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Why is the forecast error of quarterly GDP in Japan so large? – From an international comparison of quarterly GDP forecast situation

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ABSTRACT

We examined the accuracy of prediction of Canada, Japan, United Kingdom, and United States from the viewpoint of forecast errors. Compared with the forecast error of each country at the around same time, the forecast error of Japan is about 2 times larger. In case of Japan, even immediately before release of quarterly GDP, the forecast error is over 1 %, which is the same level of forecast error as 94 days before in the United States and 135 days before in Canada.

Evaluating the characteristics of forecast errors, it can be pointed out that Japan's forecasts are as efficient as those of other countries, and the addition of major economic statistics is unlikely to improve forecast errors. The reason for Japan's large forecast errors is the fluctuations in the GDP growth rate. These results provide evidence that volatile GDP may make the outlook worse.

Large fluctuations in Japan's quarterly GDP have already been pointed out. It is necessary to examine the factors behind the large fluctuations in the rate of change in Japan's quarterly GDP.

1. Introduction

Quarterly GDP is a statistic that can systematically grasp the economy of a country and counts as important data to make policy decisions. However, it has traditionally faced trade-off issues such as estimation accuracy and early publication. According to newspaper reports, there are reports of doubts regarding GDP accuracy when the first preliminary quarterly GDP significantly differs from the forecast in advance. In addition, in the case of the second preliminary quarterly GDP, if it is significantly revised from the preliminary quarterly GDP, there are reports of doubts about GDP. This situation, although observed especially in Japan, is not unique to Japan.

Regarding the estimation accuracy, research has been conducted on international comparison of the revision in ex-post of quarterly GDP and whether the revision in ex-post can be predicted. Previous studies have shown that Japan has a higher range of revisions among OECD countries (Ahmad et al. (2004) etc.). Using a real time database for macroeconomic variables including GDP, Faust et al. (2005) indicates that it is quite difficult to predict revisions. The large revisions also make it difficult to predict true GDP.

On the other hand, regarding the first preliminary, GDP is announced with a lag of approximately 30–50 days after the end of the target quarter. For this reason, there are many previous studies on models that predict quarterly GDP on time and improve prediction accuracy, including nowcast predictions methods. Regarding the accuracy of the prediction model, previous studies on the prediction accuracy of GDP in each country and performance comparison of the prediction model have been conducted. Although there are many previous studies on the accuracy of new prediction methods through comparative studies with conventional prediction methods, there are not many comparative studies on prediction accuracy between countries. For quarterly GDP forecasts, high forecast accuracy is considered essential, but if there is a significant difference in forecast accuracy in terms of international comparisons, the issues maybe specific to one particular country in the forecast situation.

In this paper, we will examine the uniqueness of the forecast situation in Japan's quarterly GDP by comparing the forecast error in other countries. After confirming whether the prediction enhances the prediction accuracy, the cause of "the forecast error is large even with the optimum prediction" is examined. In the next section we summarize previous studies on the accuracy of estimation and prediction on quarterly GDP. Chapter 3 organizes the data used in this paper and we show an international comparison of quarterly and annual GDP forecast errors in Chapter 4. Chapter 5 conducts empirical analysis on forecast accuracy and identifies factors that affect forecast errors in Japan. Finally, Chapter 6 concludes.

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2. Previous studies on the accuracy of quarterly GDP

2.1. Forecast accuracy and forecast formation

Predictors have an incentive to minimize forecast errors, assuming that users of predictions want accurate predictions. Based on this premise, there are many previous studies on estimation methods that improve the rationality of forecast formation and the accuracy of forecasts.

2.1.1. (Rationality of prediction formation using forecast survey)

Asako et al. (1989) used the annual GDP forecasts of 38 institutions to verify the homogeneity of forecasts in Japan. The results of an analysis using annual data from 1975 to 1987 showed that the predictions were homogenous among institutions, with a poor accuracy rate of 52.8 %. The rationality of predictions made by prediction agencies is denied. Ashiya (2002) examines the rationality of forecasts using annual GDP forecasts by 70 economists from 1980 to 1998 compiled by Toyo Keizai Inc. From the analysis results, it is pointed out that it is not a rational prediction. Ashiya (2007) analyzed the accuracy, efficiency and rationality of real GDP forecasts using Japanese government economic outlook from 1980 to 2002 and indicated that there was a significant upward bias in forecast, and that the government's economic outlook was optimistic.

Regarding the forecast accuracy of macroeconomic statistics other than GDP, Aggarwal and Mohanty (2000) examine whether the forecasts of Japan's macroeconomic statistics compiled by Money Market Services (MMS) are reasonably implemented without bias. They find that forecasts, except for industrial production, are rational using monthly economic indicators from 1988 to 1995. They point out that it is important to examine the effects of MMS macroeconomic forecasts because MMS affect asset prices. On the other hand, Fukuda and Soma (2019) use economic forecasts in actual policy evaluation using the ESP[1] Forecast for inflation forecasts collected by the Japan Center for Economic Research. They estimate the panel Phillips curve using level projections from 2010 to 2019 and show that central bank's inflation targeting can reduce uncertainty for future monetary policy actions only if inflation targeting is an achievable target.

2.1.2. (Improvement of prediction accuracy through examination of prediction methods)

To improve the prediction accuracy for quarterly GDP, nowcast prediction has been studied. GDP nowcast forecasts are published periodically from the New York Fed as Staff Nowcast and the Atlanta Federal Reserve Bank as "GDPNow" based on dynamic factor models using monthly statistics. In Japan, Urasawa (2014) and Hayashi and Tachi (2020) make quarterly GDP forecasts using a dynamic factor model. Urasawa (2014) finds that a single-index dynamic factor model using mixed-frequency data performs well on GDP in comparison to the consensus forecasts (forecast survey). This means nowcast prediction has the advantage of early assessment of ongoing economic activities in Japan. Maehashi and Shintani (2020) compared the Factor Model and Machine learning for monthly statistics forecast. Regarding models that increase the accuracy of monthly macroeconomic statistics forecasts such as industrial production and the consumer price index, they point out that the accuracy of forecasts using common factors extracted from principal components for machine learning is the highest.

There are many previous studies on prediction formation using annual data. Although it is possible to examine the accuracy and the forecast formation by annual data, it is difficult to analysis in detail the causes of forecasts errors. In particular, it is necessary to specify whether the cause of forecast errors is due to unexpected changes in the economic environment, the accuracy of economic statistics, or the forecasting ability of forecasters. This paper focuses on quarterly GDP projections mainly, also annual GDP projections.

2.2. Revision study and Real-Time database

Regarding quarterly GDP, previous studies have been conducted on the characteristics of revisions in the search for true GDP. Ahmad et al. (2004) show that Japan is by far the largest revision based on the results of past OECD revisions analysis studies, while the quarterly GDP revisions of other G7 countries are about the same in each country. Tachi (2007) points out that while Japan is in the category of larger revisions than other countries in the revision status of OECD countries, the introduction of new estimation methods may result in smaller revisions in Japan. However, Komaki (2022) indicates, an international comparison of quarterly GDP revisions using real-time data from 2000 to 2019, shows that Japan is about 2–3 times larger than US and UK on revision between first preliminary and second preliminary, and first preliminary and latest GDP.

As for whether such revisions in ex-post are predictable, Mankiw and Shapiro (1986) estimate the revisions that the preliminary quarterly GDP efficiently using the information available at the time of estimation. As a result, the US GDP is an efficient estimate, so the revision is unpredictable. In addition, Faust et al. (2005) analyzed the situation of each G7 country and pointed out that although it is difficult to predict the revision of the United States as in the previous research, Italy, Japan, and the United Kingdom may be predictable because quarterly GDP is not estimated efficiently. Similar to previous studies, Komaki (2020, 2022) shows that Japan's quarterly GDP is a noisy estimate.[2]

Macroeconomic data, including quarterly GDP, will be revised ex post. The data used when making policy decisions may be revised to show a deviation from the preliminary data. Under these circumstances, it has been recognized that the economic data and information used at time of decision-making should be prepared as real-time data. If the revision of macroeconomic data is predictable, it will be possible to make policy decisions in anticipation of the revision status of preliminary data. However, if the coverage of the statistics is not sufficient and the accuracy of the basic statistics is poor, it will be difficult to predict the revision. If it is difficult to predict the revision of the preliminary data, the policy decision based on the preliminary data is not optimal.

Orphanides (1997, 1998), which analyzed US monetary policy, was the first analysis using real-time data. Orphanides (1997, 1998) can explain the situation of monetary policy according to the Taylor rule using the revised data. However, using real-time data makes it possible to analyze that policy management was incorrect. On the other hand, for fiscal policy, the major issue is whether fiscal policy is restraining or amplifying against economic fluctuations. Cimadomo (2008) points out that although the revised data is amplifying, it becomes suppressive when analyzed with real-time data. Concerned about this situation, it is also necessary for each country to construct real-time data and appropriately evaluate policies.

2.3. Cases of problem in forecast errors

Regarding Japan's GDP, it was reported that "the reliability in statistics fluctuates, revisions in case of Japan, the largest in the G7" (Nikkei Shimbun, December 10, 2019). Furthermore, in the same article, "Japan's GDP has the largest fluctuation among the member countries," was commented by an executive of the OECD Statistics Department.

In addition to the above-mentioned reports, there have been frequent

[1] ESP Forecast is a monthly survey on the outlook of Japan's economy. Around 40 leading forecasters from private institutes in Japan participate in this survey.

[2] Sekino (2007) shows that the weight of news has been increasing in recent GDP due to changes in the estimation method.

Table 1
Examples of unexpected significant forecast error in Japan.

publication date	target	Head line of Newspaper	Forecast error (%)	Actual (%)	Forecast (%)
21-May-19	1Q 2019	Unexpected growth, 2.1% increase, sharp drop in imports	2.16	2.10	-0.06
14-Aug-19	2Q 2019	Why was it higher than the upper limit (1.7%) of forecasts	1.55	1.80	0.25
14-Nov-19	3Q 2019	Before tax increase, consumption growth is sluggish, 0.2% increase	-0.60	0.20	0.80
9-Dec-19		Significantly revised upward from 0.2% to 1.8%	-	1,80	-
10-Dec-19		the Reliability in statistics fluctuates, Revisions is the largest in the G7			

Notes: These articles are created by the author based on the Nikkei Telecom. Forecast data is JCER ESP Forecast (JP SPF).
Source: Japan Center for Economic Research "ESP Forecast", Nihon keizai Shimbun

Table 2
The reliability of GDP report in articles of Newspaper.

	matter	Number of articles
Basic statistics and estimation method of GDP	Gap between first and second estimation	11
	Questions about Basic statistics with insufficient economic conditions and Estimation methods	9
Gap between forecasts in advance and actual GDP	Gap with business sentiment and other economic indicators	10
	Gap with GDP forecast	3

Notes: The table is created from newspaper reports organized by factor regarding the content of articles on the reliability of GDP since 2000, with the keywords "trust", "credit", and "unexpected".
Source: Nihon keizai shimbun

reports doubting the reliability of GDP estimation in Japan. For example, according to the GDP announcement in 2019, an unexpected significant upward forecast error can be found (Table 1). In the preliminary GDP for 2019:1Q, negative growth (−0.06 %) was predicted. However, the actual growth was unexpectedly large (2.10 %). GDP growth for 2019:2Q was predicted to be 0.25 %, it was, in actual, 1.80 % that exceeded the upper of the forecast range. Conversely, the first GDP for 2019: 3 Q showed slightly lower growth (0.20 %) than expected (0.80 %). However, in the second estimation, it turned out to be a significant upward revision (1.80 %). This implied that there had been an unexpected revision of forecast for the third consecutive quarter.

Using the keywords "trust," "credit," and "unexpected," we collect the newspaper reports on the articles of the reliability of GDP since 2000. If we look at newspaper reports, we can classify the problems in the preliminary quarterly GDP into two problems: (1) Insufficient basic statistics and estimation methods for quarterly GDP, and (2) Large gaps between forecasts and actual quarterly GDP (Table 2).

We analysis whether this situation is unique to Japan. We examine the situation after the release of quarterly GDP using four words "unexpected," "doubtful," "unreliable" and "disappointed," in major countries since 2000 (Table 3). For the most part, I only found articles with the word "unexpected". On the other hand, I could not find any articles on the reliability of GDP.

According to comparison with Japan and other countries in Newspaper reports, the probable causes for this situation of large forecast error are as follows:

1. Low predictive ability
2. The predictor intentionally makes a wrong prediction
3. No matter how hard the forecaster tries, GDP cannot be predicted accurately
4. GDP does not reflect the true economic situation or GDP is moving differently from other economic indicators

In case of Japan, previous studies have pointed out that annual GDP forecasts may reflect the predictor's intentions. However, the forecasts based on quarterly GDP are often the policy judgment materials. In addition, if the forecast is predicted just before the announcement of GDP, it is considered that there is a strong incentive to make an accurate forecast. Based on previous studies, quarterly GDP forecasts require more accuracy than annual GDP forecasts. Therefore, in this paper, we assume that the forecaster makes quarterly GDP forecasts in pursuit of forecast accuracy.

However, since the basic statistics used to estimate GDP are sample surveys and cannot capture all economic activities, GDP is calculated considering various assumptions to estimate the "true economic state." In the case of quarterly GDP, the measurement error of basic statistics is larger than that on an annual basis, and the measurement error is not always the same every quarter. For this reason, it is pointed out that the measurement error is also affected by the previous term, and the effect of the error is amplified in the GDP of this term (Kunitomo and Sato, 2016).

Table 3
Unexpected forecast error on articles of Newspaper in other countries.

	publication date	Head line of Newspaper	target	Forecast error (%)	Actual (%)	Forecast (%)
USA	27-Apr-01	First Quarter GDP Report Packs a Surprise	2001 Q1	1.20	2.00	0.80
	26-Apr-19	Unexpectedly accelerated growth rate	2019 Q1	1.10	3.20	2.10
Canada	29-May-15	Unexpectedly accelerated growth rate	2015 1Q	-0.90	-0.60	0.30
	1-Mar-19	Unexpectedly accelerated growth rate	2018 4Q	-0.80	0.40	1.20
UK	22-Feb-18	GDP unexpectedly revised downward	2017 Q4	-0.10	0.40	0.50
	9-Aug-19	Unexpectedly low growth rate	2019 Q2	-0.20	-0.20	0.00
France	22-Dec-17	Unexpectedly revised upward	2017 Q3	0.10	0.60	0.50
	30-Jul-19	Unexpectedly low growth rate	2019 2Q	-0.10	0.20	0.30
Germany	16-Aug-11	Unexpectedly low growth rate	2011 Q2	-0.40	0.10	0.50
	15-May-18	Disappointment with lower growth than expected	2018 Q1	-0.10	0.30	0.40
	14-Nov-19	Unexpectedly higher growth rate than expected	2019 Q3	0.20	0.10	-0.10
Italy	15-May-14	Unexpectedly low despite the recovery period	2014 Q1	-0.30	-0.10	0.20
	6-Aug-14	Decrease below the lower limit of forecast (0.4% -0.1%)	2014 Q2	-0.40	-0.20	0.20
	15-May-14	Unexpectedly low growth rate	2014 Q1	-0.30	-0.10	0.20
Sweden	31-Jul-19	Unexpectedly low growth rate	2019 Q2	-0.50	-0.10	0.40

Notes: The notation is an article in various newspapers, in which "unexpected," "doubtful," "unreliable" and "disappointed" is used as a search word.

Table 4
Summary of quarterly forecast variables evaluated in this study.

	Data		Source	Definition	Sample periods	Forecast Timing (days, before target GDP)								
Canada	Staff Economic Projections	(CA BEP)	Bank of Canada	Q to Q (Annual Rate)	2000 1Q - 2019 4Q	**45**	**135**							
USA	The Survey of Professional Forecasters	(US SPF)	Federal Reserve Bank of Philadelphia		2000 1Q - 2019 4Q	**74**	**165**	256	348	439				
	Staff Economic Projections	(US BEP)	Report to the FOMC on Economic Conditions and Monetary Policy		2000 1Q - 2015 4Q	**6**	**47**	**94**	**138**	185	229	276	320	367
Japan	JCER ESP Forecast	(JP SPF)	Japan Center for Economic Research		2004 2Q - 2019 4Q	**4**	**34**	**66**	**95**	**126**	**157**			
UK	MPC's projections	(UK BEP)	Bank of England, "Monetary Policy Report"	Y to Y	2007 3Q - 2019 4Q	7	**80**	**171**	262	353				

Notes: "Q to Q" indicates quarter-over-quarter growth annualized percentage points. "Y to Y" indicates Percentage change, latest quarter on corresponding quarter of previous year. For the forecast data name, the name in parentheses is used in this paper. The forecasts used for analysis in this paper are shown in bold in the forecast timing.

Table 5
Summary of annual forecast variables.

	Data		Source	Sample periods	Forecast Timing (days, before target GDP)								
USA	The Survey of Professional Forecasters	(US SPFA)	Federal Reserve Bank of Philadelphia	2000 - 2019	**75**	**169**	260	348	440				
	Staff Economic Projections	(US BEPA)	Report to the FOMC on Economic Conditions and Monetary Policy	2000-2019	**6**	**50**	**96**	**138**	**180**	226	277	322	372
Euro	ECB Survey of Professional Forecasters	(EU SPFA)	European Central Bank	2000 - 2019	**100**	**190**	286	374	463	553	649	737	
	ECB staff macroeconomic projections for the euro area	(EU BEPA)	European Central Bank	2000 - 2019	**20**	**63**	**92**	**154**	**184**	260	353	443	535
Japan	JCER ESP Forecast	(JP SPFA)	Japan Center for Economic Research	2004 - 2019	**4**	**37**	**68**	**97**	**124**	**160**	189	219	281
	Forecasts of the Majority of the Policy Board Members	(JP BEPA)	Bank of Japan	2008 - 2019	**20**	**114**	203	304	385	479			
UK	MPC's projections	(UK BEPA)	Bank of England, "Monetary Policy Report"	2008 - 2019	**175**	263	353	447	540				

Notes: See the notes to Table 4.

Under these circumstances, quarterly GDP forecasts are made in the same way for countries including Japan.

Therefore, this paper considers the following two points.

1. Whether the prediction accuracy would be improved by adding other current information.
2. Whether forecast accuracy can be improved by referring to past actual quarterly GDP and forecasts.

Case 1 indicates the following situations. If the prediction accuracy does not improve even adding current information, it can be pointed out that the prediction sufficiently reflects the new information available at the time of prediction. Regarding item 2, even if we have sufficient estimation methods and information available, we suggest that there are other factors that increase forecast error.

3. International comparison with forecast error

3.1. Forecast data

3.1.1. (Quarterly data)

In this paper, we use first preliminary and the latest quarterly GDP using the real-time database. GDP is revised after the first quarterly GDP has been released to improve accuracy of data including the change to the benchmark revision and methodologies. Therefore, it is possible to regard the latest data as the true GDP because more information is included in the latest data. We regard the released quarterly GDP around March 2022 as the latest quarterly GDP.

As shown in Table 4, the forecast data used in this paper are as follows. For Canada, we use "the Staff Economic Projections" (hereafter CA BEP) which is calculated by quarter-over-quarter percentage change at annual rates from 2000 to 2019 released at the time of 45 days, and 135 days. CA BEP is listed in Monetary Policy Report published by Bank of Canada.

For the United States, we used FOMC "Staff Economic Projections" (hereafter US BEP) and "the Survey of Professional Forecasters" (hereafter US SPF). The materials at the US BEP are published five years after the conference. In this paper, we use the forecast data (quarter-over-quarter percentage change at annual rates) from 2000 to 2015 released at the time of 6 days, 47 days, 94 days, and 138 days before the first quarterly GDP. But 6 days before GDP forecasts are not available for all time periods in Table 5. In addition, we use US SPF (Median, quarter-over-quarter percentage change at annual rates) from 2000 to 2019 released at the time of 74 days, and 165 days.

For Japan, we use "the ESP forecast survey" (hereafter, JP SPF) compiled by a private research institute. This forecast data has been newly introduced compared to other countries, and since August 2004, the forecast data of professional forecasters have been aggregated. We use the data (quarter-over-quarter percentage change at annual rates) from 2004 to 2019 released at the time of 4 days, 34 days, 66 days, 95 days, 126 days, and 157 days before the first preliminary quarterly GDP.

For the United Kingdom, Quarterly Monetary Policy Report published by the Bank of England (2015) sets out the economic analysis and inflation projections that the Monetary Policy Committee (MPC) to make its interest rate decisions. However, the MPC's projections (hereafter UK BEP) before 2007 3Q are not included in the report. We use the

Table 6
Comparison with quarterly forecast errors.

Forecast Timing (days before target GDP)	CA					45 days									135 days				
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days			138 days				
	BEP																		
	JP SPF	4 days		34 days				66 days				95 days		126 days			157 days		
	UK									80 days								171 days	
	BEP																		
Comparison with First preliminary quarterly GDP	CA					0.82	(1.07)								1.09	(1.46)			
	BEP																		
	US									0.98	(1.29)							1.27	(1.69)
	SPF																		
	US	0.71	(1.23)			0.78	(1.00)					1.09	(1.46)		1.22	(1.63)			
	BEP																		
	JP SPF	1.07	(1.36)	1.64	(2.10)			1.95	(2.60)			2.12	(2.97)	2.22	(3.26)		2.31	(3.36)	
	UK									0.40	(0.40)							0.61	(0.69)
	BEP																		
Comparison with latest quarterly GDP	CA					1.09	(1.42)								1.39	(1.80)			
	BEP																		
	US									1.32	(1.67)							1.51	(2.03)
	SPF																		
	US	1.25	(1.80)			1.22	(1.58)					1.44	(1.89)		1.62	(2.14)			
	BEP																		
	JP SPF	1.83	(2.42)	2.19	(2.79)			2.44	(3.10)			2.64	(3.48)	2.77	(3.83)		2.91	(3.99)	
	UK									0.59	(0.81)							0.69	(1.07)
	BEP																		

Notes: The forecast error shows the average of the deviation between the actual and the forecast based on the absolute value. The standard deviation is calculated from the difference between the actual result and the forecast. These forecast errors are calculated as the difference between the First preliminary (or latest value) of quarterly GDP and the forecast at each time point. The latest value release is published on February 24, 2022, in the United States, published on February 11, 2022 in the United Kingdom, published on March 1, 2022 in Canada, and published on March 9, 2022 in Japan. Numbers in parentheses indicate standard deviation. "UK BEP" indicates on Percentage change of latest quarter on corresponding quarter of previous year. Others shows quarter-over-quarter growth annualized percentage points.
Source: The data are calculated from the data shown in Table 4.

Table 7
Forecast error on contribution basis by Quarterly GDP component in Japan.

Forecast Timing (days, before target GDP)		4 days		34 days		66 days		95 days		126 days		157 days	
Comparison with First preliminary GDP	GDP	0.25	(0.32)	0.37	(0.46)	0.43	(0.55)	0.56	(0.59)	0.70	(0.56)	0.79	(0.58)
	PrivateConsumption	0.13	(0.33)	0.22	(0.54)	0.25	(0.62)	0.34	(0.67)	0.41	(0.66)	0.45	(0.66)
	Private non-residence investment	0.14	(1.15)	0.17	(1.43)	0.19	(1.52)	0.23	(1.63)	0.22	(1.65)	0.22	(1.65)
	Exports	0.14	(1.11)	0.23	(1.75)	0.27	(2.03)	0.34	(2.38)	0.40	(2.54)	0.46	(2.79)
	Imports	0.13	(1.02)	0.21	(1.56)	0.23	(1.75)	0.35	(1.92)	0.34	(1.98)	0.34	(2.03)
	Other Components	0.42	(2.30)	0.42	(2.31)	0.42	(2.30)	1.00	(2.33)	1.00	(2.34)	1.00	(2.33)
Comparison with latest quarterly GDP	GDP	0.47	(0.63)	0.54	(0.70)	0.57	(0.74)	0.59	(0.76)	0.59	(0.75)	0.64	(0.79)
	PrivateConsumption	0.24	(0.57)	0.28	(0.69)	0.31	(0.75)	0.33	(0.80)	0.33	(0.80)	0.33	(0.80)
	Private non-residence investment	0.19	(1.73)	0.16	(1.58)	0.16	(1.54)	0.18	(1.65)	0.17	(1.64)	0.18	(1.68)
	Exports	0.16	(1.31)	0.26	(1.90)	0.30	(2.24)	0.33	(2.53)	0.36	(2.75)	0.38	(3.09)
	Imports	0.15	(1.03)	0.21	(1.56)	0.23	(1.72)	0.25	(1.93)	0.26	(2.00)	0.27	(2.07)
	Other Components	0.29	(1.23)	0.30	(1.27)	0.30	(1.26)	0.31	(1.28)	0.31	(1.28)	0.31	(1.29)

Notes: Forecast error shows the contribution based on the absolute average gap between the actual GDP and the forecast using the share (average) of each component to GDP from 2009 to 2019. These forecast errors are calculated as the difference between the First release (or latest value) of quarterly GDP and the forecast value at each time point. Other Components can be obtained as residuals for the four published components. The latest value is published on March 9, 2022, in Japan. Numbers in parentheses indicate standard deviation.
Source: Japan Center for Economic Research "ESP Forecast", Cabinet office (Economic and Social Research Institute)

data from 2004 to 2019 released at the time of 80 days and 171 days before the first preliminary quarterly GDP. As UK BEP is calculated by percentage change of latest quarter on corresponding quarter of previous year, the characteristics on forecast are different from others forecast like CA BEP and USBEP.

3.1.2. (Annual data)

We also analyzed the annual GDP. Since the error in the basic statistics of annual GDP is small, it is expected that the estimation error is smaller than that of quarterly GDP. In addition, annual GDP does not fluctuate due to seasonal factors, so it is expected that variability will be small. Therefore, in order to evaluate the difference from quarterly GDP, we examine the forecast error of annual GDP. Regarding annual GDP, we used four regions: the United States, Europe, the United Kingdom, and Japan (Table 5). Actual annual GDP is calculated using preliminary base GDP.

As US forecast of annual GDP, we use “the Staff Economic Projections” (hereafter US BEPA) from 2000 to 2019 released at the time of 6 days, 50 days, 96 days, 138 days and 180 days before the preliminary annual GDP and “the Survey of Professional Forecasters” (hereafter US SPFA) from 2000 to 2019 released at the time of 75 days and 169 days before the preliminary annual GDP. Annual forecast data for Canada are not available, but for Europe countries GDP forecasts, we have annual GDP forecasts available. One is “ECB staff macroeconomic projections for the euro area” (hereafter, EU SPFA) compiled by the European Central Bank (ECB) (2013). We also have access to ECB “Survey of Professional Forecasters” (hereafter, EU BEPA). We use EU SPFA from 2000 to 2019 released at the time of 100 days and 190 days before the preliminary annual GDP and EU BEPA from 2000 to 2019 released at the time of 20 days, 63 days, 92 days, 154 days and 184 days before the preliminary annual GDP.

In Japan, we use “the Forecasts of the Majority of the Policy Board Members” (hereafter, JP BEPA) by Bank of Japan. Since October 2000, " The Outlook for Economic Activity and Prices " has been published twice a year (at the end of April and end of October) as a forecast by the Bank of Japan’s policymakers. From 2008, it will also be published at the end of July and the end of January, and therefore forecasts are to be predicted four times a year. Since the ESP forecast survey also publishes annual GDP forecasts (hereafter, JP SPFA), we use them. We use JP BEPA from 2008 to 2019 released at the time of 20 days and 114 days before the preliminary annual GDP and JP SPFA from 2004 to 2019 released at the time of 4 days, 37 days, 68 days, 97 days, 124 days and 160 days before the preliminary annual GDP. For the United Kingdom, we use the MPC’s projections (hereafter UK BEPA) from 2008 to 2019 released at the time of 175 days before the preliminary annual GDP.

3.2. Quarterly base forecast error

3.2.1. Quarterly GDP

We find that the closer to the announcement of the first preliminary quarterly GDP, the smaller the forecast error and standard deviation (Table 6). Comparing the forecast errors in mostly the same period, the forecast error in Japan is about two times as large as that of other countries. Forecast errors around 120–130 days before are 2.22 for Japan (JP SPF), 1.22 for US (US SPF), and 1.09 for Canada (CA BEP). Forecast errors around 90 days before are 2.12 for Japan (JP SPF), 1.09 for US (US BEP), and 0.40 for UK (UK BEP).

Furthermore, the forecast error of the closest to the announcement of quarterly GDP is less than 1 %; 0.71 % for USA (US BEP), 0.99 % for UK (UK BEP), but for Japan (JP SPF) it is over 1 %. This is the same level as the forecasts error for the United States (US BEP) and Canada (CA BEP) on 3–4 months before. In this way, we find that the forecast error in Japan has not decreased significantly even just before the quarterly GDP compared to other countries.

In the forecast error based on the latest GDP, the forecast error is expanding compared with the preliminary GDP base in each country. However, as mentioned above, Japan has about twice the forecast error of other countries. The forecast error 150–160 days before is 2.91 for Japan (JP SPF), 1.81 for USA (US SPF), and 0.69 for the UK (UK BEP). In addition, the forecast error of 120–130 days before is 2.77 in Japan (JP SPF), 1.62 in USA (US BEP), and 1.39 in Canada (CA BEP). The forecast error in Japan is remarkably large.

3.2.2. Components of quarterly GDP in Japan

Four components are available for JP SPF: private consumption, Private non-residence investment, exports, and imports (Table 7). We found that the forecast errors and standard deviations of all components decreased significantly as the release of the actual quarterly GDP approached. It shows that the prediction accuracy is improved by the newly added information. However, the pace of decline in forecast errors for Private non-residence investment is not as large as for other items. The forecast error of the residual was more than twice as large as that of the four items, and although the prediction error was halved 66 days before, it did not decrease thereafter, accounting for a large portion

of forecast error in total.[3]

As for the latest value base, the magnitude of the forecast error is almost the same as the first release base. However, the pace of decrease in forecast error is small, and there is no significant reduction in forecast error from a certain point in time, as seen in the first release base. In addition, for undisclosed (residuals) components, the forecast errors are not as large as those on the first release base and are about the same as private consumption.

3.3. Annual base forecast error

3.3.1. Annual GDP

In terms of annual forecast error, we cannot insist that forecast error in Japan is significantly larger than other countries (Table 8). Based on the first preliminary GDP, the forecast error 160–180 days ago is 0.57 for JP SPFA, 0.48 for the UK BEPA, 0.57 for US BEPA, 0.31 for EU SPFA, and 0.21 for US SPFA. Even 90 days before, the forecast error in JP SPFA is 0.36, and 0.37 for US BEPA. This tendency can also be confirmed by the forecast error based on the latest value. Thus, unlike the quarterly GDP basis, in Japan forecast error is not significantly large on an annual basis. This indicates that the forecast situation and ability for Japanese predictors is not inferior to that of other countries.

3.3.2. Components of annual GDP in Japan

We also checked the components that affect the annual GDP forecast error. We identified forecast errors by component of annual GDP on a preliminary base from 2009 to 2019.

In the forecast (124 days before), private consumption had the largest errors (0.24 %), followed by export (0.20 %), private non-residential investment (0.15 %) and change in private inventories (0.10 %). After adding the actual quarterly GDP, we can use three quarters of data (68 days ago), the forecast error was reduced. Forecast error of Private non-residential investment and change in private inventories are below 0.07 %, but private consumption still had forecast error of 0.10 %. This trend continued even 4 days before the release of the annual GDP.

On the other hand, compared with the latest annual estimates, the forecast errors were the largest for private non-residential investment (0.37 %), followed by change in private inventories (0.29 %) and private consumption (0.28 %) (Table 9).

According to the annual forecast errors, it is highly likely that change in private inventories fluctuations account for most of the forecast errors estimated from the residuals on a quarterly basis. There are many opinions that it is difficult to estimate private inventories because there are few statistics that can be used for estimation. In particular, as Miwa (2014) points out, private inventories have little impact on an annual basis, but fluctuate greatly on a quarterly basis. For this reason, quarterly estimates of GDP may be a major obstacle to improving the accuracy of estimates. However, this point cannot be confirmed in this paper because forecast data for inventories on a quarterly basis are not available.

4. Evaluating the characteristics of forecast error

4.1. Basic model

This section assesses the characteristics of forecast error. The variable notation used in this section are summarized in Table 10. Corporate, households and policy makers would like to obtain the optimal quarterly GDP x_t^* in order to make optimal decisions. However, as, x_t^* cannot be observed until the time has passed in many cases, we use the preliminary quarterly GDP x_t^Q that will be released after the quarter ends. Moreover, since we want to obtain x_t^* as soon as possible, we require highly accurate GDP forecast. Here, let x_t^F predicted based on the available information in the $t$period be the optimum forecast. Optimal forecasts are created by efficiently using the available information at that time. Here, the forecast is x_t^P at each time t. x_t^P may be the same as x_t^F, but it may be different. This depends on whether the predictor estimates using appropriate estimation method for x_t^Q and how much statistical information is available for x_t^Q.

Let x_t^P be the predicted value of x_t^Q in the t period. It is assumed that. consists of x_t^Q and the error ν_t in the estimation. However, for ν_t, the average is zero and uncorrelation with x_t^Q. In other words, if x_t^Q and ν_t, are independent relations (irrelevant), they can be expressed as the following Eq. (1).

$$x_t^P \equiv x_t^Q + \nu_t \tag{1}$$

In order to confirm whether x_t^P is a rational prediction for x_t^Q, we examined the statistical attributes of forecast error. ν_t in Eq. (1). As for forecast error, if x_t^P and x_t^Q are equivalent, there is no need for a test. But if all the basic statistics are not available at that time of prediction, x_t^P and x_t^Q do not match. Moreover, if the estimation method of x_t^Q is not well known to the forecasters, forecasters cannot estimate x_t^P rationally. Therefore, we estimate whether forecast error is rational as follows.

4.2. Unbiasedness test

We check whether there is any bias in the forecast error. If the prediction is biased, it will be difficult to make an accurate prediction. We assessed unbiasedness of forecast errors ν_t using ordinary least squares (OLS) regression as Eq. (2).

$$\left(x_t^Q - x_t^P\right) = \beta_0 + \varepsilon_t \tag{2}$$

where ε_t is a zero-mean error term. Under the null hypothesis of unbiasedness $\beta_0 = 0$, if $\beta_0 > 0$, forecasts have been systematically too low. If $\beta_0 < 0$, forecasts have been too high. We estimated the regression using OLS with Heteroscedasticity and Autocorrelation Consistent (HAC) standard errors.

4.3. Weak efficiency test

Weak efficiency test evaluates whether forecasts could have been made more accurate if they were scaled by a constant and if a constant were added to or subtracted from them. We use Eq. (3).

$$x_t^Q = \beta_0 + \beta_1 x_t^P + \varepsilon_t \tag{3}$$

weak efficiency requires $\beta_1 = 1$ and unbiasedness requires $\beta_0 = 0$.

4.4. Strong efficiency test

In we call "strong" efficiency test, we assess forecast errors when we add on other information that was known when the forecasts were made. If forecast errors are correlated with any such information, we reduce forecast errors by incorporating that information when the forecasts were made. We estimated the following Eq. (4) using OLS with HAC standard errors:

$$\left(x_t^Q - x_t^P\right) = \beta_0 + \beta_1 W_t + \varepsilon_t \tag{4}$$

where ε_t is a zero-mean error term. Under the null hypothesis of Strong efficiency, we evaluate $\beta_1 = 0$. In this study, we used industrial product index, retail sales and unemployment rate as W_t. Because industrial product index, retail sales are the statistic used to estimate quarterly

[3] Since 2000, there have been frequent economic shocks such as the Lehman shock, major earthquakes, the spread of Covid-19, and international regional conflicts. Change in private inventories, which has a relatively small forecast error on an annual GDP base, may affect the forecast error.

Table 8
Comparison with annual forecast errors.

Forecast Timing (days, before target GDP)										
	US SPFA				75 days				169 days	
	US BEPA	6 days		50 days		96 days		138 days		180 days
	JP SPFA	4 days		37 days	68 days	97 days	124 days		160 days	
	JP BEPA		20 days				114 days			
	EU SPFA					100 days				190 days
	EU BEPA		20 days		63 days	92 days		154 days		184 days
	UK BEPA								175 days	
Comparison with First preliminary quarterly GDP	US SPFA				0.10 (0.12)				0.21 (0.30)	
	US BEPA	0.12 (0.16)		0.24 (0.31)		0.37 (0.44)		0.39 (0.57)		0.57 (0.76)
	JP SPFA	0.17 (0.21)		0.20 (0.26)	0.24 (0.31)	0.36 (0.50)	0.49 (0.69)		0.57 (0.84)	
	JP BEPA		0.20 (0.25)				0.55 (0.62)			
	EU SPFA					0.11 (0.16)				0.31 (0.39)
	EU BEPA		0.03 (0.03)		0.05 (0.06)	0.05 (0.09)		0.10 (0.13)		0.15 (0.24)
	UK BEPA								0.48 (0.56)	
Comparison with latest quarterly GDP	US SPFA				0.29 (0.42)				0.39 (0.53)	
	US BEPA	0.43 (0.63)		0.44 (0.64)		0.60 (0.88)		0.61 (1.12)		0.86 (1.19)
	JP SPFA	0.54 (0.63)		0.53 (0.62)	0.53 (0.64)	0.56 (0.68)	0.62 (0.79)		0.70 (0.97)	
	JP BEPA		0.49 (0.56)				0.54 (0.73)			
	EU SPFA					0.41 (0.42)				0.46 (0.55)
	EU BEPA		0.39 (0.36)		0.30 (0.27)	0.44 (0.46)		0.36 (0.33)		0.48 (0.56)
	UK BEPA								0.51 (0.65)	

Notes: These forecast errors are calculated as the difference between the First release (or latest value) of annual GDP and the forecast at each time point. The latest value is published on February 24, 2022 in the United States, published on February 11, 2022 in the United Kingdom, published on March 1, 2022 in Canada, and published on March 9, 2022 in Japan. Numbers in parentheses indicate standard deviation.
Source: The data are calculated from the data shown in Table 4.

GDP. In addition, since quarterly GDP fluctuations indicate overall economic activity, we used unemployment rate, a statistic that indicates the supply and demand of economic activity (labor market).

4.5. Impact of actual GDP fluctuation, past forecast error and revision

We extend the Strong efficiency test on 4.4 section to evaluate whether past fluctuations or predictions errors or revisions in actual quarterly GDP affect predictions. If the optimal forecast$x_t^F$is made, the forecast error is a rational forecast error and should not correlate with past actual x_t^Q or past forecast x_t^P.

Table 11 shows the fluctuation and revision range of Canada, the US, UK, and Japan. In this Table 11, fluctuation is defined as the standard deviation of the quarter-on-quarter growth rate of quarterly GDP. In the case of Japan, the fluctuation and revision are about twice as large as that in the other countries. This means that not only is the scale of revision large, but it is also more volatile than other countries. Therefore, we examine whether past fluctuation and past revision affect the forecast at each forecast time.

4.5.1. Fluctuations of past actual GDP

We assume that when we make forecasts, we consider the fluctuation in the rate of change as a reference. We estimate the following Eqs. 5–1. In this section we define the fluctuation as the difference between the actual preliminary GDP one quarter ago and second quarter ago.

$$\left(x_t^Q - x_t^P\right) = \beta_1 + \beta_2\left(x_{t-1}^{Q1} - x_{t-2}^{Q1}\right) + \varepsilon_t \qquad (5\ \ \text{-}1)$$

where ε_t is a zero-mean error term. Under the null hypothesis of Strong efficiency, we evaluate $\beta_2 = 0$.

4.5.2. Reference to change in past forecast

We use Eqs. 5–2–1 to estimate whether the change of the just before previous forecast will affect the revision of the current forecast. We assume revisions to predictions are made when information is added that may improve prediction accuracy. Here, we use two explanatory variables as past prediction results. First, we use the modification of the previous prediction as an explanatory variable. For example, in the case of US BEP, at forecasting 6 days before the release of actual GDP we refer information of difference between 47-day before and 94-day before forecasts.

$$\left(x_t^Q - x_t^{Pi}\right) = \beta_1 + \beta_2\left(x_{t-1}^{Pi} - x_{t-1}^{Pi-1}\right) + \varepsilon_t \qquad (5\ \ \text{-}2\ \ \text{-}1)$$

One more point, we assume we also use information in same time forecast one year ago. We estimate Eqs. 5–2–2. For example, in the case of US BEP, if the forecast is made 6 days before, we refer previous information of difference between 6-day before and 47-day before forecasts one year ago.

$$\left(x_t^Q - x_t^{Pi}\right) = \beta_1 + \beta_2\left(x_{t-1}^{agoPi} - x_{t-1}^{agoPi-1}\right) + \varepsilon_t \qquad (5\ \ \text{-}2\ \ \text{-}2)$$

where ε_t is a zero-mean error term in Eqs. 5–2–1 and 5–2–2. Under the null hypothesis of Strong efficiency, we evaluate $\beta_2 = 0$.

4.5.3. <Revision of actual GDP>

Since quarterly GDP is revised every quarterly, revisions to the latest values include not only the accurate statistical information used for estimation, but also differences in estimation methods. In order to forecast the true GDP x_t^*, we assume that the forecaster takes into account past revisions of GDP to make forecasts. In this estimation, we use revisions between the first preliminary and the second preliminary GDP (Eqs. 5–3–1), revisions between the second preliminary and the latest GDP (Eqs. 5–3–2). and revisions between the first preliminary and the latest GDP (Eqs. 5–3–3).

$$\left(x_t^Q - x_t^P\right) = \beta_1 + \beta_2\left(x_{t-1}^{Q2} - x_{t-1}^{Q1}\right) + \varepsilon_t \qquad (5\ \ \text{-}3\ \ \text{-}1)$$

Table 9
Forecast error on contribution basis by annual GDP component in Japan.

Forecast Timing (days, before target GDP)		4 days		37 days		68 days		97 days		124 days		160. days	
Comparison with preliminary annual GDP	GDP	0.17	(0.21)	0.20	(0.26)	0.24	(0.31)	0.36	(0.50)	0.49	(0.69)	0.57	(0.84)
	PrivateConsumption	0.10	(0.20)	0.10	(0.22)	0.10	(0.25)	0.21	(0.45)	0.24	(0.52)	0.29	(0.57)
	Private Residential Investment	0.01	(0.38)	0.01	(0.43)	0.01	(0.41)	0.02	(1.08)	0.03	(1.33)	0.03	(1.42)
	Private non-residence investment	0.07	(0.61)	0.08	(0.65)	0.07	(0.56)	0.14	(1.23)	0.15	(1.32)	0.16	(1.41)
	Change in Private Inventories	0.05	(0.07)	0.06	(0.07)	0.07	(0.08)	0.10	(0.11)	0.10	(0.11)	0.20	(0.26)
	Government Consumption	0.02	(0.15)	0.02	(0.15)	0.03	(0.20)	0.04	(0.25)	0.04	(0.25)	0.08	(0.47)
	Change in Public Inventories	0.03	(0.94)	0.03	(1.04)	0.04	(1.19)	0.06	(1.75)	0.07	(2.15)	0.10	(3.10)
	Exports	0.07	(0.48)	0.08	(0.59)	0.10	(0.71)	0.17	(1.23)	0.20	(1.52)	0.23	(1.67)
	Imports	0.05	(0.40)	0.06	(0.58)	0.08	(0.66)	0.12	(1.02)	0.14	(1.28)	0.16	(1.38)
Comparison with latest annual GDP	GDP	0.54	(0.63)	0.53	(0.62)	0.53	(0.64)	0.56	(0.68)	0.62	(0.79)	0.70	(0.97)
	PrivateConsumption	0.23	(0.56)	0.23	(0.55)	0.24	(0.56)	0.27	(0.60)	0.28	(0.63)	0.28	(0.66)
	Private Residential Investment	0.05	(2.31)	0.05	(2.25)	0.05	(2.23)	0.05	(2.55)	0.05	(2.63)	0.05	(2.60)
	Private non-residence investment	0.33	(2.53)	0.34	(2.64)	0.37	(2.83)	0.38	(2.97)	0.37	(2.96)	0.30	(2.39)
	Change in Private Inventories	0.25	(0.38)	0.25	(0.38)	0.28	(0.41)	0.28	(0.43)	0.29	(0.43)	0.32	(0.51)
	Government Consumption	0.08	(0.58)	0.08	(0.58)	0.09	(0.56)	0.10	(0.64)	0.09	(0.62)	0.11	(0.66)
	Change in Public Inventories	0.18	(5.23)	0.18	(5.24)	0.18	(5.16)	0.15	(4.36)	0.15	(4.09)	0.12	(2.93)
	Exports	0.12	(0.50)	0.13	(0.58)	0.12	(0.65)	0.15	(1.21)	0.19	(1.54)	0.21	(1.72)
	Imports	0.12	(0.66)	0.12	(0.70)	0.12	(0.67)	0.13	(0.74)	0.14	(0.96)	0.14	(1.00)

Notes: Forecast error shows the contribution based on the absolute average gap between the actual GDP and the forecast using the share (average) of each component to GDP from 2009 to 2019. These forecast errors are calculated as the difference between the First preliminary (or latest value) of quarterly GDP and the forecast value at each time point. The latest value is published on March 9, 2022 in Japan. Numbers in parentheses indicate standard deviation.
Source: Japan Center for Economic Research "ESP Forecast", Cabinet office (Economic and Social Research Institute)

Table 10
Variable notation in this study.

Variable sign	Variable attributes
x_t^*	optimal quarterly GDP
x_t^{Q1}	first preliminary quarterly GDP
x_t^{Q2}	second preliminary quarterly GDP
x_t^{Qf}	latest quarterly GDP
x_t^{Pi}	predicted value in i days before the actal GDP
x_t^{agoPi}	predicted value in i days one year ago
x_t^F	optimal predicted value
$\nu_t (= x_t^Q - x_t^P)$	forecast error
ε_t	a zero-mean error term

Table 11
Fluctuation and revision of Canada, US, UK, and Japan.

	Fluctuation			Revision	
	First	Second	Latest	First→Second	First→Latest
Canada	0.50 %	0.50 %	0.60 %	0.06 %	0.20 %
				(0.08 %)	(0.25 %)
US	0.47 %	0.51 %	0.57 %	0.11 %	0.30 %
				(0.15 %)	(0.37 %)
Japan	0.97 %	0.96 %	1.05 %	0.22 %	0.47 %
				(0.32 %)	(0.58 %)
UK	0.51 %	0.50 %	0.54 %	0.05 %	0.24 %
				(0.08 %)	(0.31 %)

Notes: Quarterly GDP is calculated as the quarter-on-quarter growth rate from the real-time database of each country from 2000 to 2019. Fluctuation shows the standard deviation. The upper part of Revision shows the absolute average of the revision, and the lower part shows the standard deviation due to the raw data. First and Second indicate first and second preliminary GDP respectively. The latest value are the data published before and after March 2022 in each country.
Source: Statistics Canada, Bureau of Economic Analysis, Office for National Statistics, Cabinet office.

$$\left(x_t^Q - x_t^P\right) = \beta_1 + \beta_2\left(x_{t-1}^{Qf} - x_{t-1}^{Q2}\right) + \varepsilon_t \qquad (5\ -3\ -2)$$

$$\left(x_t^Q - x_t^P\right) = \beta_1 + \beta_2\left(x_{t-1}^{Qf} - x_{t-1}^{Q1}\right) + \varepsilon_t \qquad (5\ -3\ -3)$$

where ε_t is a zero-mean error term in Eq. 5–3–1, 5–3–2 and 5–2–2. Under the null hypothesis of Strong efficiency, we evaluate $\beta_2 = 0$.

5. Empirical results

5.1. Unbiasedness test

Regarding the bias test, except for UK BEP and US SPF 165 days before, the null hypothesis of unbiasedness $\beta_0 = 0$ is not rejected in the preliminary quarterly GDP results. Many predictions, including JP SPF, are not biased. On the other hand, regarding the latest values, we can reject the US SPF 165 days before and the US BEP 138 days before, but we cannot reject the null hypothesis for the other predictions (Table 12).

5.2. Efficiency test

Two models were used to analyze whether the predicted values fully utilized the information at the time of prediction. Combined with the results of the bias test in Section 5.1, except for UK BEP 80 and 171 days before, US BEP 6 and 138 days before, US SPF 165 days before and JP SPF 34 days before, the null hypothesis of weak efficiency $\beta_1 = 1$ and unbiasedness $\beta_0 = 0$ is not rejected in the preliminary quarterly GDP results. For latest quarterly GDP, except for US BEP 94 and 138 days before, US SPF 165 days before and around 3 months before forecast of JP SPF, the null hypothesis of weak efficiency is not rejected. In particular, these results provide evidence that three forecasts of JP SPF around 3 months before have been weakly inefficient on latest quarterly GDP (Table 13).

In the “strong” efficiency test, we examined whether the forecast error would be improved when other economic indicators are added. In

Table 12
The results of Unbiasedness test.

Forecast Timing (days, before target GDP)																			
	CA					45 days								135 days					
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days				138 days			
	BEP																		
	JP	4 days		34 days				66 days				95 days		126 days				157 days	
	SPF																		
	UK									80 days								171 days	
	BEP																		
Comparison with First preliminary quarterly GDP	CA					0.01	(0.90)							-0.22	(0.15)				
	BEP																		
	US									-0.05	(0.71)							-0.36*	(0.07)
	SPF																		
	US	0.08	(0.28)			0.14	(0.28)					-0.03	(0.85)	-0.24	(0.20)				
	BEP																		
	JP	0.03	(0.87)	-0.18	(0.54)			-0.38	(0.30)			-0.59	(0.17)	-0.64	(0.17)			-0.78	(0.11)
	SPF																		
	UK									-0.42**	(0.01)							-0.32***	(0.00)
	BEP																		
Comparison with latest quarterly GDP	CA					0.13	(0.43)							-0.11	(0.61)				
	BEP																		
	US									-0.23	(0.14)							-0.55**	(0.02)
	SPF																		
	US	-0.15	(0.46)			-0.11	(0.46)					-0.28	(0.15)	-0.47**	(0.04)				
	BEP																		
	JP	-0.05	(0.85)	-0.26	(0.52)			-0.46	(0.33)			-0.66	(0.22)	-0.68	(0.25)			-0.81	(0.18)
	SPF																		
	UK									-0.08	(0.74)							-0.01	(0.98)
	BEP																		

Notes: The estimated values in the table show the coefficient of β_0 in Eq. (2). The numbers in parentheses indicate the results (p-value) of the Wald test with $\beta_0 = 0$.

Table 13
The results of "weak" efficiency test.

Forecast Timing (days, before target GDP)																	
	CA					45 days								135 days			
	BEP																
	US									74 days						165 days	
	SPF																
	US	6 days				47 days						94 days		138 days			
	BEP																
	JP	4 days		34 days				66 days				95 days		126 days		157 days	
	SPF																
	UK									80 days						171 days	
	BEP																
Comparison with First preliminary quarterly GDP	CA					0.89	(0.41)							1.02	(0.35)		
	BEP																
	US									0.94	(0.79)					0.92*	(0.09)
	SPF																
	US	0.94**	(0.01)			0.93	(0.11)					0.82	(0.32)	0.77*	(0.06)		
	BEP																
	JP	1.05	(0.35)	1.25**	(0.02)			1.26	(0.23)			1.46	(0.27)	1.39	(0.30)	1.42	(0.23)
	SPF																
	UK									1.09**	(0.02)					1.04***	(0.00)
	BEP																
Comparison with latest quarterly GDP	CA					1.01	(0.72)							1.19	(0.61)		
	BEP																
	US									1.02	(0.32)					1.05**	(0.03)
	SPF																
	US	0.97	(0.65)			0.97	(0.67)					0.88*	(0.09)	0.78**	(0.01)		
	BEP																
	JP	1.22***	(0.00)	1.48***	(0.00)			1.54**	(0.04)			1.85	(0.15)	1.75	(0.16)	1.72	(0.24)
	SPF																
	UK									1.00	(0.90)					0.97	(0.95)
	BEP																

Notes: The estimated values in the table show the coefficient of β_1 in Eq. (3). The numbers in parentheses indicate the results (p-value) of the Wald test with $\beta_0 = 0$, $\beta_1 = 1$.
* ** $p < 0.01$, * * $p < 0.05$, * $P < 0.1$.

Table 14
The results of "strong" efficiency test.

Industrial Product Index																					
Forecast Timing (days, before target GDP)	CA						45 days										135 days				
	BEP																				
	US									74 days										165 days	
	SPF																				
	US	6 days					47 days						94 days				138 days				
	BEP																				
	JP	4 days		34 days				66 days					95 days		126 days				157 days		
	SPF																				
	UK									80 days										171 days	
	BEP																				
Comparison with First preliminary quarterly GDP	CA						0.00	(0.97)									0.08	(0.09)			
	BEP																				
	US									-0.04	(0.19)									-0.02	(0.69)
	SPF																				
	US	0.01	(0.65)				-0.04	(0.11)					-0.07*	(0.09)			-0.04	(0.46)			
	BEP																				
	JP	0.01	(0.58)	0.04	(0.24)				0.06	(0.13)			0.09*	(0.06)	0.09	(0.14)			0.11*	(0.08)	
	SPF																				
	UK									0.02	(0.40)									0.03*	(0.06)
	BEP																				
Comparison with latest quarterly GDP	CA						0.03	(0.45)									-9.10	(0.12)			
	BEP																				
	US									0.56	(0.80)									-2.00	(0.75)
	SPF																				
	US	0.08*	(0.05)				0.04	(0.96)					2.70	(0.44)			-0.51	(0.99)			
	BEP																				
	JP	0.01	(0.58)	-4.26	(0.27)				-6.53	(0.17)			-9.54	(0.17)	-9.83	(0.24)			-12.26	(0.16)	
	SPF																				
	UK									4.33	(0.33)									4.33	(0.25)
	BEP																				
Retail Sales																					
Forecast Timing (days, before target GDP)	CA						45 days										135 days				
	BEP																				
	US									74 days										165 days	
	SPF																				
	US	6 days					47 days						94 days				138 days				
	BEP																				
	JP	4 days		34 days				66 days					95 days		126 days				157 days		
	SPF																				
	UK									80 days										171 days	
	BEP																				
Comparison with First preliminary quarterly GDP	CA						-2.64	(0.71)									12.58	(0.04)			
	BEP																				
	US									0.12	(0.97)									10.09	(0.27)
	SPF																				
	US	-4.63***	(0.00)				-2.89	(0.12)					-2.56	(0.64)			0.92	(0.91)			
	BEP																				
	JP	0.02	(0.75)	0.15	(0.14)				0.25*	(0.07)			0.32	(0.10)	0.35	(0.13)			0.43*	(0.08)	
	SPF																				
	UK									20.55**	(0.01)									9.76	(0.00)
	BEP																				
Comparison with latest quarterly GDP	CA						3.16	(0.63)									18.38	(0.15)			
	BEP																				

(*continued on next page*)

Table 14 (*continued*)

	US SPF										5.63	(0.35)								15.60	(0.16)
	US BEP	2.25	(0.76)			2.41	(0.59)						2.73	(0.73)			6.71	(0.52)			
	JP SPF	0.06	(0.73)	0.19	(0.38)			0.29	(0.23)				0.37	(0.20)	0.38	(0.22)			0.46	(0.16)	
	UK BEP										22.30	(0.17)								10.71	(0.33)
Unemployment rate																					
Forecast Timing (days, before target GDP)	CA BEP					45 days											135 days				
	US SPF										74 days									165 days	
	US BEP	6 days				47 days							94 days				138 days				
	JP SPF	4 days		34 days				66 days					95 days		126 days				157 days		
	UK BEP										80 days									171 days	
Comparison with First preliminary quarterly GDP	CA BEP					0.02	(0.92)										0.13	(0.55)			
	US SPF										0.02	(0.85)								0.03	(0.85)
	US BEP	0.00	(0.97)			0.00	(0.97)						0.04	(0.76)			0.02	(0.86)			
	JP SPF	0.08	(0.66)	0.28	(0.36)			0.30	(0.44)				0.38	(0.38)	0.42	(0.36)			0.28	(0.58)	
	UK BEP										-0.13*	(0.07)								-0.09**	(0.01)
Comparison with latest quarterly GDP	CA BEP					-0.10	(0.59)										0.02	(0.94)			
	US SPF										0.00	(0.97)								0.01	(0.96)
	US BEP	-0.13	(0.17)			0.01	(0.90)						0.05	(0.66)			0.03	(0.81)			
	JP SPF	0.30	(0.38)	0.50	(0.27)			0.52	(0.32)				0.59	(0.30)	0.70	(0.24)			0.56	(0.38)	
	UK BEP										0.01	(0.94)								0.05	(0.59)

Notes: The estimated values in the table show the coefficient of β_1 in Eq. (4). The numbers in parentheses indicate the results (p-value) of the Wald test with $\beta_1 = 0$. * ** p < 0.01, * * p < 0.05, * P < 0.1.

Table 15
The results of impact of actual GDP fluctuations and past forecast errors.

Fluctuations of past actual GDP																			
Forecast Timing (days, before target GDP)	CA					45 days									135 days				
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days			138 days				
	BEP																		
	JP	4 days		34 days				66 days				95 days		126 days			157 days		
	SPF																		
	UK									80 days								171 days	
	BEP																		
Difference between the actual preliminary quarterly GDP one quarter ago and second quarter ago	CA					-0.01	(0.91)								0.21**	(0.02)			
	BEP																		
	US									0.06	(0.41)							0.21	(0.10)
	SPF																		
	US	0.02	(0.43)			0.06	(0.27)					0.11	(0.22)		0.11	(0.32)			
	BEP																		
	JP	0.07	(0.12)	0.12**	(0.02)			0.16***	(0.00)			0.18**	(0.03)	0.18*	(0.06)		0.19*	(0.06)	
	SPF																		
	UK									0.47***	(0.00)							0.15***	(0.00)
	BEP																		
Reference to change in past forecast																			
Forecast Timing (days, before target GDP)	CA					45 days									135 days				
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days			138 days				
	BEP																		
	JP	4 days		34 days				66 days				95 days		126 days			157 days		
	SPF																		
	UK									80 days								171 days	
	BEP																		
Change of the just before previous forecast	CA					-0.26**	(0.01)								-	-			
	BEP																		
	US									-0.22	(0.41)							-	-
	SPF																		
	US	-0.16	(0.16)			0.03	(0.84)					-0.14	(0.62)		-	-			
	BEP																		
	JP	0.01	(0.94)	0.09	(0.79)			0.16	(0.66)			0.54	(0.19)	-0.60*	(0.05)		-	-	
	SPF																		
	UK									-0.62***	(0.00)							-	-
	BEP																		
Change in same time forecast one year ago	CA					-0.03	(0.78)								0.17**	(0.03)			
	BEP																		
	US									0.05	(0.55)							0.16	(0.29)
	SPF																		
	US	0.02	(0.90)			0.10	(0.29)					0.08	(0.45)		0.06	(0.60)			
	BEP																		
	JP	0.04	(0.68)	0.21**	(0.02)			0.24**	(0.02)			0.25**	(0.04)	0.23 *	(0.08)		0.23	(0.10)	
	SPF																		
	UK									0.73***	(0.00)							0.34**	(0.03)
	BEP																		
Revision of actual GDP																			

(*continued on next page*)

Table 15 (*continued*)

Revision of actual GDP																			
Forecast Timing (days, before target GDP)	CA					45 days									135 days				
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days			138 days				
	BEP																		
	JP	4 days		34 days				66 days				95 days		126 days			157 days		
	SPF																		
	UK									80 days								171 days	
	BEP																		
Forecast Timing (days, before target GDP)	CA					45 days									135 days				
	BEP																		
	US									74 days								165 days	
	SPF																		
	US	6 days				47 days						94 days			138 days				
	BEP																		
	JP	4 days		34 days				66 days				95 days		126 days			157 days		
	SPF																		
	UK									80 days								171 days	
	BEP																		
Revision from 1st to 2nd preliminary quarterly GDP	CA					0.72*	(0.09)								1.15**	(0.03)			
	BEP																		
	US									0.21	(0.38)							0.74*	(0.07)
	SPF																		
	US	-0.01	(0.92)			0.05	(0.79)					0.23	(0.27)		0.49*	(0.07)			
	BEP																		
	JP	-0.11	(0.53)	-0.23	(0.47)			-0.35	(0.37)			-0.38	(0.35)	-0.36	(0.40)		-0.38	(0.37)	
	SPF																		
	UK									2.24*	(0.05)							1.91***	(0.00)
	BEP																		
Revision from 2nd preliminary to latest quarterly GDP	CA					0.13	(0.33)								0.13	(0.49)			
	BEP																		
	US									0.07	(0.34)							0.09	(0.48)
	SPF																		
	US	-0.03	(0.40)			0.04	(0.53)					0.09	(0.28)		0.09	(0.32)			
	BEP																		
	JP	0.03	(0.73)	0.10	(0.42)			0.12	(0.40)			0.10	(0.54)	0.07	(0.69)		0.03	(0.84)	
	SPF																		
	UK									0.29	(0.28)							0.13*	(0.08)
	BEP																		
Revision from 1st preliminary to latest quarterly GDP	CA					0.19	(0.21)								0.23	(0.15)			
	BEP																		
	US									0.10	(0.23)							0.21	(0.21)
	SPF																		
	US	-0.03	(0.37)			0.05	(0.50)					0.13	(0.13)		0.18	(0.10)			
	BEP																		
	JP	0.01	(0.93)	0.04	(0.75)			0.04	(0.82)			0.01	(0.95)	-0.01	(0.95)		-0.04	(0.81)	
	SPF																		
	UK									0.31	(0.24)							0.15**	(0.03)
	BEP																		

Notes: The estimated values in the table show the coefficient of β_2 in equation (5–1,5–2–1, 5–2–2, 5–3–1, 5–3–2, 5–3–3). The numbers in parentheses indicate the results (p-value) of the Wald test with $\beta_2 = 0$. * ** $p < 0.01$, * * $p < 0.05$, * $P < 0.1$.

many forecasts, the addition of major economic statistics cannot be expected to improve the forecast error.[4] When the industrial production index is added as the basic data for the forecast, the forecast error can be expected to improve in only 4 cases (UK BEP in 171 days, JP SPF in 157 days, JP SPF in 95 days and US BEP in 94days). We also found that if industrial production information is added to the forecast in three months before the release of quarterly GDP, it will affect the forecast. But, in the latest forecasts, the addition of industrial production does not affect the forecasts.

The non-manufacturing industry accounts for about 70–80 % of total GDP. Among them, only 5 forecasts (US BEP in 6 days, UK BEP in 80 and 171 days, JP SPF in 66 and 157 days) are significant when we check whether retail sales, which have a large weight in individual industries. In particular, US BEP in 6-days and UK BEP in 171-day predictions strongly show significance. However, many predictions are not significant.

In addition, When the unemployment rate is added, the effect on forecast preparation cannot be confirmed except for UK BEP. In the case of latest forecasts, we find that the unemployment rate has no effect on any of the forecasts (Table 14).

Although some results of efficiency test show that UK forecast is not efficient for first preliminary quarterly GDP, US, Canada and Japan can be judged to be efficient forecasts except some cases. Therefore, we regard that there is another reason why the forecast error in Japan is twice as large as in other countries.

5.3. Impact of actual GDP fluctuation, past forecast error and revision

We evaluate whether past predictions errors or fluctuations or revisions in actual quarterly GDP affect predictions.

5.3.1. Fluctuations of past actual GDP

Top part of Table 15 indicates the results of effect of fluctuations in GDP growth rate. Although the effect cannot be confirmed in the US SPF and US BEP, we find that GDP fluctuations effects in 135 days before of CA BEP and 80 and 171 days before of UK BEP. Furthermore fluctuations in GDP growth rate significantly affect forecast errors in JPF SPF except 4 days before forecast. As shown in Table 11, we can confirm that large fluctuations in quarterly GDP in Japan may be a factor in increasing forecast errors.

5.3.2. Reference to change in past forecast

Middle of Table 15 shows the results of effect to change of the previous forecast. As for the change of the previous prediction, we only find the effects in 45 days before of CA BEP, 126 days before of JP SPF and 80 days before of UK BEP. On the other hand, we significantly confirm that forecasts in JP SPF are affected by information in same time forecast one year ago except for 157 days before. We also find three cases of CA BEP (135 days before) and UK BEP (80 and 171 days before) is influenced by information in same time forecast one year ago.

5.3.3. Revision of actual GDP

Regarding the impact of the revision of GDP, we cannot confirm any significant impact in Japan (bottom of Table 15). However, the revision from 1st to 2nd preliminary has a significant impact on CA BEP (45 and 135 days before), US SPF (165 days before), US BEP (138 days before) and UK BEP (80 and 171 days before). And the revision from 1st and 2nd preliminary to latest quarterly GDP has only two cases in UK BEP (171 days before).

These results show that Japan's forecasts are affected by quarterly GDP fluctuations that can be observed at the time of forecasting. It is also affected by changes in predictions made at the same time one year ago. This may indicate that Japan's forecasts are aware of the seasonality of GDP in each quarter.

[4] The estimation results here may be affected by the statistics used for estimating each country's preliminary GDP.

6. Conclusion remarks

In this paper, we examined the prediction situation of each country through international comparison of forecast errors. From the estimation results, it is confirmed that the forecasting situation in Japan is quite unique compared to other countries. Comparing with the forecast error of each country at the around same time, we found that the forecast error of Japan is about 2 times larger. Since the amount of information required for forecast increases with each revision of the forecast, we find in each country that the forecast error has been reduced. However, in Japan, even immediately before the release of quarterly GDP (around 4 days before), the forecast error is over 1 %, which is the same level of forecast error as 94 days before in the United States and 135 days before in Canada. In other words, the forecast error cannot be reduced even immediately before announcement of quarterly GDP in Japan.

From the evaluation of the characteristics in Japanese and other countries' forecast error, improvement of the forecast error cannot be expected even if major economic statistics are added. We can point out that Japan's forecast is as efficient as that of other countries.

Regarding the Japanese forecast error, we can confirm that although the revision of the actual GDP does not affect the forecast error, fluctuations in the actual GDP and changes in the forecast in the same period one year ago do affect the forecast error. In particular, as seen in Table 11, Japan's actual GDP fluctuations are about twice as large as those of other countries, it suggests that they have a large impact on forecasts.

Problems with Japan's quarterly GDP have already been pointed out as the large fluctuations and large revision. One possible cause of the large fluctuations in quarterly GDP is that there are components such as change in private inventories that high fluctuation and difficult to predict.

For businesses and households, it is necessary to be able to predict future economic trends more accurately to make appropriate decisions now and in the future. In addition, it is natural for policy makers to make predictions regarding major economic statistics that make policy decisions when they assess policy effects. This volatile GDP may make the outlook worse. We require that the forecast error for preliminary quarterly GDP is reduced.

Data Availability

Data will be made available on request.

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