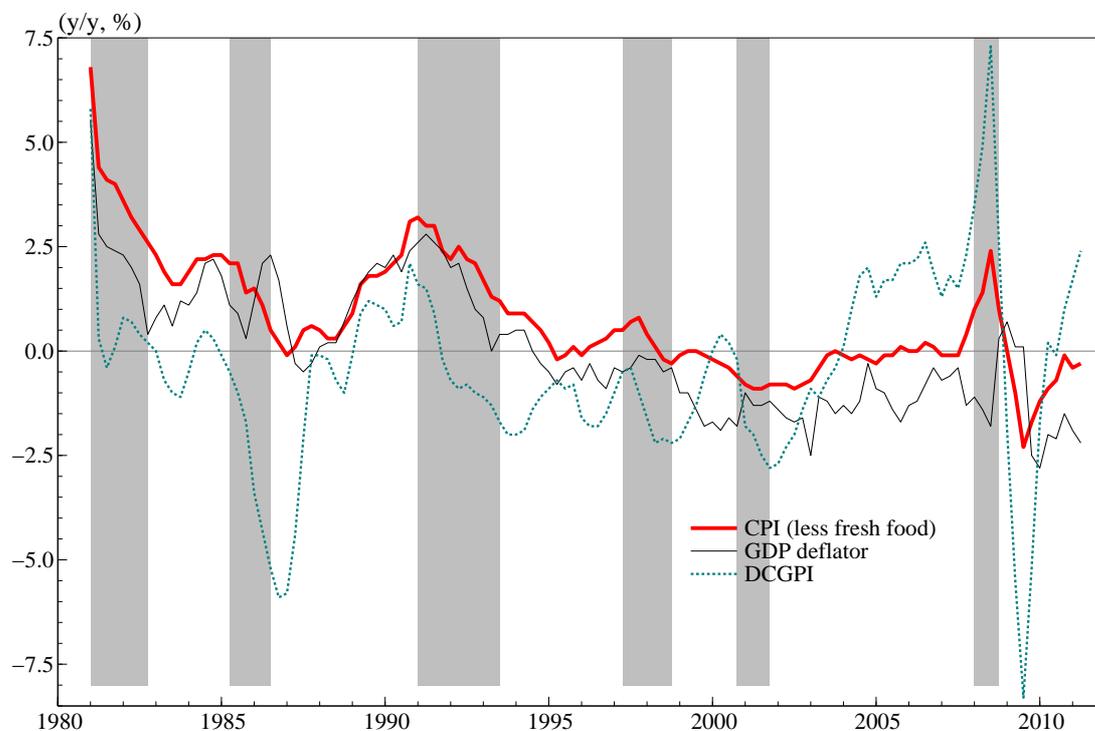
Note: DCGPI stands for the domestic corporate goods price index. Data prior to 2000Q4 are those of the domestic wholesale price index. The CPI is adjusted so as to exclude the effects of changes in consumption tax rates and subsidies for high school tuition (the same applies below).

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

A breakdown of CPI inflation into its major components suggests that most of components contributed to the slowdown in CPI inflation from the mid-1990s onward. For instance, durable goods prices, which had pushed down inflation already since the mid-1980s, fell more rapidly in the 2000s. Price changes in other goods and services, which used to raise inflation, became almost flat or turned negative in the 1990s. On the other hand, the energy component raised inflation from 2000 onward, reflecting developments in commodity markets.

The personal consumption deflator, one of major components of the GDP deflator, tends to closely track the CPI (Figure 2). This implies that the relative weakness of GDP deflator inflation compared to CPI inflation is attributable to the two other major components of the GDP deflator. One is the fixed business investment deflator, which tends to decline faster than the personal consumption deflator, reflecting rapid technological progresses in capital goods. The other is the net exports deflator, which significantly pushed down the GDP deflator around the middle of the 2000s. This provides indication that the pass-through of increases in import prices—as a result of commodity prices hikes—to domestic and export prices was limited at the time (Jinushi, a panel discussant). Meanwhile, a breakdown of the GDP deflator by economic activity suggests that IT-related industries (communications, electric machinery) faced massive declines in their deflators (Table 2).

Figure 1: Inflation Rates



Note: The shaded bars indicate a period of recession.

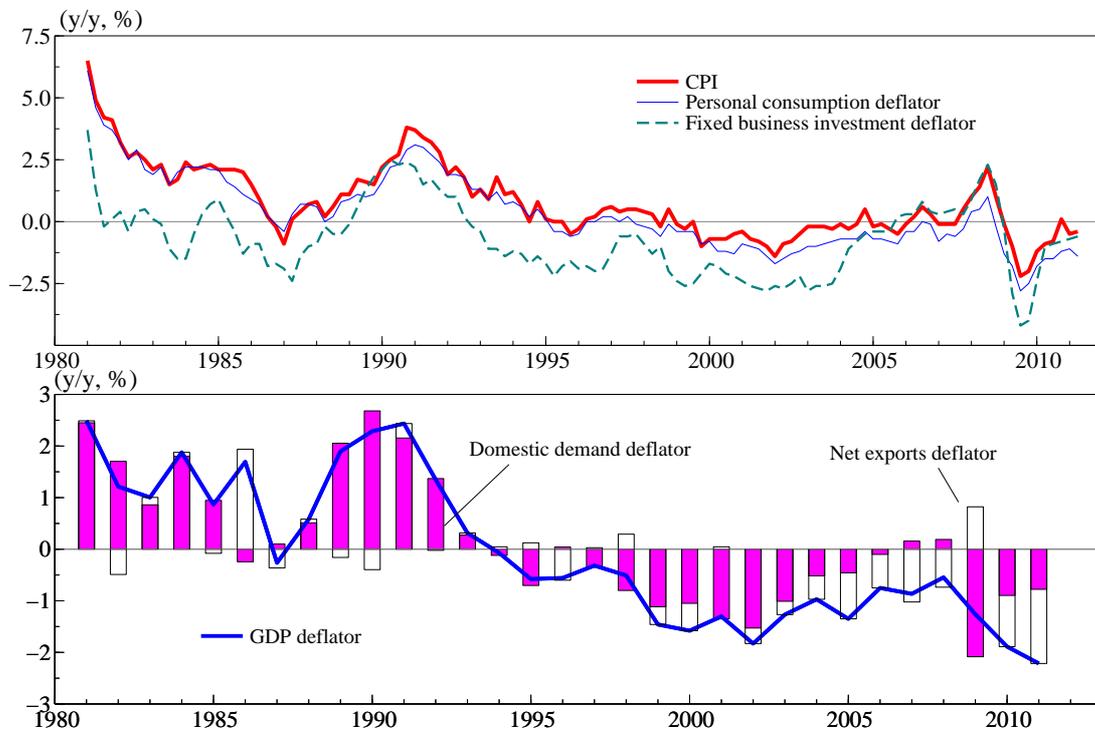
Sources: Bank of Japan, Cabinet Office, Ministry of Internal Affairs and Communications.

Table 2: GDP Deflator by Economic Activity (cumulative changes, %)

	1990- 2009	1990- 2000	2000- 2009
GDP deflator	-8.3	1.0	-9.3
Real estates	15.2	16.8	-1.6
Construction	11.2	11.9	-0.7
Services	3.1	11.2	-8.1
Wholesale and retail	-5.0	-4.1	-0.9
Finance and insurance	-2.4	-3.8	1.4
Communications	-68.1	-39.7	-28.4
Electric machinery	-118.9	-51.1	-67.8

Source: Cabinet Office.

Figure 2: GDP Deflator



Sources: Cabinet Office, Ministry of Internal Affairs and Communications.

## 2.2 Cross-country comparison

Japan's CPI inflation rates have been consistently lower than those of the United States and the euro area (Figure 3, top left-hand panel). For instance, the difference between CPI inflation rates in Japan and the United States (based on five-year backward moving average) amounted to about -2 percentage points in the 1990s (second panel on the right-hand side). The difference widened to around -3 percentage points for the 2000s before narrowing somewhat following the Lehman crisis.

Japan's inflation is lower with regard to both goods and services prices. The gap in goods prices inflation shows some volatility, presumably due to the effects of the exchange rates and commodity prices (Figure 3, top right-hand panel). Meanwhile, the gap in service prices inflation has been more stable, even in the latter half of the 2000s (second panel on the left-hand side).

The comparatively low CPI inflation in Japan does not seem to be attributable to any specific item. While it is true that the inflation gap between Japan on the one hand and the United States and the euro area on the other is particularly pronounced in durable good prices (Figure 3, third panel on the left-hand side)—probably because of the greater weights attached to IT-related gadgets (PC, flat-panel TV, etc.), the greater competition among retailers of these products, and the difference in the manners of quality adjustment in the CPI compilation—durable goods are not the only component where there is a notable gap (third panel on the right-hand side). For instance, when stripping out the effects of housing rents, the measurement of which differs considerably from country to country, service price inflation is notably weaker in Japan (bottom right-hand panel).

The weakness in nominal variables in Japan can also be observed in unit labor costs and long-term bond yields, which are rough proxies of the costs of labor and capital for producing goods and services (Figure 4).

## 2.3 Correlation with other variables

There exists a clear positive correlation between inflation and the output gap (indicated by the thick regression line in the top left-hand panel of Figure 5).<sup>1</sup> However, that positive correlation appears to have weakened—as indicated by the flatter regression line for the post-2000 sample—and have shifted downward as inflation slowed from the 1980s to the 1990s and then the 2000s.

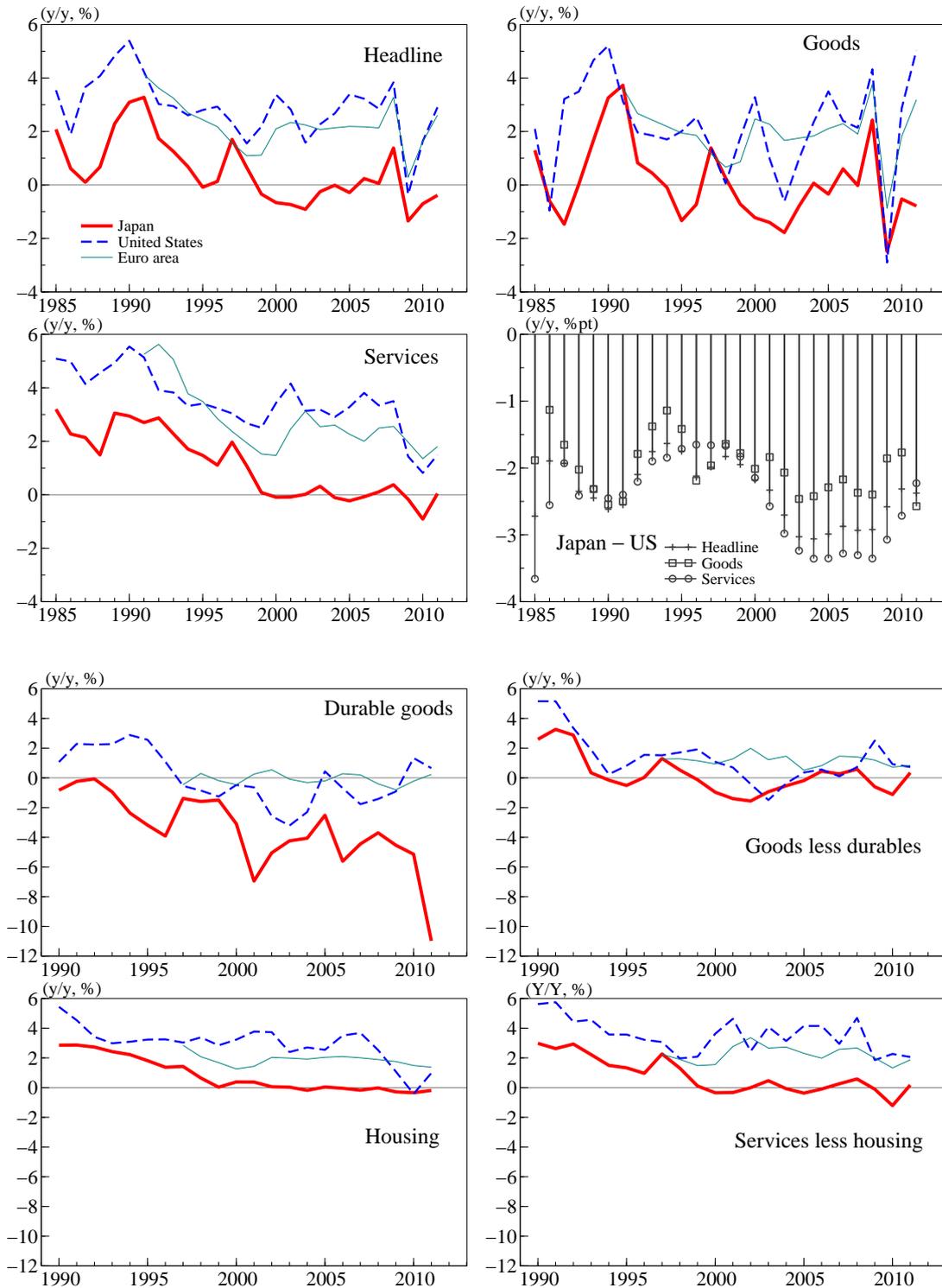
Similarly, a clear correlation can be observed between nominal wage increases and the unemployment rate (right-hand panel of Figure 5). However, that correlation becomes weak if the sample is limited to the period after 2000—the coefficient of determination ( $R^2$ ) drops to 0.12 from 0.59 for the entire sample.

In contrast, no clear correlation emerges between inflation and money. If money velocity  $v$  is stable, cross plots of inflation rates  $\Delta p$  and changes in money over real GDP

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<sup>1</sup>The output gap is lagged by four quarters to maximize its correlation with inflation.

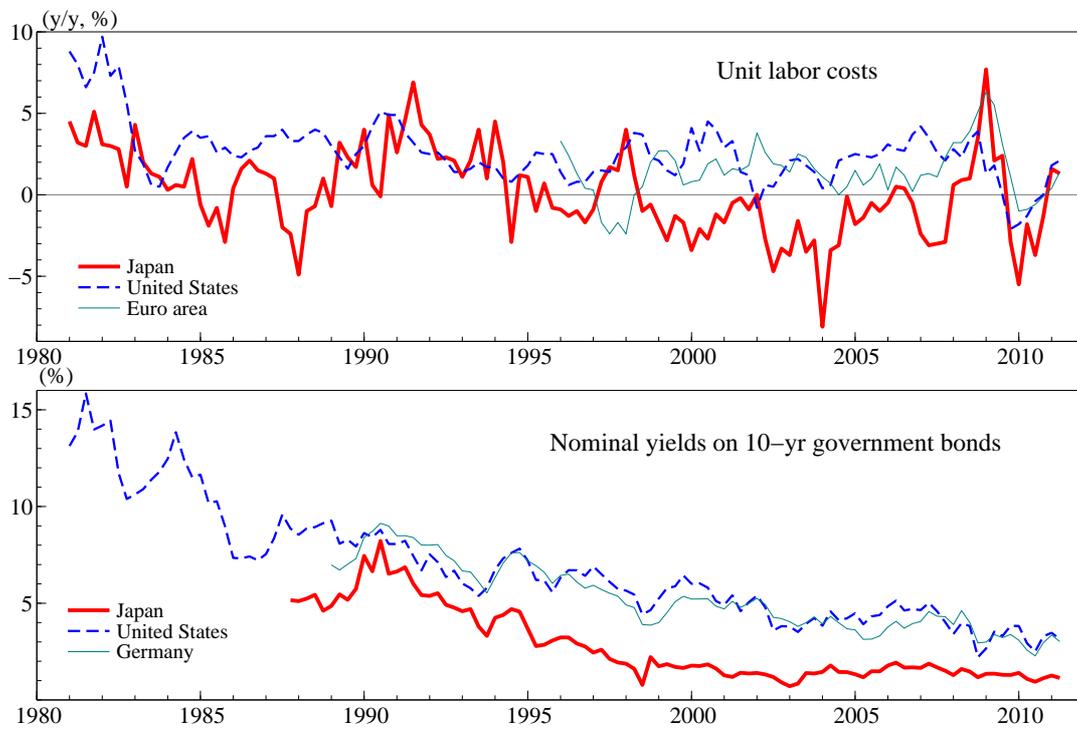
Figure 3: Cross-Country Comparison (CPI)



Note: The index lines in the second panel on the right-hand side show difference in headline, goods and services inflation rates (rate in Japan minus rate in the United States). Five-year backward moving averages are taken to smooth out cyclical fluctuations.

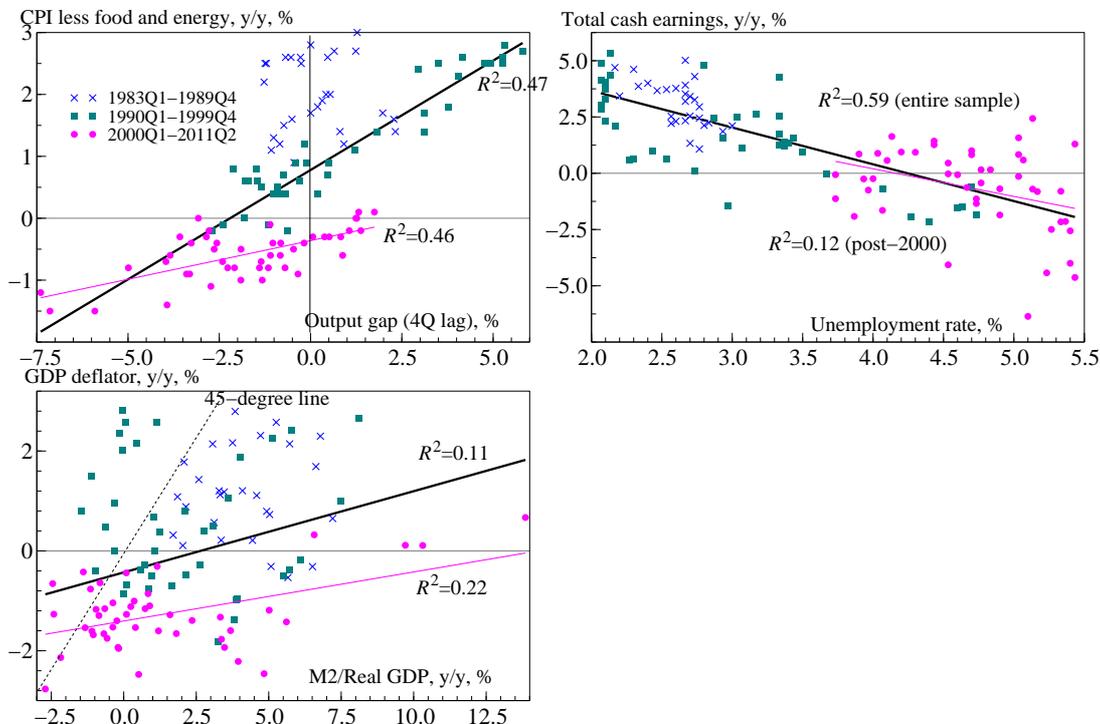
Sources: Ministry of Internal Affairs and Communications, US Bureau of Labor Statistics, Eurostat.

Figure 4: Unit Labor Costs and Nominal Yields



Sources: Cabine Office, US Bureau of Labor Statistics, Eurostat, Bloomberg.

Figure 5: Correlation with Other Variables



Note: Regression lines are calculated for the entire observation period (thick lines) and the post-2000 periods (thin lines). The  $R^2$  values are for the corresponding regression lines.

Sources: Bank of Japan, Cabinet Office, Ministry of Internal Affairs and Communications, Ministry of Health, Labour and Welfare.

$\Delta m - \Delta y$  should scatter around the 45-degree line (lower left-hand panel of Figure 5).<sup>2</sup> However, there is no strong correlation between these two variables and the slopes of the regression lines are far from the 45-degree lines.<sup>3</sup> This may be taken as indicating that money velocity is not sufficiently stable in Japan.<sup>4</sup>

### 3 Pathology

In order to examine the causes for this long-lasting deflation, we couch our investigation in terms of the now-standard New Keynesian Phillips curve, which explains inflation  $\pi_t$  by inflation expectations  $E_t\pi_{t+1}$ , the output gap  $Gap_t = y_t - y_t^n$  and other factors  $u_t$  such

<sup>2</sup>This is because  $\Delta p = \Delta m - \Delta y + \Delta v$  (or  $MV = PY$ ).

<sup>3</sup>Kimura et al. (2010) point out that in recent years the correlation has become obscure not only in Japan but also in other major industrial countries.

<sup>4</sup>See Sudo (2011) for a discussion of recent developments in money velocity in Japan.

Table 3: Inflation Contribution of Phillips Curve Variables (annual average, %)

	1987- 1990	1990- 1995	1996- 2000	2001- 2005	2006- 2009
CPI (less fresh food)	1.4	1.3	0.0	-0.4	0.0
<i>Contribution to CPI:</i>					
Own lag	0.5	0.4	0.0	-0.1	0.0
Trend inflation	1.5	1.2	0.7	0.6	0.9
Output gap	0.6	0.1	-0.3	-0.4	-0.3
Others	-1.2	-0.4	-0.4	-0.6	-0.6

that:

$$\pi_t = \beta E_t \pi_{t+1} + \alpha Gap_t + u_t. \quad (1)$$

Following Cogley and Sbordone (2008), we first estimate equation (1) by introducing time-varying trend inflation  $\bar{\pi}_t$ . In addition, inflation inertia and time-varying coefficients are taken into account (see Appendix 1 for details of the estimation):

$$(\pi_t - \bar{\pi}_t) = \rho_t (\pi_{t-1} - \bar{\pi}_t) + b_t E_t (\pi_{t+1} - \bar{\pi}_t) + a_t Gap_t + u_t. \quad (2)$$

Here, trend inflation  $\bar{\pi}_t$  corresponds to long-run inflation expectations, to which inflation converges in the absence of additional shocks.

Table 3 shows the contributions of  $\pi_{t-1}$ ,  $\bar{\pi}_t$ ,  $Gap_t$  and  $u_t$  to the actual rate of CPI inflation. As can be seen, each of the four components contributes to the weakness in price developments. For example, the positive contribution of trend inflation diminished from the mid-1990s, while the contribution of the output gap turned negative. Moreover, the negative contribution of other factor increased somewhat during the 2000s.

In the remainder of this section, we will examine developments in each of the explanatory variables and consider what the driving forces are underlying these developments. In dosing so, we exploit the contributions of submitted papers.

### 3.1 Inflation expectations

While there is a wide range of evidence suggesting that inflation expectations in Japan have declined, questions remain regarding how far and why. We will address these questions one by one.

#### 3.1.1 How far have inflation expectations declined?

Figure 6 shows various measures of expected inflation. All of them suggest that expected inflation declined to a greater or lesser extent over the past two decades or so. For

instance, a survey of professional forecasters (the Consensus Forecast) shows that their forecast of inflation for a horizon of 6 to 10 years declined from 3 percent in the early 1990s to almost zero in the first half of the 2000s. Inflation expectations then recovered somewhat and have recently been stable around 1 percent. Trend inflation as estimated in the manner described above tracks Consensus Forecast inflation, partly because it utilizes information from the Consensus Forecast survey to detect trend inflation (see Appendix 1). Furthermore, a broadly similar inflation trend is obtained by Saito et al. (2012), who estimate trend inflation in their dynamic stochastic general equilibrium (DSGE) model by imposing a standard set of theoretical restrictions without relying on the survey.<sup>5</sup>

Particular importance is placed on the question whether or not expected inflation has fallen into the negative territory (Watanabe, 2012). The reason is that, as argued by Benhabib et al. (2001) and Bullard (2010), if expected inflation was indeed negative, then Japan may have found itself in a liquidity trap equilibrium, in which the central bank was prevented from escaping from such a trap by cutting its policy interest rate due to the zero lower bound on the nominal interest rate. Heuristically, the Fisher equation,  $i = r^n + \pi^e$ , where  $i$  is the short-term nominal interest rate,  $r^n$  is the natural rate of interest and  $\pi^e$  is expected inflation, suggests that the zero lower bound on  $i$  becomes binding only when  $\pi^e$  becomes negative as long as  $r^n$  remains positive. We will discuss the possibility of a negative  $r^n$  later.

Although no consensus has yet emerged, it is quite likely that expected inflation has remained positive. Most surveys conducted either among professional forecasters or households suggest that long-run expected inflation has declined but remains around 0.5%-1%. Such surveys include, for example, the above-mentioned Consensus Forecast as well as original household surveys conducted by Watanabe (2012). Of course, the reliability of these surveys may be questioned—Ito (a panel discussant), for instance, argues that households do not take quality adjustment into account and underlying inflation expectations therefore are lower than the survey responses suggest. However, as seen above, these survey results seem to be consistent with the model-based inflation expectations estimated by Saito et al. (2012).

Two additional complications may arise with regard to this issue. One is that in contrast with the other indicators of inflation expectations, break-even inflation rates

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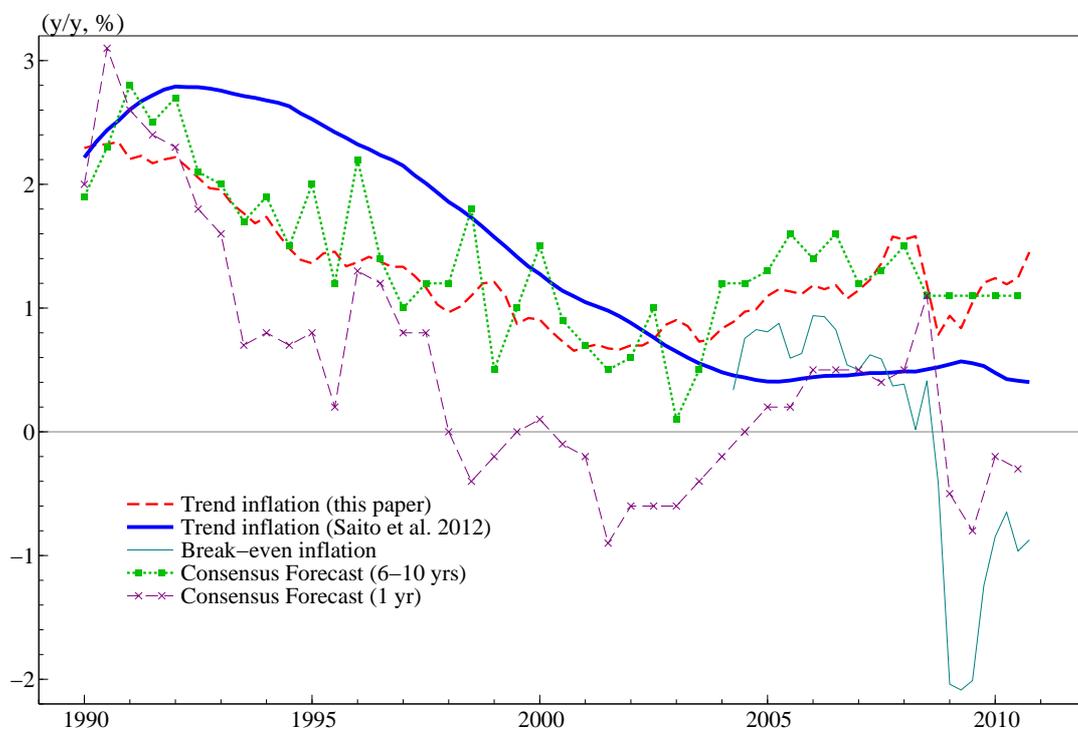
<sup>5</sup> In order to incorporate time-varying trend inflation, Saito et al. (2012) extend the estimated DSGE model of Fueki et al. (2010) which can be thought of as a Japanese equivalent to the Federal Reserve Board's Estimated, Dynamic Optimization-based (EDO) model (Edge et al., 2007; Chung et al., 2010). This is achieved by changing the policy rule as follows:

$$\hat{R}_t = \phi^r \hat{R}_{t-1} + (1 - \phi^r)[\phi^{h,gdp}(\hat{x}_t) + \phi^{\Delta h,gdp}(\hat{x}_t - \hat{x}_{t-1}) + \phi^{\pi,gdp}(\hat{\pi}_t^{p,c} - \hat{\pi}_t^{p,c*})] + \varepsilon_t^r,$$

$$\hat{\pi}_t^{p,c*} = \rho^T \hat{\pi}_{t-1}^{p,c*} + \varepsilon_t^T,$$

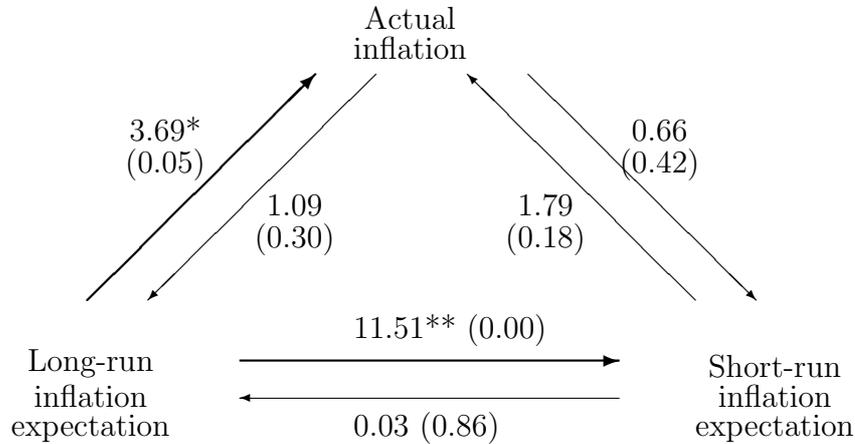
where  $\hat{R}_t$  is the short-term nominal interest rate,  $\hat{x}_t$  is the output gap defined as the deviation of real GDP from its efficient level, and  $\hat{\pi}_t^{p,c}$  is the inflation rate measured by the consumption-goods deflator.  $\hat{\pi}_t^{p,c*}$  is the target inflation rate, which varies over time as indicated by the second equation.  $\varepsilon_t^r$  and  $\varepsilon_t^T$  are shocks to the respective processes. Here and below, mathematical notations follow original papers at the expense of notational consistency within this paper.

Figure 6: Expected Inflation



Sources: Ministry of Internal Affairs and Communications, Consensus Forecast, Bloomberg.

Figure 7: Granger Causality Tests



Note:  $\chi^2$  tests of linear restrictions on zero coefficients based on a tri-variate VAR model with constant terms (sample period: 1990H1-2010H2). Figures in parentheses are q-values. Actual inflation is measured in terms of q/q of CPI (less food and energy). Long- and short-run inflation expectations are “Trend inflation (this paper)” and “Consensus Forecast (1 yr)” in Figure 6.

have become negative since the Lehman shock (Figure 6). However, one should probably not read too much into the negative break-even inflation rates due to the lack of market liquidity in Treasury Inflation-Protected Securities (TIPS). The outstanding amount of Japanese TIPS was mere USD84.5 billion at the end of March 2008, less than one fifth of the corresponding US value, and the Ministry of Finance has suspended the issuance of inflation-indexed bonds since August 2008.

The other complication is related to short-run expected inflation, which occasionally takes negative values since the 1990s. In their estimates of the Phillips curve, Fuhrer et al. (2011) argue that it is short-run expected inflation, rather than its long-run peer, that is relevant for Japan’s inflation dynamics. However, the result does not accord with a simple VAR estimation, which suggests that trend inflation causes actual inflation and short-run expected inflation in a Granger sense, but not vice versa (Figure 7). Bernanke (2007) also stresses the importance of long-run inflation expectations for price- and wage-setting.

### 3.1.2 Why have inflation expectations declined?

Turning to the question why expected inflation has declined over the past two decades or so, Saito et al. (2012) argue that, from a theoretical perspective, the reason is either that the central bank has lowered its target rate for inflation or that the public has become more suspicious about the achievability of the target rate once the nominal interest rate has reached the zero floor.

The central bank’s communication strategy may also have mattered. Ito (a panel discussant) claims that the Bank of Japan’s (BoJ’s) projection for weak inflation may have had the effect of damping inflation expectations. Indeed, the BoJ, which began to publish its board members’ outlook for growth and inflation from 2000, often foresaw weak price developments *correctly*. In contrast, the various long-run expected inflation rates mentioned above seem to have been more firmly anchored to positive values, after the BoJ announced its ‘understanding’ (now ‘goal’) of price stability in 2006.<sup>6</sup> Table 4 summarizes how the BoJ has communicated its thinking on price stability. This summary reveals that (i) the BoJ has continuously defined price stability as a situation of neither inflation nor deflation; (ii) the BoJ openly acknowledged as early as in 1997 the possibility of a measurement bias, a year after the publication of the Boskin Report (Boskin et al., 1996); and (iii) the BoJ has improved its style of communication, for example, by putting a numerical figure for the price stability goal.

As argued by Tobin (1972), Okun (1981) and Akerlof and Shiller (2009), public attitudes (or ‘norm’) toward the price level may also have mattered in forming inflation expectations. On that score, it is important to note that, in the 1990s, coupled with the very strong yen, the public seems to have felt that prices in Japan were too expensive compared to prices in other industrial countries. Or at least that is what the tone of the government and the media at the time, which tended to report that Japanese prices should be slashed, suggests (Table 5). In fact, that perception was warranted, as seen in the wide difference between domestic and foreign prices during the 1990s (Figure 17 below). It was only after turn of the millennium that the media began to pay more attention to the hazardous effects of deflation. The number of newspaper articles on deflation jumped in 2001, which may indicate that public attitudes toward the price level changed discontinuously at that time (Figure 8). The press coverage seems to have been affected by the government’s “declaration of deflation” in 2001 and 2009, when its Monthly Economic Report used the term “deflation,” as indicated in Table 5.

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<sup>6</sup>As indicated by Table 4, the BoJ set a goal at 1 percent on February 14, 2012. Shirakawa (2012a) elaborates on its level by saying “[S]imply announcing out of the blue that the Bank aims to achieve 2 percent inflation is not enough. Above all, this might raise unnecessary uncertainties for businesses and households. Furthermore, if the announcement was trusted and inflation expectations rose accordingly, it is financial markets that would respond most quickly. There would then be a risk of a premature rise in long-term yields before actual prices and wages start to rise. Under such circumstances, the prices of Japanese government securities, a large share of which is owned by financial institutions, would go down, thereby heightening the risk of undermining such institutions’ lending activities. Owing to these concerns, we judged that it was best to leave the CPI inflation rate at 1 percent for the time being and exert efforts to achieve that goal. On top of this, the Bank will review “the price stability goal in the medium to long term” once a year while analyzing the level of progress that has been made toward strengthening the growth potential and the changes that have occurred in the general public’s perception of prices.”

Table 4: Bank of Japan’s Communication

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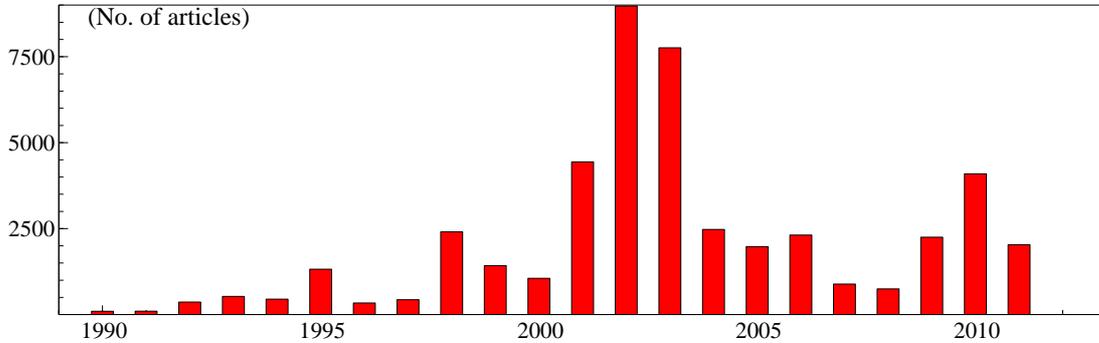
<p>1994-05-27: <i>Principles for the Conduct and the Goal of Monetary Policy</i> (Speech made by Governor Mieno) (authors’ translation)</p> <p>1996-10-11: <i>Financial Innovation, Financial Market Globalization, and Monetary Policy Management</i> (Speech made by Governor Matsushita)</p> <p>1997-06-27: <i>A New Framework of Monetary Policy under the New Bank of Japan Law</i> (Speech made by Governor Matsushita)</p> <p>2000-10-13: <i>On Price Stability</i></p> <p>2006-03-09: <i>The Introduction of a New Framework for the Conduct of Monetary Policy</i></p> <p>2006-03-09: <i>An Understanding of Medium- to Long-term Price Stability</i></p> <p>2007-04-27: <i>Outlook for Economic Activity and Prices</i></p> <p>2009-12-18 <i>Clarification of the ‘Understanding of Medium- to Long-Term Price Stability’</i></p> <p>2012-02-14: <i>The Price Stability Goal in the Medium to Long Term</i></p>	<p>“One of main goals of monetary policy is delivering ‘sustainable growth without inflation’ in the medium- to long-run.” “The question is often posed on which price indicator, the Consumer Price Index or the Wholesale Price Index, the definition of price stability should be based. However, it is inappropriate to single out a price indicator, as the goal of monetary policy is the ‘stability of prices’ not ‘stability of a price index.’”</p> <p>“The Bank of Japan ... intends to manage monetary policy appropriately with the aim of maintaining price stability, preventing inflation or deflation of domestic prices.”</p> <p>“It is, however, not easy to define price stability. There are diverse types of price indicators: for example, the Consumer Price Index, Wholesale Price Indexes, and the GDP deflator. Each of these has its limitation, such as the range of items covered or the timing of release. Further, many studies have been conducted more recently on the possibility that these indicators offer a substantially biased measurement of prices.”</p> <p>“[I]t is not deemed appropriate to define price stability by numerical values.” “Price stability, a situation neither inflationary nor deflationary, can be conceptually defined as an environment where economic agents including households and firms can make decisions regarding such economic activity as consumption and investment without being concerned about the fluctuation of the general price level.”</p> <p>“Price stability is a state where various economic agents including households and firms may make decisions regarding such economic activities as consumption and investments without being concerned about the fluctuations in the general price level.” “Price stability is, conceptually, a state where the change in the price index without measurement bias is zero percent.”</p> <p>“It was agreed that, by making use of the rate of year-on-year change in the consumer price index to describe the understanding, an approximate range between zero and two percent was generally consistent with the distribution of each Board member’s understanding of medium- to long-term price stability. Most Board members’ median figures fell on both sides of one percent.”</p> <p>“The ‘understanding’ expressed in terms of the year-on-year rate of change in the CPI, takes the form of a range approximately between 0 and 2 percent, with most Policy Board members’ median figures falling on one side or the other of 1 percent.”</p> <p>“In a positive range of 2 percent or lower, and the midpoints of most Policy Board members’ ‘understanding’ are around 1 percent.”</p> <p>“The Bank judges that ‘the price stability goal in the medium to long term’ is in a positive range of 2 percent or lower in terms of the year-on-year rate of change in the consumer price index (CPI) and, more specifically, set a goal at 1 percent for the time being.”</p>
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Table 5: Government and Media Reports on Price Level

Government Reports	
1993 July: <i>Annual Report on Japan's Economy (FY1993)</i>	“While Japanese income per capita converted to US dollars is one of the highest in the world, living standards in reality as such are not. This is mainly because of the gap between internal and external prices. ... Consumers would be better off if prices in Japan declined, narrowing this domestic-foreign price difference.”
1999 June: <i>Report of the Committee on Price Problems under Zero Inflation</i>	“Deflation is a situation where sub-par growth and a fall in prices take place simultaneously.” “A fall in prices does not necessarily incur recession.” “It would be appropriate for the authorities to aim at zero inflation. However, some margin needs to be taken into account, given the positive measurement bias in the consumer price index.”
2001 March: <i>Monthly Economic Report</i>	“The Japanese economy is in a mild deflationary phase, if deflation is defined as ‘a continuing decline in prices.’”
2001 December: <i>Annual Report on Japan's Economy and Public Finances (2000-2001)</i>	“[U]nder the current situation of the Japanese economy, even a mild deflation is believed to have adverse effects on the economy.”
2009 November: <i>Monthly Economic Report</i>	“Recent price developments show that the Japanese economy is in a mild deflationary phase.”
Op-Ed Articles in Major Newspapers	
1994-10-04: <i>Can We Self-Praise Price Stability?</i> (Nikkei Shimbun)	“A 10% appreciation of the yen would increase households’ real purchasing power by 30 to 40 thousands yens on average. The Price Report for FY1994, which the Economic Planning Agency published last week, stressed price stability amid the appreciation of the yen by presenting the above estimation. The CPI increased by 1.2% in FY1993. ... However, the Report appears to sing its own praises too much on price stability. In fact, consumer prices in Japan should have been lowered.”
1998-07-27: <i>Is Inflation Adjustment Really a Good Deal?</i> (Asahi Shimbun)	“Some commentators in the market as well as in academia have turned to inflation in order to lift the economy. They claim that deliberately created inflation would sort out the problems of Japan’s economy, where sales have declined and prices have fallen. This is so called ‘inflation adjustment.’ ... The costs of pursuing such a policy are much too large. It is difficult to imagine that this is a worthwhile policy.”
2001-03-17: <i>Conquer Deflation, Once Admitted</i> (Nikkei Shimbun)	“Among major advanced economies, Japan is the only country where prices have continued to decline. The Government and the Bank of Japan should quickly come up with specific policies to conquer this deflation.”
2003-11-16: <i>Don't Forget the Homework of Conquering Deflation</i> (Asahi Shimbun)	“Deflation places a greater burden on firms and individuals who borrow money, as the amount they have to pay back does not fall even when prices fall. This is the problem of deflation.”
Note: Most of the quotes are the authors’ translation.	

Figure 8: Press Coverage of Deflation



Note: The figure shows the number of hits for the search term “deflation” in articles of major newspapers (Nikkei, Asahi, Mainichi, Yomiuri, Sankei). The figure for 2011 is the annualized value of the number of hits for articles up to September that year.

## 3.2 The output gap

There is a consensus among researchers that the output gap has remained negative for almost the entire period since the mid-1990s. Figure 9 shows various measures of the output gap. Both when employing a production function approach (BOJ) and a survey measure (Tankan), the results suggest that the output gap has remained negative since the early 1990s except for short intervals in the latter halves of the 1990s and the 2000s. The model-based measure by Saito et al. (2012) points to a broadly similar trend.

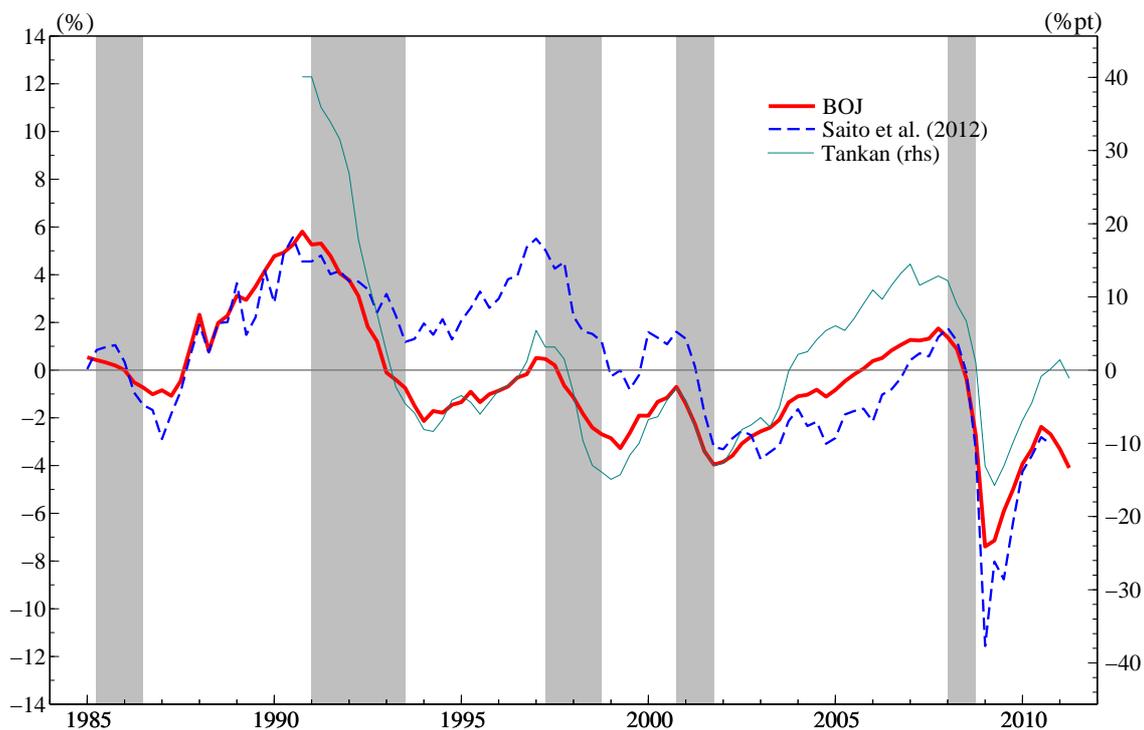
However, no consensus has emerged regarding why the output gap has remained negative for such a long duration. As discussed below, there are various attempts to explain the phenomenon. As these explanations are not mutually exclusive, it may well be the case that the mechanisms they describe have worked simultaneously.

### 3.2.1 Why has the output gap remained negative for a long time?

The simplest answer to the question could be mere bad luck. Just “unfortunately,” Japan has been hit by a series of large negative demand shocks. These include the demand shock resulting from the collapse of the asset price bubble in the early 1990s; the Japanese financial crisis and the Asian currency crisis in the latter half of the 1990s; the collapse of the US dotcom bubble in the early 2000s; and the global financial crisis in the latter half of the 2000s. Instead of sighing over these “unlucky” events, however, researchers are trying to understand the forces underlying them. Since deterioration of the output gap has been accompanied with a decline in the potential growth rate, researchers have been trying to explain the link between two.

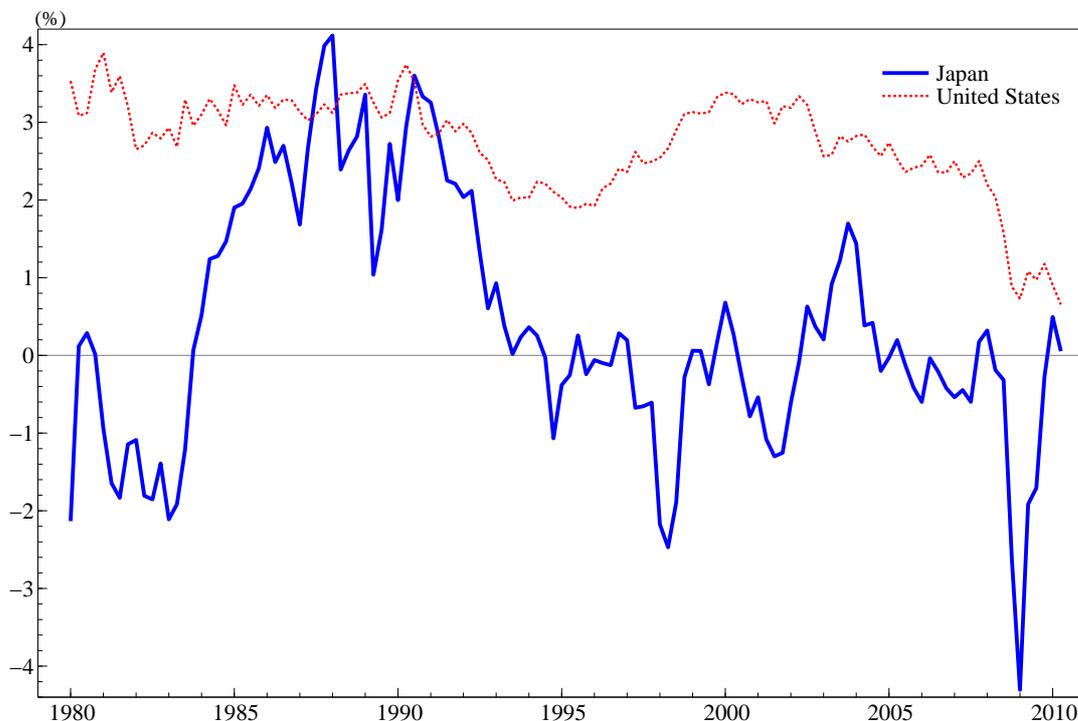
One strand of explanations of the negative output gap suggests that it is caused by a

Figure 9: Output Gaps



Note: “BOJ” refers to the output gap estimated by the Research and Statistics Department, Bank of Japan (Hara et al., 2006), while “Tankan” refers to the weighted averages of the production capacity DI and employment conditions DI in the Tankan Corporate Survey. The FY1990-2010 averages of capital and labor shares in the National Accounts are used as the weight. Finally, “Saito et al. (2012)” is the output gap estimated based on their DSGE model, where the output gap is defined as the deviation of real GDP from its potential level (Fueki et al., 2010). The shaded bars indicate periods of recession.

Figure 10: Natural Rate of Interest



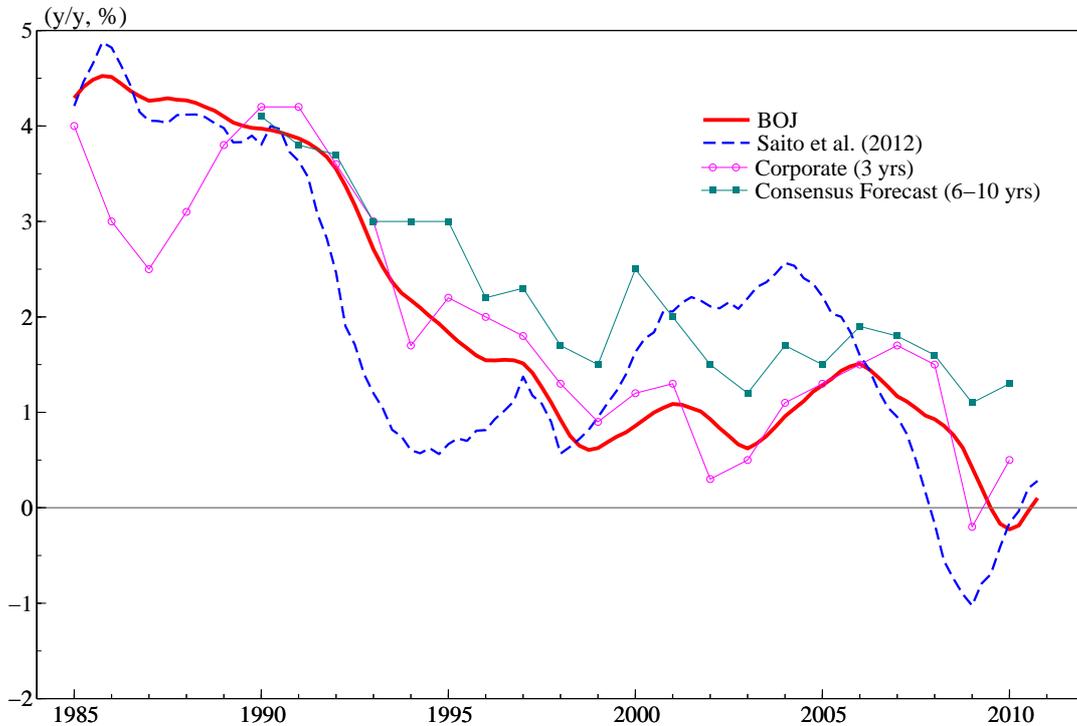
Note: Figures for the United States are originally from Williams (2009).

Source: Watanabe (2012).

decline in the natural rate of interest and the zero lower bound on the nominal interest rate. For instance, following the approach of Laubach and Williams (2003), Watanabe (2012) shows that, along with the potential growth rate, the natural interest rate in Japan has declined to an extent that it has fallen into negative territory (Figure 10). In that case, once the central bank faced the zero floor, it was no longer able to lower the policy rate in tandem with the decline in the natural interest rate. This may have produced the negative output gap, since the policy rate was too restrictive compared to the natural rate. Couching his argument in the Fisher equation,  $i = r^n + \pi^e$ , Watanabe (2012) suggests that instead of the negative inflation expectations  $\pi^e$ , the reason why the economy has fallen into a liquidity trap is the negative natural interest rate  $r^n$ . Essentially, this line of argument is same as Krugman's (1998).

However, just like in the case of inflation expectations, whether the natural rate of interest, which is unobservable, has become negative is a matter of debate. Figure 11 shows various measures of potential growth, which are assumed to be linked with the natural rate of the interest rate. All of the measures of potential growth—be they based on a production function approach (BOJ), estimates from a model (Saito et al., 2012), a corporate survey (Corporate) or the forecasts of economists (Consensus Forecast)—point

Figure 11: Potential Growth



Note: “BOJ” refers to the potential growth rate estimated by the Research and Statistics Department, Bank of Japan (Hara et al., 2006), while “Saito et al. (2012)” refers to the potential growth rate estimated based on their DSGE model. “Corporate (3 yrs)” refers to the outlook for the 3 years ahead real demand growth rate for industry in the Annual Survey of Corporate Behavior (Cabinet Office). Finally, “Consensus Forecast (6-10 yrs)” refers to the Consensus Forecast for the average real GDP growth rate for the next 6 to 10 years.

to a decline in the potential growth rate, but none of them show a negative potential growth rate except for a short interval around the Lehman crisis. Furthermore, in their analysis of historical decompositions of the inflation rate, Saito et al. (2012) show the effects of the zero lower bound of the nominal interest rate on inflation are rather small, as long as these effects are captured by negative monetary policy shocks.<sup>7</sup>

Another strand of explanations sees a link between lower (but not necessarily negative) potential growth and the deterioration in the output gap via growth expectations. Saito et al. (2012) argue that weaker growth expectations have squeezed demand more than supply. The key question is whether permanent or transitory negative shocks on productivity have lowered potential growth. In the case of permanent shocks, a “pre-

<sup>7</sup>As seen in footnote 5, the DSGE model of Saito et al. (2012) does not explicitly model the zero lower bound and thus estimated monetary policy shocks are assumed to capture the effects of the zero lower bound.

emptive” reaction of the demand side to a future decline in supply potential may reduce demand heavily and thus lead to deterioration in the output gap. On the other hand, in the case of transitory shocks, consumption smoothing may lead to a limited reaction on the demand side and thus improve the output gap. Saito et al. (2012) show, in line with this kind of reasoning, a permanent negative shock to productivity drags down inflation, while a transitory shock lifts inflation (Figure 12).<sup>8</sup>

Moreover, they also explore the theoretical possibility that prices become weaker if, for some reasons (lack of innovative entrepreneurs, government regulation, etc.), the supply side of the economy cannot fully respond to a change in the demand structure. For instance, it is widely assumed that population aging leads to changes in the demand structure, such as greater demand for health care and less demand for, say, automobiles. If the quantity and price of health care services are heavily regulated and cannot accommodate the growing demand of the elderly, then general prices may decline, as the elderly may save their money instead of purchasing automobiles in the expectation that health care services will be provided in the future. Another study that examines the impacts of population aging on inflation through changes in the demand structure is that by Katagiri (2012) who uses a multi-sector DSGE model with search friction. Meanwhile, Kimura et al. (2010), while not treating the output gap explicitly, argue that a decline in the natural rate of interest may reduce private expenditure, because an increase in the present discount value of government debt may reduce private expenditure.

Yet another strand of explanations focuses on the financial side. Given that Japan’s growing government debt has been financed by banks which have increased their purchases of Japanese Government Bonds (JGBs) (Figure 13), the question naturally arises whether there is any relationship between the behavior of banks and the output gap. Aoki and Sudo (2012) construct another DSGE model, in which the Value-at-Risk (VaR) constraint leads banks to accumulate large amount of JGBs instead of financing private investment (a crowding-out-like phenomenon).<sup>9</sup> They show that this worsens the output gap and thus puts downward pressures on prices (upper panels of Figure 14). They also demonstrate

<sup>8</sup>Just like the FRB/EDO model, Saito et al. (2012) construct a two-sector model, in which both permanent and transitory shocks are embedded in production functions of both sectors such as:

$$X_t^c = [K_t^{u,c}]^\alpha [(A_t^m Z_t^m) L_t^c]^{1-\alpha},$$

$$X_t^k = [K_t^{u,k}]^\alpha [(A_t^m Z_t^m)(A_t^k Z_t^k) L_t^k]^{1-\alpha},$$

where  $X_t$  is output,  $K_t^u$  is the effective capital input, and  $L_t$  is the labor input in consumption-goods-producing sector  $c$  and investment-goods-producing sector  $k$ .  $A_t^n$  and  $Z_t^n$  are technology shocks, with the former stationary in levels and the latter stationary in growth rates:

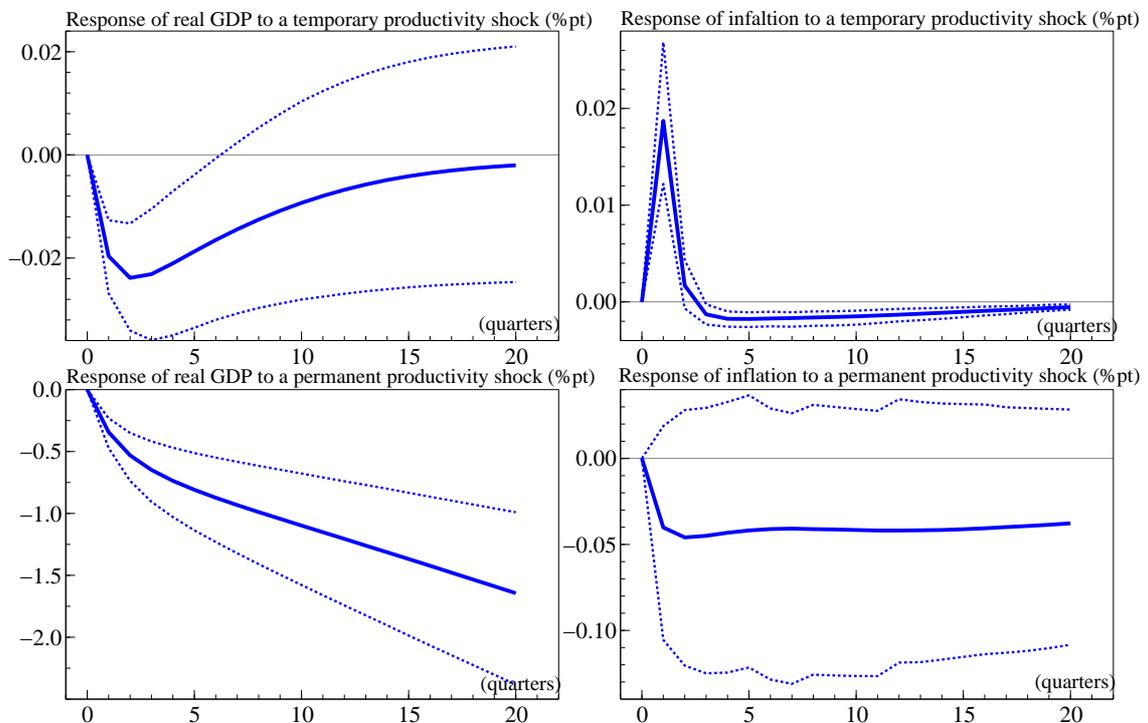
$$\ln A_t^n = \ln A_*^n + \varepsilon_t^{a,n}, \quad n \in m, k$$

$$\ln Z_t^n - \ln Z_{t-1}^n = (1 - \rho^{z,n}) \ln \Gamma_*^n + \rho^{z,n} (\ln Z_{t-1}^n - \ln Z_{t-2}^n) + \varepsilon_t^{z,n},$$

where superscript  $m$  indicates economy-wide and  $k$  the investment-goods-producing sector.  $A_*^n$  and  $\Gamma_*^n$  are the constant technology level and the constant growth rate, respectively.  $\varepsilon_t^{a,n}$  and  $\varepsilon_t^{z,n}$  correspond to transitory and permanent shocks. See Fueki et al. (2010) for more details.

<sup>9</sup>Following Adrian and Shin (2010), they model the VaR constraint as the non-negative return on

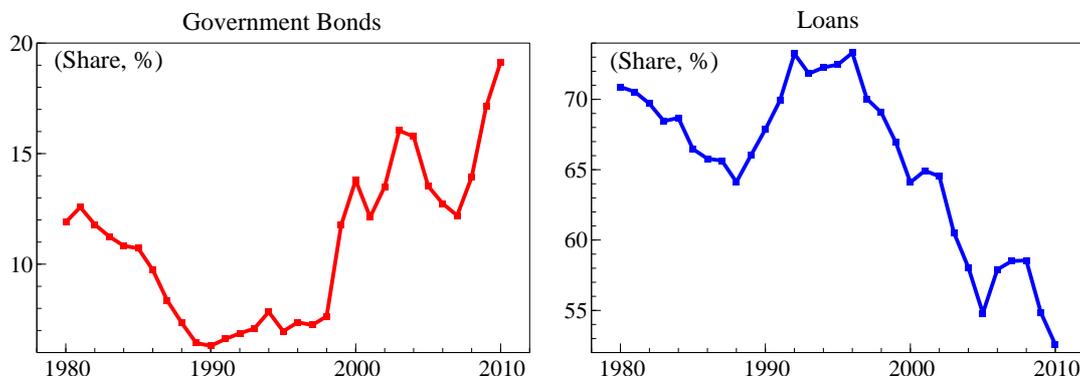
Figure 12: Effects of Temporary and Permanent Productivity Shocks



Note: Reactions to a negative one standard error shock to economy-wide productivity. The dotted lines show the 90% confidence interval.

Source: Saito et al. (2012).

Figure 13: Banks' Portfolio



Source: Aoki and Sudo (2012).

that a decline in the potential growth rate due to a negative permanent productivity shock tightens the VaR constraint and thus puts downward pressure on inflation (lower panels of Figure 14).<sup>10</sup>

### 3.3 Related issues

If, as suggested above, the lower natural rate of interest or lower potential growth is responsible for the prolonged negative output gap, the next question that arises is why Japan's growth potential has declined. Including Hayashi and Prescott's (2002) seminal study of Japan's 'lost decade,' there is an extensive literature on this issue, which it is beyond the scope of this paper to examine. At the conference, like Shirakawa (2012b), Watanabe (2012) and Ueda (concluding remarks) suggest that the malfunction of financial intermediaries after the collapse of the asset price bubble as well as the demographic trends of population aging and decline (Figure 15) may have played a role. Recently, Nishimura

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bank's net portfolio at the time of the worst outcome:

$$\underline{r}_{k,t+1}k_t(i) + \underline{r}_{b,t+1}b_t(i) - r_{d,t}d_t(i) \geq 0,$$

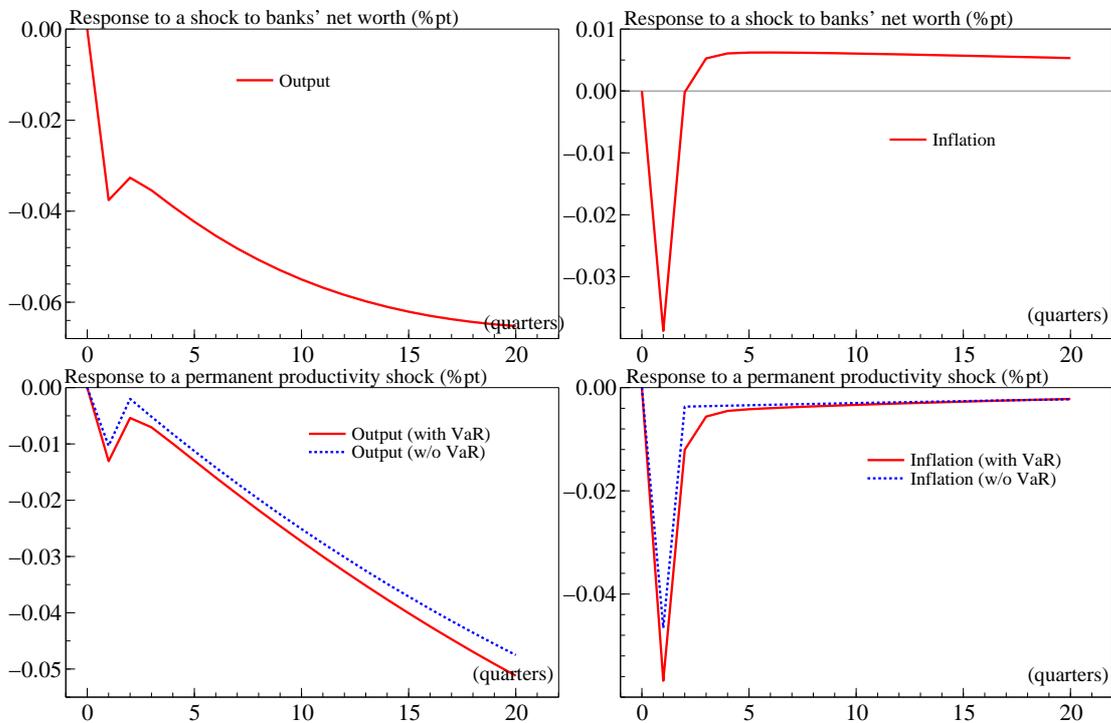
where  $k_t(i)$ ,  $b_t(i)$  and  $d_t(i)$  are capital stock (which banks own through their loans), government bonds and deposits on bank  $i$ 's balance sheet.  $\underline{r}_{k,t+1}$  and  $\underline{r}_{b,t+1}$  are the worst return on  $k_t(i)$  and  $b_t(i)$  respectively, which are assumed to follow certain stochastic processes.  $r_{d,t}$  is the predetermined interest rate on bank deposits. The constraint results in the spread

$$r_k - r_b = \frac{1 - \gamma r_d}{\gamma r_d} (\underline{r}_b - \underline{r}_k),$$

where  $\gamma$  is the survival probability of the bank. The impulse responses to a shock to bank capital can be expressed by a decline in  $\gamma$ .

<sup>10</sup>The impulse responses of inflation in Figure 14 dissipate more quickly than those in Figure 12. This may be primarily because Aoki and Sudo (2012) did not incorporate inflation indexation in their model.

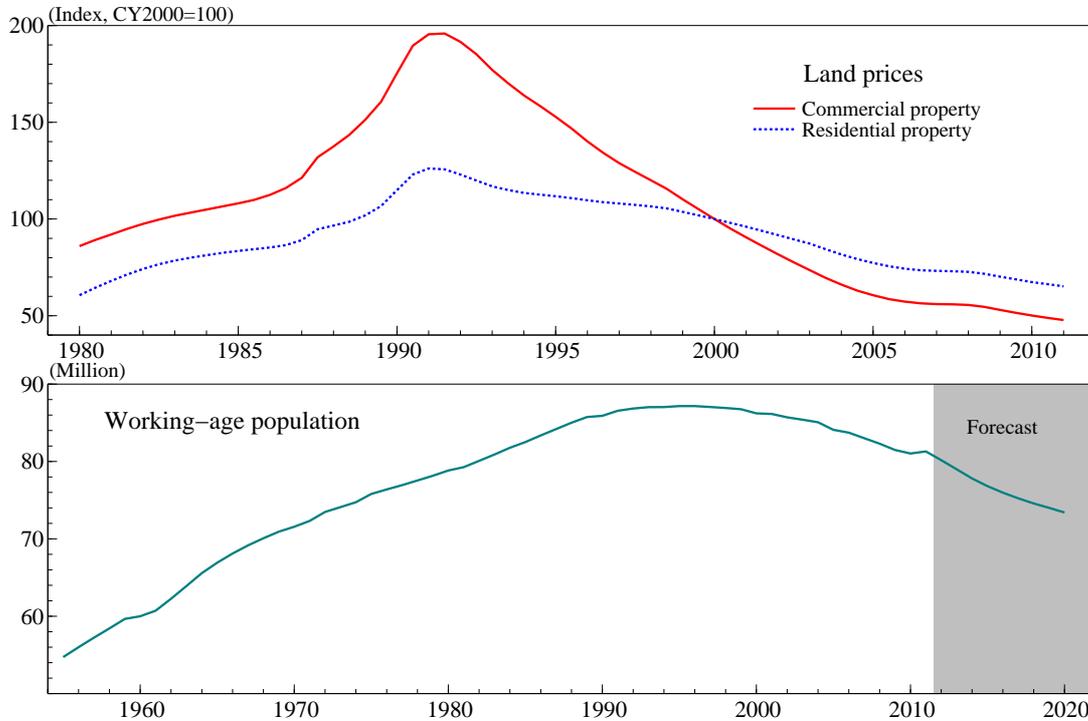
Figure 14: Effects of the VaR Constraint



Note: Reactions to a negative one standard error shock to banks' net worth and permanent productivity.

Source: Aoki and Sudo (2012).

Figure 15: Asset Prices and Demography

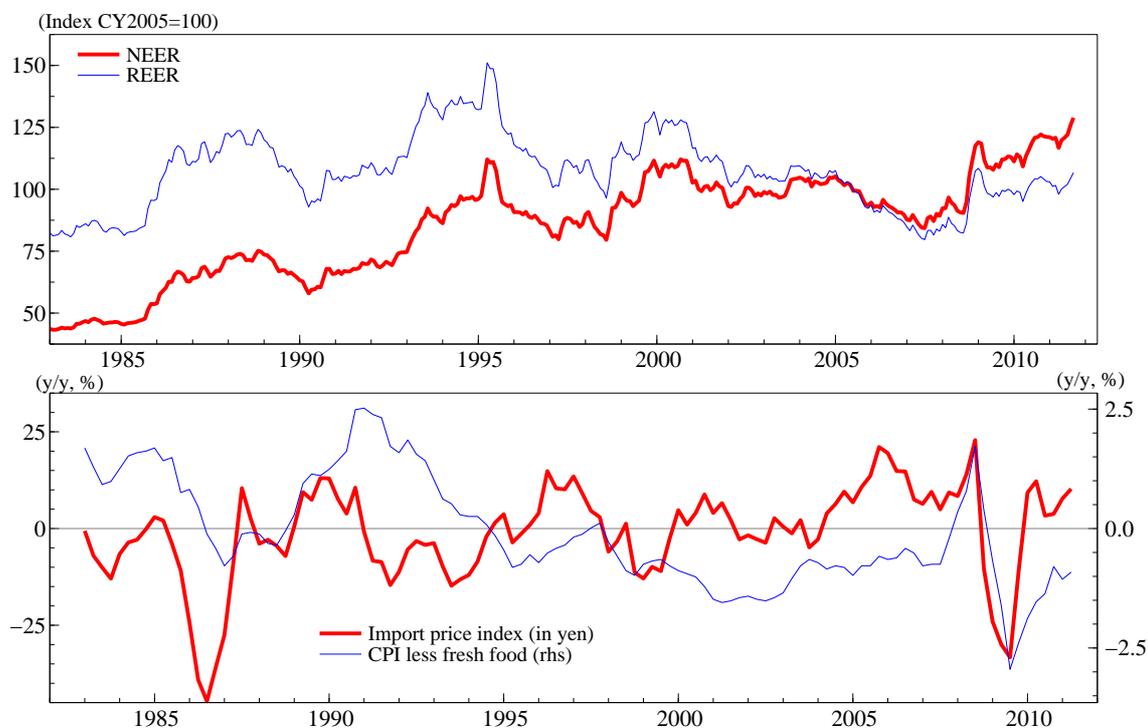


Sources: Japan Real Estate Institute, Ministry of Health, Labour and Welfare.

(2011) has highlighted the link between these two factors using an overlapping generations model in which demographic aging and decline trigger a drop in asset prices and thus lead to a distortion in financial intermediation. On the other hand, Ikeda and Saito (2012) have constructed a DSGE model in which a decline in the working-age population lowers the real interest rate and that effect is amplified by a fall in land prices in the presence of collateral constraints.

Another separate issue is why the slope of the Phillips curve has become flatter, as seen in Figure 5. Again, an extensive literature has developed in the context of the Great Moderation. Potential explanations of the flattening of the Phillips curve in Japan that have been advanced include, among others, that the impact of the global output gap on Japan's inflation has increased as a result of globalization (Borio and Filardo, 2007), or the strategic complementarity in firms' price-setting behavior plays a role (Watanabe, 2012).

Figure 16: Exchange Rates and Import Prices



Sources: Bank for International Settlements, Bank of Japan, Ministry of Internal Affairs and Communications.

### 3.4 Other Factors

In an open economy setting, external factors are added to a Phillips curve such as the one represented by equation (1). For instance, since Japan heavily relies on imports of natural resources, commodity prices are frequently added to the equation. However, given the developments in the energy components shown in Table 1, developments in commodity prices, including energy, cannot explain the chronic deflation in Japan. Import prices, which largely reflect developments in commodity prices, have shown a number of ups and downs, which is in contrast with the prolonged and steady decline in consumer prices (lower panel of Figure 16). For this reason, below, we will focus on other external factors, namely the exchange rate and domestic-foreign price differences.

#### 3.4.1 Does the appreciation of the yen matter?

Over the past few decades, the yen's nominal effective exchange rate (NEER) has appreciated as a trend (upper panel of Figure 16). At the same time, although evidence is still mixed, the pass-through of changes in the exchange rate may have declined, as, for

example Otani et al. (2003) suggest. If this is indeed the case, then, at least superficially, it might seem rather difficult to argue that the appreciation of the yen has played a significant role in deflation in Japan. However, Fukuda (a panel discussant) suggests that if the equilibrium mark-up diminished along with the declining pass-through, this would lead to lower prices domestically.

There are other arguments that suggest that the appreciation of the yen matters. For instance, Watanabe (2012) demonstrates theoretically that, as argued by McKinnon and Ohno (2001), once expectations of yen appreciation are firmly embedded among the public, Japan may fall into a liquidity trap in the presence of the zero lower bound on the nominal interest rate. Heuristically, if uncovered interest rate parity holds, i.e.,  $i = i^* + \Delta d$ , where  $i^*$  is the short-term nominal interest rate in a foreign country and  $\Delta d$  is the expected rate of depreciation,  $i$  may be subject to the zero lower bound and the economy may hence fall into a liquidity trap, when  $\Delta d < 0$  (i.e., when the yen appreciates). Furthermore, as will be discussed below, Iwasaki et al. (2012) show that the less flexible exchange rate regime of the Chinese renminbi has the effect of amplifying downward pressure of Chinese productivity shocks on Japanese inflation.

### 3.4.2 Do domestic-foreign price differences matter?

As seen in Table 5, in the 1990s, wide differences between domestic and foreign prices were a matter of concern for both policy makers and the public. The 1990s were indeed a period in which prices in Japan were considerably higher than those in other major advanced economies (upper panels of Figure 17). However, the difference declined substantially in the 2000s. Similar observations can be made with regard to GDP per capita (lower panels of Figure 17).<sup>11</sup> As highlighted by Maeda (a panel discussant), Japan deregulated in a wide range of areas during the late 1990s and early 2000s including zoning laws for large retailers, which may have contributed to slashing domestic-foreign price differences by reducing margins and/or improving productivity in the distribution chain.<sup>12</sup>

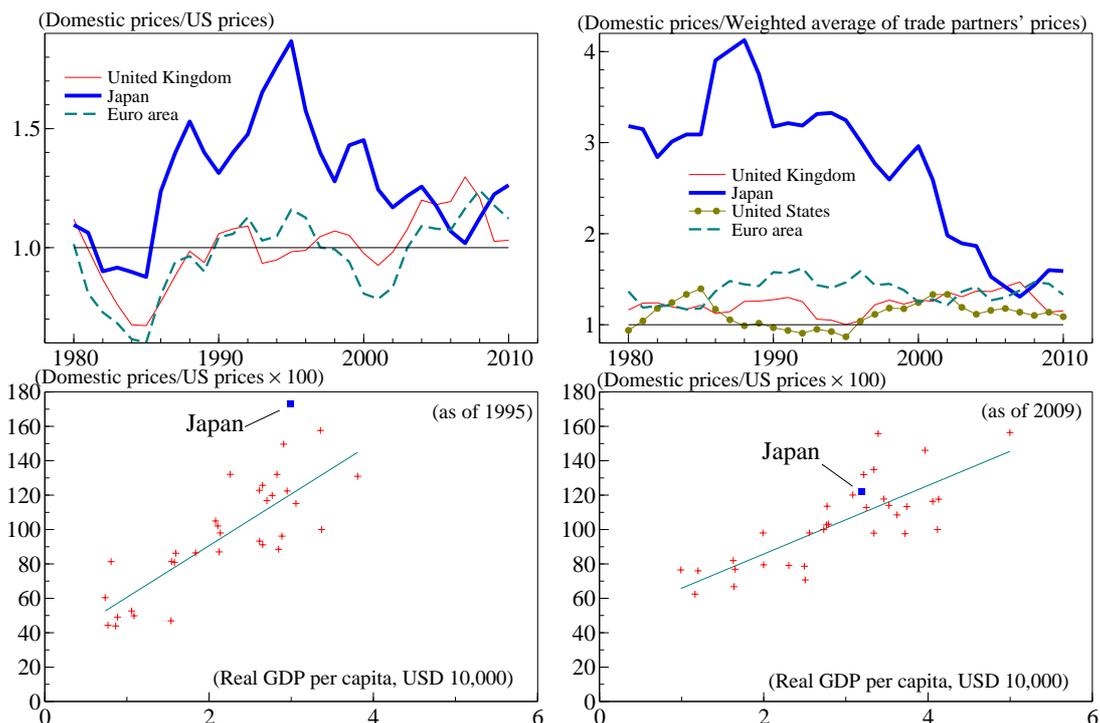
Supply shocks in emerging economies may also matter. Although supply shocks, as Sekine (2009) suggests, have affected inflation not only in Japan but also in other industrial economies, the impact may have been more pronounced in Japan as a result of the close trade links with the dynamic emerging economies of Asia, particularly China. Using industrial panel data, Iwasaki et al. (2012), for instance, find that the impact of a higher share of imports from emerging economies, which can be regarded as a proxy of productivity shocks in these economies, is greater in Japan than in the United States and Europe (Table 6). Furthermore, they construct a three-sector, three-country DSGE model (consisting of a tradable final goods, a tradable intermediate goods, and a non-tradable goods

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<sup>11</sup>The positive correlation between price levels and real GDP per capita is often taken as evidence of the Balassa-Samuelson effect.

<sup>12</sup>An effect of narrower margins can be captured by a markup shock in the New Keynesian Phillips Curve estimated by Saito et al. (2012). It might be possible to obtain more direct evidence for a change in margins using firm-level data, as demonstrated by Ariga et al. (1999). Unfortunately, there are no studies that have pursued this avenue of research in recent years.

Figure 17: Deviation from Purchasing Power Parity (PPP)



Note: Figures in upper panels are domestic-foreign price differences calculated as  $P/P^*e$ , where  $P$  is domestic prices,  $P^*$  is foreign prices and  $e$  is the market exchange rates. In the left-hand side,  $P^*$  is US prices and  $e$  is the bilateral exchange rates against the US dollar, whereas in the right-hand side  $P^*$  is prices of major trade partners and  $e$  is the nominal effective exchange rates. In the left-hand side,  $P/P^*$  is obtained from the PPP exchange rate in the IMF World Economic Outlook database and  $e$  from Bloomberg. In the right-hand side,  $e$  is obtained from the BIS nominal effective exchange rates (narrow base comprising 27 economies) and  $P/P^*$  are calculated by the authors using the above bilateral PPP exchange rate and the weights of the BIS NEERs. Lower panels are scatter diagrams of OECD countries (less Luxembourg). Real GDP per capita is based on the PPP exchange rates.

Sources: Bank for International Settlements, International Monetary Fund, Bloomberg, Penn World Table 7.0.

sector with the countries corresponding to Japan, China, and the United States) which incorporates the features that (i) Japan heavily exports intermediate goods to China in exchange for final goods; (ii) Japan-China trade links are stronger than Japan-US and US-China trade links; (iii) intermediate goods are less substitutable than final goods; and (iv) the Chinese renmenbi is fixed to the US dollar.<sup>13</sup> Their impulse response analysis of a rise in Chinese productivity in the tradable final goods sector shows that Japanese inflation falls more than US inflation (Figure 18). This is because, given the strong trade links, Japan imports more low-cost final goods from China than the United States. Despite an increase in imports from China, Japan's trade balance is less deteriorated than that of the United States, since more final goods production in China leads to higher demand for Japanese intermediate goods. The model suggests that this results in an appreciation of the yen vis-à-vis the US dollar, which puts additional downward pressure on Japanese inflation. This deflationary impact could be mitigated if China were to adopt a more flexible exchange rate regime.

## 4 Conclusion

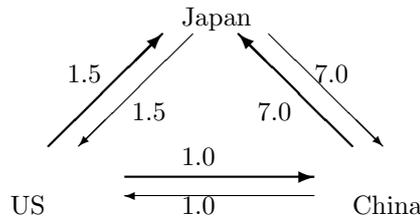
In November 2011, the Bank of Japan, together with the University of Tokyo, held a one-day conference to take stock of researches on the chronic deflation which has gripped

<sup>13</sup>The trade structure in the model is largely determined by aggregate intermediate goods  $T_{1,t}(h_2^J)$  and final goods  $T_{2,t}(j^J)$  for a final goods producer  $h_2^J$ , and a household  $j^J$  (superscript  $J$  stands for Japan), where aggregation takes place such that:

$$T_{1,t}(h_2^J) = \left[ (\mu_J^J)^{\frac{1}{\phi_1^J}} Q_{1,t}^J(h_2^J)^{1-\frac{1}{\phi_1^J}} + (\mu_U^J)^{\frac{1}{\phi_1^J}} M_{1,t}^U(h_2^J)^{1-\frac{1}{\phi_1^J}} + (\mu_C^J)^{\frac{1}{\phi_1^J}} M_{1,t}^C(h_2^J)^{1-\frac{1}{\phi_1^J}} \right]^{\frac{\phi_1^J}{\phi_1^J-1}},$$

$$T_{2,t}(j^J) = \left[ (\nu_J^J)^{\frac{1}{\phi_2^J}} Q_{2,t}^J(j^J)^{1-\frac{1}{\phi_2^J}} + (\nu_U^J)^{\frac{1}{\phi_2^J}} M_{2,t}^U(j^J)^{1-\frac{1}{\phi_2^J}} + (\nu_C^J)^{\frac{1}{\phi_2^J}} M_{2,t}^C(j^J)^{1-\frac{1}{\phi_2^J}} \right]^{\frac{\phi_2^J}{\phi_2^J-1}}.$$

Here,  $Q_{1,t}^J(h_2^J)$  and  $Q_{2,t}^J(j^J)$  are intermediate goods and final goods made by domestic producers, and  $M_{1,t}^i(h_2^J)$  and  $M_{2,t}^i(j^J)$  are those imported from the United States ( $i = U$ ) and China ( $i = C$ ). Similar equations are defined for the United States and China. Iwasaki et al. (2012) set the elasticities of substitution such that  $\phi_1^i < \phi_2^i$  ( $i \in J, U, C$ ) to express (iii). Furthermore, they adjust shares  $\mu_i^J$  and  $\nu_i^J$  to capture (i) and (ii). More specifically, they assume the following trade balances in a steady-state and adjust parameters to replicate them.



The figures are in terms of percent of GDP. They are provided here for an illustrative purposes only and do not exactly match those in their model. Thin lines represent trade flows in intermediate goods, while thick lines represent those in final goods.

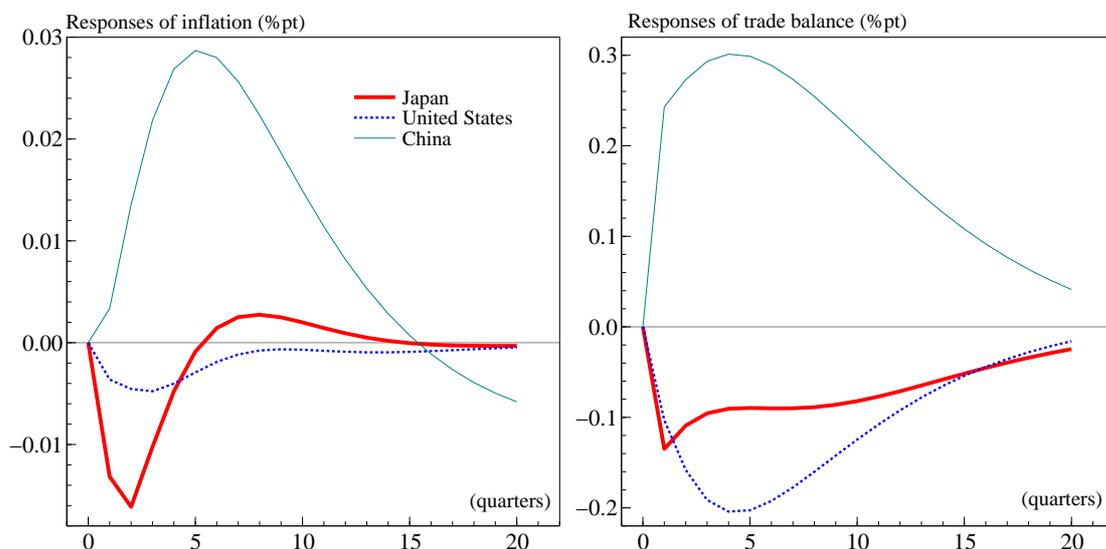
Table 6: Impact of Import Competition from Emerging Market Economies

	Japan	US	Europe
Import share	-4.689*	-2.352**	-3.531**
	(2.524)	(0.515)	(0.964)
Sample periods	1989-2007	1997-2006	1995-2008
Number of observations	988	2,702	7,010
Number of sectors	52	325	618

Note: Figures in parentheses are standard errors. \* and \*\* denote significance at the 5% and 1% confidence levels, respectively. Dependent variables are inflation measured by the producer price index (domestic corporate goods price index in the case of Japan). Industrial panel regressions using the growth rates of manufacturing outputs in the EMEs multiplied by a sector's (average) labor intensity as instrument variables. Fixed and time effects are controlled for. Results of the United States and Europe are from Auer and Fischer (2010) and Auer et al. (2010).

Sources: Iwasaki et al. (2012), Auer and Fischer (2010), Auer et al. (2010).

Figure 18: Supply Shocks from China



Note: Reactions to a positive productivity shock in China's tradable final goods sector.

Source: Iwasaki et al. (2012).

Japan since the latter half of the 1990s. The present paper represents an attempt to synthesize the studies presented at the conference by considering the various hypotheses put forward to explain this period of prolonged deflation. Specifically, causes that have been proposed include the zero-lower bound on the nominal interest rate; public attitudes ('norm') toward the price level; central bank communication; weaker growth expectations coupled with declining potential growth or the lower natural rate of interest; risk averse banking behaviors; deregulation in the distribution chain; and the rise of emerging economies.

In fact, some of these potential causes were already alluded to at the time of workshops held by the Bank of Japan in 2001. For instance, the idea that Japan had fallen into a liquidity trap was widely discussed in the literature at the time. This does not mean, however, that the conference in 2011 had little new to add. On the contrary, the studies that were presented provided important new insights that benefited from the accumulation of data over the past decade as well as advances in economics. The fact that Japan did not experience a severe acceleration of deflation (i.e., deflationary spiral) despite the large negative output gap seems to support the hypothesis that Japan has been stuck at a deflationary equilibrium due to a liquidity trap, the reason for which—such as negative inflation expectations, a negative natural interest rate, or expectations of the appreciation of the yen—however, are not fully understood. At the same time, the accumulated data over the years suggest that the fiscal multiplier does not appear to have increased as theory would lead one to expect. This has led researchers to look for alternative explanations as demonstrated by the papers submitted to the conference. Similarly, researchers at the conference benefited from advances in DSGE modeling techniques, which lead to a better understanding of inflation expectations, of the link between the output gap and the potential growth rate (the decline in which had become clearer during the decade), and of issues related with globalization.

The conference leaves a long list of hypotheses. At this stage of investigation, it is still difficult to single out one specific or dominant explanation for Japan's prolonged period of deflation and it may well be the case that it is the result of a combination of factors. We hope that further researches will shed more light on the issue. At the same time, as highlighted by Miyao et al. (2008), it may be necessary to revisit another issue associated with chronic deflation, namely its costs, which were not fully addressed by this conference. In any case, a better understanding of the causes of chronic deflation is important not only for curing Japan's ailing economy, but also for preventing other countries from suffering a similar fate.

# Appendix 1: Estimation of the Phillips Curve and Trend Inflation

This appendix presents details of the procedures for estimating the Phillips curve with time-varying parameters and trend inflation. It also touches upon the historical decomposition of inflation dynamics.

## Time-Varying Parameter Phillips Curve

The New Keynesian model as the standard framework for monetary policy analysis typically specifies inflation dynamics using the following equation, which is called a hybrid New Keynesian Phillips curve (NKPC):

$$\pi_t = \rho\pi_{t-1} + \zeta Gap_t + bE_t\pi_{t+1} + u_t, \quad (3)$$

where  $\pi_t$  is the rate of inflation in period  $t$ ;  $Gap_t$  is the output gap, which is used as a proxy variable for marginal costs;  $E_t\pi_{t+1}$  is one-period ahead expected inflation, where  $E_t$  is an expectation operator; and  $u_t$  represents shocks or other factors that are not captured by the explanatory variables. These are assumed to include effects from changes in import costs and mark-ups, etc.

Equation (3) assumes that trend inflation is zero or some constant value. Cogley and Sbordone (2008) relax this assumption and derive the following equation.<sup>14</sup>

$$\begin{aligned} (\pi_t - \bar{\pi}_t) &= \tilde{\rho}_t(\pi_{t-1} - \bar{\pi}_t) + \zeta_t Gap_t + b_{1t}\tilde{E}_t(\pi_{t+1} - \bar{\pi}_t) \\ &+ b_{2t}\tilde{E}_t \sum_{j=2}^{\infty} \varphi_{1t}^{j-1}(\pi_{t+j} - \bar{\pi}_t) + u_t, \end{aligned} \quad (4)$$

Equation (4) differs from (3) in two respects: first, equation (4) includes additional explanatory variables such as trend inflation  $\bar{\pi}_t$  and higher-order inflation expectations  $\tilde{E}_t \sum_{j=2}^{\infty} \varphi_{1t}^{j-1}(\pi_{t+j} - \bar{\pi}_t)$ ; second, as indicated by the subscripts on the parameters on lagged inflation and the output gap, the parameters are not invariant over time. In fact, Cogley and Sbordone (2008) show that there is a relationship between each parameter and trend inflation such that higher trend inflation implies a lower weight on the current output gap and a greater weight on expected future inflation.

## Estimating the time-varying Phillips curve

Estimation of a time-varying parameter NKPC involves two steps. In the first step, a reduced-form VAR is estimated. In the next step, the parameters of the NKPC are

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<sup>14</sup>The original equation derived by Cogley and Sbordone (2008) includes additional terms such as the expectations of the discount factor and real output growth. We omit these terms because preliminary estimation indicates that their contributions are negligible. In fact, Cogley and Sbordone (2008) themselves, using U.S. data, find that excluding these terms has little impact on the estimation results.

obtained by matching the conditional expectations generated from the VAR and the NKPC.

Step 1: Estimating the reduced-form VAR

To begin with, a reduced-form VAR with time-varying parameters and stochastic volatility is estimated using the following specification:<sup>15</sup>

$$x_t = X_t' \Theta_t + \epsilon_{xt},$$

where  $x_t$  is a vector of endogenous variables  $X_t' = I \otimes [1 \ x_{t-l}']$ ;  $x_{t-l}$  represents lagged values of  $x_t$ , where the maximum lag is set to two; and  $\Theta_t$  is a vector of time-varying parameters.

Endogenous variables are the inflation rate  $\pi_t$  measured in terms of CPI less fresh food and adjusted to exclude the effects of changes in the consumption tax rate and subsidies for high school tuition, and the output gap  $Gap_t$  estimated by the Research and Statistics Department, Bank of Japan.<sup>16</sup> The data sample covers the period 1980Q1-2010Q4 and the data up to 1985Q4 are used as a training sample for initializing the prior. In order to estimate trend inflation effectively, we extend Cogley and Sbordone's approach by including inflation expectations from the survey (expected rate of inflation for six to ten years ahead, published in the Consensus Forecasts).<sup>17</sup>

Time-varying parameter  $\Theta_t$  and VAR innovations  $\epsilon_{xt}$  follow a random walk process and a geometric random walk process respectively,

$$\begin{aligned} \Theta_t &= \Theta_{t-1} + v_t, \\ \epsilon_{xt} &= V_t^{1/2} \xi_t, \\ V_t &= B^{-1} H_t B^{-1}, \\ \ln h_{it} &= \ln h_{it-1} + \sigma_i \eta_{it}. \end{aligned}$$

where  $H_t$  is a diagonal matrix with elements  $h_{it}$ ,  $B$  is a lower triangular matrix, and  $v_t$ ,  $\xi_t$ , and  $\eta_t$  follow a standard normal distribution.  $B$  and  $\sigma_i$  are estimated.

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<sup>15</sup>The estimation is based on an MCMC algorithm using the hyper-parameter of Cogley and Sbordone (2008).

<sup>16</sup>As a proxy variable for marginal costs, Cogley and Sbordone (2008) use the labor share of national income instead of the output gap.

<sup>17</sup>To be more precise, we add an observation equation with a measurement error term to the above reduced-form VAR.

Step 2: Matching the expectation formation processes

Next, we will match the expectation formation process of the reduce-form VAR with that of the NKPC. The reduced-form VAR can be rewritten as

$$z_t = \mu_t + A_t z_{t-1} + \epsilon_{zt}, \quad (5)$$

where  $z_t = (x_t, x_{t-1}, \dots, x_{t-p+1})'$ . Then, the conditional expectations of inflation measured by the deviations from trend inflation can be expressed as

$$\tilde{E}(\hat{\pi}_t | \hat{z}_{t-1}) = e'_\pi A_t \hat{z}_{t-1},$$

where  $e_k$  is a selection vector picking up variable  $k$ , and  $\hat{z}_t = z_t - (I - A_t)^{-1} \mu_t$ . The conditional expectation of inflation derived from the time-varying parameter NKPC is

$$\tilde{E}(\hat{\pi}_t | \hat{z}_{t-1}) = \tilde{\rho} e'_\pi \hat{z}_{t-1} + \xi e'_{Gap} A_t \hat{z}_{t-1} + b_1 e'_\pi A_t^2 \hat{z}_{t-1} + b_2 e'_\pi (I - \varphi_1 A_t)^{-1} A_t^3 \hat{z}_{t-1}.$$

This implies

$$e'_\pi A_t = \tilde{\rho} e'_\pi I + \xi e'_{Gap} A_t + b_1 e'_\pi A_t^2 + b_2 e'_\pi (I - \varphi_1 A_t)^{-1} A_t^3 \equiv g(\mu_t, A_t, \psi),$$

where  $\psi$  represents the parameters of the Calvo model  $(\alpha, \rho, \theta)$ , where  $\alpha$  is the fraction of sticky-price firms,  $\rho$  is the degree of indexation, and  $\theta$  is the elasticity of substitution among differentiated goods. We obtain these parameter values by minimizing the square of  $e'_\pi A_t - g(\mu_t, A_t, \psi)$  given  $\mu_t$  and  $A_t$  of the reduced-form VAR (5).

## Historical Decomposition of Inflation Dynamics

The historical decomposition of inflation in Table 3 is conducted by using the following equation, which is obtained by solving equation (4) forward:<sup>18</sup>

$$\pi_t = (1 - \tilde{\rho}_t) \bar{\pi}_t + \tilde{\rho}_t \pi_{t-1} + \tilde{E}_t \sum_{j=0}^{\infty} \varphi_{1t}^j \zeta_t Gap_{t+j} + u_t.$$

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<sup>18</sup>Since estimates of  $b_{2t}$  are de-minimis,  $\tilde{E}_t \sum_{j=2}^{\infty} \varphi_{1t}^{j-1} (\pi_t - \bar{p}_t)$  is ignored here.

## Appendix 2: Conference Program

### PRICE DEVELOPMENTS IN JAPAN AND THEIR BACKGROUNDS: EXPERIENCES SINCE THE 1990S

4th Joint Conference by the Center for Advanced Research in Finance of the  
University of Tokyo and the Research and Statistics Department of the Bank of Japan

(November 24, 2011, Bank of Japan)

- 9:00 Opening Remarks **Eiji Maeda**, Bank of Japan
- 9:05 Opening Session  
*Backgrounds of Price Developments in Japan: Facts and Issues*  
Presenter **Kenji Nishizaki**, Bank of Japan
- 9:50 Session 1  
Chairperson **Ryuzo Miyao**, Bank of Japan
- Long-Lasting Deflation under the Zero Interest Rate Environment*  
Presenter **Tsutomu Watanabe**, Tokyo University  
Discussant **Kenn Ariga**, Kyoto University
- Structural Problems and Price Dynamics in Japan*  
Presenters **Ichiro Fukunaga**, Bank of Japan  
**Masashi Saito**, Bank of Japan  
Discussant **Yasushi Iwamoto**, Tokyo University
- 12:00 Lunch
- 13:30 Session 2  
Chairperson **Yuzo Honda**, Kansai University
- Impacts of Supply Shocks from Emerging Economies*  
Presenters **Masahiro Kawai**, Asian Development Bank  
**Naohisa Hirakata**, Bank of Japan  
Discussant **Yoichi Matsubayashi**, Kobe University
- Asset Portfolio Choice of Banks and Inflation Dynamics*  
Presenters **Kosuke Aoki**, Tokyo University  
**Nao Sudo**, Bank of Japan  
Discussant **Yosuke Takeda**, Sophia University
- 15:30 Coffee Break

- 15:45 Panel Discussion  
Moderator **Kiyohiko G. Nishimura**, Bank of Japan  
Panelists **Takatoshi Ito**, Tokyo University  
**Toshiki Jinushi**, Kobe University  
**Shin-ichi Fukuda**, Tokyo University  
**Eiji Maeda**, Bank of Japan
- 17:45 Concluding Remarks **Kazuo Ueda**, Tokyo University
- 18:00 Adjournment

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