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Predicting the Industry Impacts of Covid-19 Using a Bayesian Structural Time Series Model
— Impact of Roughly 108 Trillion Yen on Sales of Listed Companies —

Yudai Suzuki, Shinpei Ikeno, Shodai Manabe, Yutaro Tachibana, Ryo Nakai
DX Consulting Department
Nomura Research Institute, Ltd.

■ **Summary**

- A Bayesian structural time series model is a time series model with excellent flexibility and readability that enables structured representation of trends, seasonality, and the impacts of exogenous variables that have complex effects.
- This proposal presents a model of the impact of Covid-19 on the sales of listed companies on the basis of the macroeconomic forecast results calculated by Nomura Securities in February and March 2020, before and after the effects of Covid-19 became apparent.
- As a result of the above, the impact on the sales of listed companies is estimated to be about 108 trillion yen, the industry with the largest impact is the transportation equipment industry, and the peak impact is predicted to be the first quarter of 2020.
- Going forward, we plan to revise our predictions in conjunction with the latest macroeconomic forecasts, and to offer more detailed analyses of each industry from time to time.

■ **Characteristics of a Bayesian Structural Time Series Model**

A structural time series model is a kind of state-space model, and is a model that can separately express different components (trends, seasonality, etc.) existing in a time series. As one example of this, in 2017, Steven L. Scott proposed a Bayesian structural time series model that can take in various exogenous variables in addition to components such as trends and seasonality[*1]. Generally, time-series data has a small number of points (e.g., even if there is monthly data for five years, there are only 60 points) and is not good at incorporating a large number of explanatory variables, but in a Bayesian structural time series

model, a "spike and slab" regression:[*2] is applied to the explanatory variables and the degree of influence of each variable on the prediction is updated by a Bayesian approach, making it easier to adopt some important variables, while other variables become more difficult to adopt. As a result, the model is capable of achieving improved model stability when a large number of exogenous variables are inputted, and expressing which variables are more important in a probabilistic manner.

■ Modeling the Impact of Covid-19 on Different Industries

In this proposal, using the above model, we forecast the quarterly sales of listed companies in each industry up to FY2021, using forecasted of macroeconomic indicators as explanatory variables. The data used to create the model are as follows.

Category	Subject	Term	Source/Acquisition Date
Objective variables	Sales by industry of Japanese l isted companies based on classified 33 industrial sectors of Tokyo Stock Exchange	2007 Q1–2019 Q3	Securities reports/ quarterly reports
Explanatory variables (Actual values)	Macroeconomic indicators (18 categories)	2007 Q1–2019 Q3	Government statistics[*3]
Explanatory variables (Forecasted values)	Macroeconomic indicators (18 categories)	2019 Q4–2021 Q4	Nomura Report[*4] "Japan: Economic Outlook for 2019-2021" (February 17, 2020) Nomura Report "Japan: Economic Outlook for FY 2019-2021 (revised)" (March 27, 2020)

We will use specific cases to demonstrate the rationale and results of the model.

1. Setting the Objective Variables

First, among all the companies listed on the Japanese stock exchanges, the subject companies are those that had sales in the third quarter of 2019. The objective variable is the aggregated quarterly sales by industry of each of these companies from 2007 to the third quarter of 2019[*5].

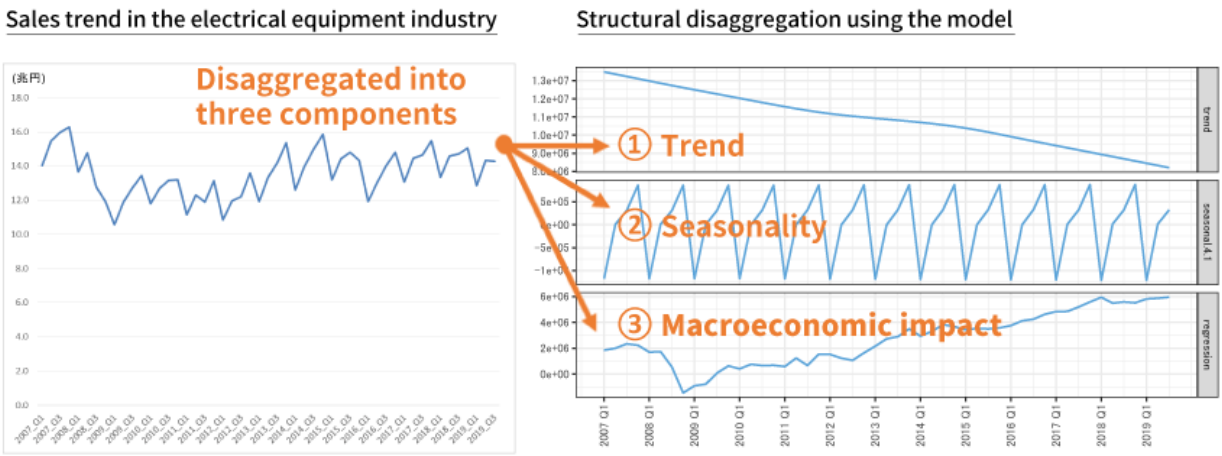
2. Setting the Explanatory Variables

The explanatory variables used are 18 types of macroeconomic indicators, including GDP, in addition to the characteristics of the series itself, such as trends and seasonal factors. These are based on the indicators forecast by Nomura Securities in the economic forecasts conducted in February and March 2020.

3. Structure and Interpretation of Model

As discussed above, the main characteristics of a Bayesian structural time are that **a) the model structure can be expressed in a disaggregated manner**, and **b) the importance of each explanatory variable can be evaluated**. First, the characteristic of a) will be explained taking the electrical equipment industry as an example. The left side of Fig. 1 shows the sales trend in the electrical equipment industry since 2007. It is disaggregated into three components using a Bayesian structural time series model. The first of these is the trend. Although the market appears to be flat, the model estimates that the underlying market trend is declining, as the market is not growing relative to macroeconomic growth. The second component is seasonality. The model captures the cyclical trend of increasing sales from the first quarter to the fourth quarter and peaking in the third quarter. The third is the effect of explanatory variables, which in this model show the effect of macroeconomic indicators. It can be seen that the impact of the Lehman shock was most pronounced starting from the latter half of 2008, but since then the impact of the earthquake and that of the consumption tax hike etc. have been relatively minor, and overall it is judged to have been on an upward trend for several years.

Fig. 1: Sales Trend Transition and Structural Disassembly by Model in the Electrical Equipment Industry



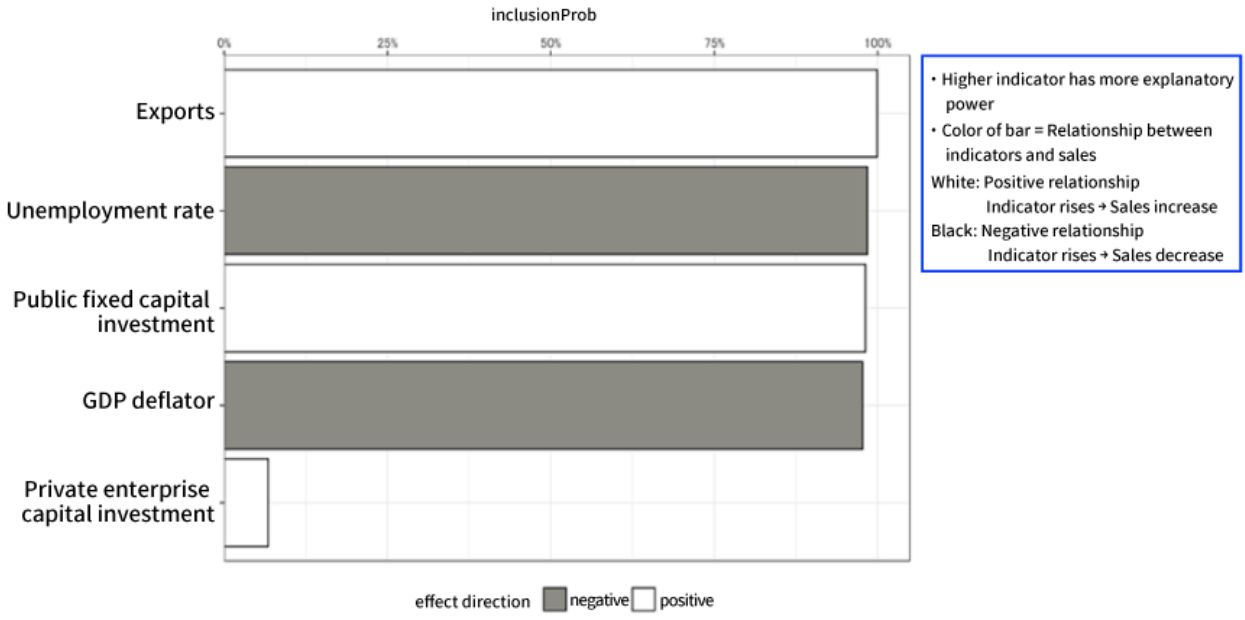
The above is an explanation of the feature **a) that the model structure can be expressed in a disaggregated manner.**

Next, we will explain **b) that the importance of each explanatory variable can be evaluated by giving an actual example.** Fig. 2 shows "Inclusion Probability", which is the probability that the regression coefficient of each economic index is not 0 (i.e., impacts the predictions of the model)[*6]. For example, in the figure below, "export" is adopted as an explanatory variable with a probability of almost 100%,

while “private enterprise capital investment” has a probability of adoption of less than 10%, and the impact is relatively small.

Further, the color coding of the bar on the graph shows the relationship between each index and the amount of sales. White indicates a positive relationship, and black indicates a negative relationship. For example, taking the unemployment rate as an example, it is natural to think that the lower the unemployment rate is, the better the economy will be and the more positive it will be for sales, and it is natural to assume a negative relationship. The bars on the model are also represented as black, suggesting a negative relationship. In practice, it is important to adopt appropriate explanatory variables from the perspective of business and interpretability in view of the relationship between explanatory variables and objective variables as described above.

Fig. 2. Materiality Assessment of Macroeconomic Indicators in the Prediction Model in the Electrical Equipment Industry

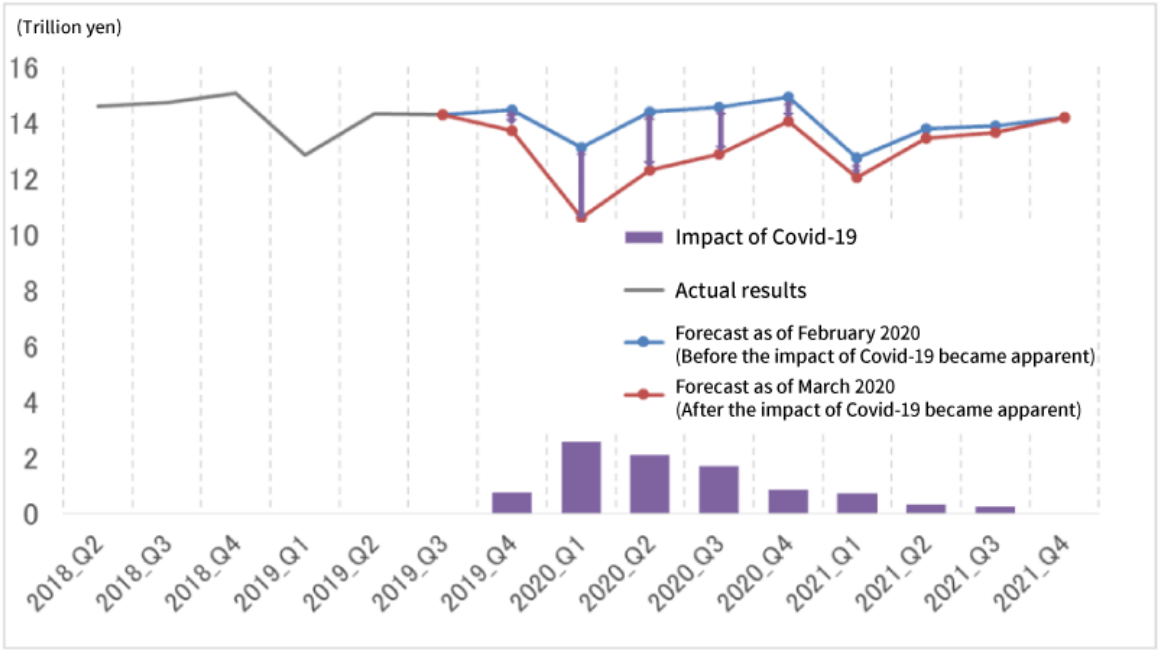


4. Estimating the Impacts of Covid-19

This proposal aims to estimate the impact of Covid-19 by the difference between the forecasts of economic indicators before (as of February 20) and after (as of March 20) the impact of Covid-19 became apparent. See Fig. 3 for details. First, the actual results are shown as a gray line until the third quarter of 2019. The blue line is the sales forecast of the electrical equipment industry based on the forecast of macroeconomic indicators as of February 2020. As of February 20th, although the impact of Covid-19 was expected, it was mainly discussed in terms of the Chinese economy, such as a decrease in inbound demand due to the shutdown of major cities in China and a decrease in exports to China,

and it was thought that the impact would be relatively minor. Meanwhile, the red line is the forecast as of March 2020. This is a scenario that considers the effects of the stagnation of the world economy and the decrease in domestic consumption due to stay-at-home guidelines. In this paper, the purple difference bounded by these two lines is defined as "the impact of Covid-19 on listed companies." In the electrical equipment industry, the impact of Covid-19 was in full swing and at its greatest in the first quarter of 2020 and has been gradually diminishing, but it is estimated that the downward trend will continue until the third quarter of 2021. Naturally, the scale and duration of impacts will differ from industry to industry. In the next section, we list the estimation results by industry and consider the overall trend.

Fig. 3: Estimating the Impact of Covid-19 using the Prediction Model in the Electrical Equipment Industry



■ Forecast Results

Table 1 shows the estimated impact of Covid-19. Regarding the impact on all listed companies from the fourth quarter of 2019 to the fourth quarter of 2021, the loss due to Covid-19 is forecasted to be about 108 trillion yen[*7]. This is about 6% of total sales, and is expected to reach about 11% in the first quarter of 2020, which will see the greatest impact. Although it will later recover from the impact, it is expected that it will be difficult to regain the sales that would have been achieved in 2021 had Covid-19 not occurred.

The CFO Survey, regularly conducted by Professor John Graham of Duke University for more than 20 years, has surveyed CFOs around the world about the outlook for sales in the coming year. According to the results of the survey conducted starting on March 15, 2020, CFOs in the Americas and Europe expect sales

to decline by 1-2% in the most likely cases, and by about 15%. in the worst case[*8]. Considering the original difference in growth potential between Japanese companies and Western companies, it can be said that the sales decrease of about 6% estimated by this model is sufficiently realistic. It is suggested that, in light of these forecasts, companies should prepare for a decline in not only short-term cash flow but also long-term sales.

Table 1 Sales Forecast (Before/after the impact of Covid-19 became apparent)

*(Trillion yen)

Year	Quarter	Sales forecast		Impact (estimate)	
		As of March (Impact of Covid-19 is considered)	As of February (Before the impact of Covid-19 became apparent)	Amount	Ratio (Forecast ratio as of February)
		1,829.32	1,937.19	-107.86	-5.57%
2019	Q4	205.97	214.58	-8.61	-4.01%
2020	Total	788.13	856.04	-67.91	-7.93%
	Q1	183.36	205.95	-22.59	-10.97%
	Q2	196.38	213.18	-16.80	-7.88%
	Q3	198.35	215.49	-17.13	-7.95%
	Q4	210.04	221.42	-11.38	-5.14%
2021	Total	835.22	866.56	-31.34	-3.62%
	Q1	196.75	207.63	-10.88	-5.24%
	Q2	207.52	215.66	-8.13	-3.77%
	Q3	211.31	218.71	-7.41	-3.39%
	Q4	219.64	224.57	-4.93	-2.19%

Table 2 (Reference) FY 2018 Sales Results

*(Trillion yen)

Year	Quarter	Sales results
2018	Total for the period	837.84
	Q1	201.12
	Q2	208.67
	Q3	213.29
	Q4	214.77

Table 3 shows the impact forecast by industry. The industries that are expected to experience a particularly large impact are equipment manufacturers, with transportation equipment manufacturers being representative examples of this. Their businesses are highly linked to the economy and are expected to be the most affected. In addition, a large decrease is forecasted in industries that are easily affected by the import and export situation of steel and other commodities. Meanwhile, the impact on retail foodstuffs with strong domestic demand and the pharmaceutical industry is relatively small. This is probably because a certain amount of demand is stable regardless of economic fluctuations. The impact forecasted here is based on the economic outlook and does not take into account the impact of the restriction of movement peculiar to measures for Covid-19 (e.g., air transportation).

The variables used for prediction have been selected using a statistical model, but the variables mainly used in the model are listed in Table 4. GDP, fluctuations thereof, the unemployment rate, and imports and exports are used for most industries. For industries with more BtoC business, consumer price indices are also used. For industries with more BtoB business, forecasts consist of the GDP deflator, which represents prices, as well as industrial production, capital investment by private companies, and the like.

■ Proposal Based on Forecast Results

In this proposal, we estimated how each industry would be impacted in accordance with the economic outlook by building our own forecasting model. Of course, factors unique to Covid-19, especially the direct restriction on the movement and activities of people, may have a greater impact on some industries, and conversely, some industries such as the telecommunications industry may not necessarily experience a negative impact. In business activities, proper forecasting is the first step in building the right strategy. In public policy, a good estimate of the impact could give priority to supporting industries that are likely to face more difficult situations. We hope that the impacts estimated in this paper will be used as the starting point for discussions, and from that point on how much upside/downside is expected depending on industry-specific trends will be examined.

Going forward, we will continue to update industry-specific forecasts in conjunction with the revision of the economic outlook, and we will also delve into specific industries and offer future outlooks.

Table 3 Sales Forcast (by Industry, before/After appearance of Covid-19)

*(1 billion yen)

Industry	Total for the period				Trend of impact ratio									
	Sales forecast as of March (Impact of Covid-19 is considered)	Sales forecast as of February (Before impact of Covid-19 became apparent)	Impact amount (estimate)	Impact ratio (estimate; forecast ratio as of February)	2019 Q4	2020 Q1	2020 Q2	2020 Q3	2020 Q4	2021 Q1	2021 Q2	2021 Q3	2021 Q4	(Reference) 2018 sales results
Total	1,829,322	1,937,186	-107,865	-6%	96%	89%	92%	92%	95%	95%	96%	97%	98%	837,840
Transportation equipment	208,911	231,025	-22,114	-10%	92%	76%	89%	87%	93%	92%	94%	94%	97%	103,738
Wholesale business	234,029	250,140	-16,111	-6%	96%	91%	92%	92%	93%	93%	94%	95%	95%	111,061
Electrical equipment	163,901	176,719	-12,818	-7%	95%	81%	86%	88%	94%	95%	98%	98%	100%	81,884
Chemicals	85,949	93,537	-7,587	-8%	94%	83%	89%	88%	92%	92%	95%	95%	97%	41,152
Machinery	66,787	73,672	-6,884	-9%	95%	83%	86%	86%	91%	91%	93%	94%	97%	32,378
Iron and steel	28,961	34,662	-5,701	-16%	90%	72%	76%	75%	83%	84%	88%	90%	94%	14,036
Electric power and gas	55,333	60,406	-5,073	-8%	97%	89%	90%	88%	92%	91%	92%	91%	93%	26,232
Banking	57,833	62,313	-4,480	-7%	95%	91%	91%	89%	92%	92%	93%	94%	97%	27,416
Nonferrous metals	20,576	23,847	-3,270	-14%	92%	71%	77%	79%	87%	88%	93%	94%	96%	11,144
Oil and coal products	43,669	46,644	-2,975	-6%	96%	90%	91%	90%	93%	93%	95%	96%	97%	19,157
Marine transportation	5,455	7,502	-2,047	-27%	83%	64%	67%	62%	70%	70%	77%	79%	86%	4,337
Services	87,401	89,213	-1,812	-2%	98%	96%	97%	97%	98%	98%	99%	99%	99%	35,875
Information & communication	129,198	130,940	-1,741	-1%	98%	96%	97%	98%	99%	100%	100%	100%	100%	53,956
Foodstuffs	60,310	61,869	-1,558	-3%	98%	97%	97%	97%	97%	97%	98%	98%	99%	26,979
Land transportation	57,195	58,739	-1,544	-3%	98%	95%	96%	96%	97%	98%	98%	99%	99%	24,917
Rubber products	13,859	15,177	-1,318	-9%	90%	83%	91%	89%	92%	92%	94%	95%	97%	6,695
Other products	22,255	23,544	-1,289	-5%	98%	95%	94%	93%	94%	93%	94%	95%	96%	10,276
Glass and ceramics products	15,159	16,440	-1,281	-8%	95%	86%	88%	88%	92%	92%	95%	95%	97%	7,177
Construction	84,519	85,776	-1,257	-1%	99%	98%	98%	98%	99%	98%	99%	99%	100%	34,337
Insurance	72,663	73,824	-1,161	-2%	99%	98%	98%	98%	98%	98%	98%	99%	99%	33,634
Textiles and apparel	12,641	13,752	-1,111	-8%	95%	87%	89%	89%	92%	92%	94%	94%	96%	6,205
Metal products	17,913	18,994	-1,081	-6%	96%	91%	92%	92%	94%	94%	96%	96%	98%	8,180
Retail business	151,853	152,833	-979	-1%	99%	99%	99%	99%	99%	100%	100%	100%	100%	61,611
Precision instruments	11,634	12,453	-819	-7%	96%	84%	89%	90%	94%	95%	97%	97%	99%	5,472
Securities and commodities futures	7,239	7,871	-632	-8%	92%	82%	89%	90%	94%	94%	95%	95%	96%	3,458
Pulp and paper	11,001	11,482	-481	-4%	97%	91%	93%	94%	96%	97%	98%	98%	98%	5,035
Aviation	8,006	8,484	-478	-6%	96%	90%	92%	92%	94%	94%	96%	97%	98%	3,665
Real estate	33,219	33,607	-387	-1%	99%	98%	98%	98%	99%	99%	99%	99%	100%	13,174
Warehousing and logistics	6,767	7,034	-266	-4%	98%	96%	95%	95%	96%	96%	96%	97%	98%	2,984
Mining	1,049	1,226	-177	-14%	90%	83%	82%	82%	86%	86%	86%	88%	88%	553
Fisheries, agriculture & forestry	4,857	4,977	-120	-2%	95%	96%	97%	97%	98%	98%	99%	99%	99%	2,127
Other financial business	19,553	19,567	-14	-0%	100%	100%	100%	100%	100%	100%	100%	100%	100%	8,250
Pharmaceuticals	29,624	28,921	704	2%	101%	102%	103%	104%	103%	103%	103%	102%	101%	10,742

Table 4 List of Adopted Variables

Industry	Adopted variables
0050. Fisheries, agriculture & forestry	GDP deflator, Unemployment rate, Consumer price index; CPI, Imports
1050. Mining	GDP deflator,Indices of industrial production; IIP,Producer price index; PPI, Exports, Imports
2050. Construction	Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Private housing investment
3050. Foodstuffs	Unemployment rate, Private enterprise capital investments, Imports
3100. Textiles and apparel	GDP deflator, Unemployment rate, Private enterprise capital investments, Private final consumption expenditure
3150. Pulp and paper	GDP deflator, Unemployment rate, Private enterprise capital investments, Exports, Imports
3200. Chemicals	GDP (difference), Unemployment rate, Exports, Imports
3250. Pharmaceuticals	GDP, GDP (difference), Unemployment rate
3300. Oil and coal products	Unemployment rate, Indices of industrial production; IIP, Exports
3350. Rubber products	GDP (difference), Unemployment rate, Exports, Imports
3400. Glass and ceramics products	GDP (difference), GDP deflator, Unemployment rate, Public fixed capital investment, Indices of industrial production; IIP, Private enterprise capital investments, Exports, Imports
3450. Iron and steel	GDP (difference), GDP deflator, Unemployment rate, Indices of industrial production; IIP, Private enterprise capital investments, Exports, Imports
3500. Nonferrous metals	GDP deflator, Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Exports, Imports
3550. Metal products	GDP (difference), GDP deflator, Unemployment rate, Public fixed capital investment,Indices of industrial production; IIP, Private enterprise capital investments, Exports, Imports
3600. Machinery	GDP (difference), GDP deflator, Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Exports, Imports
3650. Electrical equipment	GDP deflator, Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Exports
3700. Transportation equipment	GDP (difference), Unemployment rate, Indices of industrial production; IIP, Exports
3750. Precision instruments	GDP deflator, Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Exports
3800. Other products	GDP deflator, Unemployment rate, Producer price index; PPI, Private enterprise capital investments
4050. Electric power and gas	GDP deflator, Unemployment rate, Producer price index; PPI, Private enterprise capital investments
5050. Land transportation	GDP deflator, Unemployment rate, Indices of industrial production; IIP, Private enterprise capital investments, Imports
5100. Marine transportation	Unemployment rate, Producer price index; PPI, Exports, Imports
5150. Air transportation	GDP deflator, Unemployment rate, Indices of industrial production; IIP, Private enterprise capital investments, Exports, Imports
5200. Warehousing and logistics	GDP, Unemployment rate, Indices of industrial production; IIP, Private Inventory investment
5250. Information & communication	Public fixed capital investment, Consumer price index; CPI, Private enterprise capital investments, Private final consumption expenditure, Imports
6050. Wholesale business	GDP deflator, Unemployment rate, Indices of industrial production; IIP, Producer price index; PPI, Exports, Imports
6100. Retail business	Unemployment rate, Indices of industrial production; IIP, Consumer price index; CPI, Private final consumption expenditure, Exports, Imports
7050. Banking	GDP, GDP (difference), GDP deflator, Unemployment rate, Private enterprise capital investments, Private final consumption expenditure, Exports
7100. Securities and commodities futures	GDP, GDP (difference), GDP deflator, Unemployment rate, Private enterprise capital investments, Private final consumption expenditure, Exports
7150. Insurance	GDP, GDP (difference), GDP deflator, Unemployment rate, Private enterprise capital investments, Private final consumption expenditure
7200. Other financial business	GDP, GDP (difference), Unemployment rate
8050. Real estate	Unemployment rate, Public fixed capital investment, Private enterprise capital investments, Private housing investment
9050. Services	GDP deflator, Unemployment rate, Private enterprise capital investments, Private final consumption expenditure, Exports, Imports

*1：Steven L. Scott and Hal R. *Varian, Predicting the present with Bayesian structural time series,* International Journal of Mathematical Modelling and Numerical Optimisation, Vol. 5, No. 1/2, 2014.

*2：See *1 above for details.

*3：“National Accounts” (Cabinet Office), “Industrial Production/Shipping/Inventory Index” (Ministry of Economy, Trade and Industry), “Corporate Price Index” (Bank of Japan, Research and Statistics Bureau), “2015 Consumer Price Index” (Ministry of Internal Affairs and Communications), "2010 Standard Consumer Price Index" (Ministry of Internal Affairs and Communications), "Labor Force

Survey" (Ministry of Internal Affairs and Communications) (acquired March 31, 2020); however, 2010-based indicators were processed by NRI on the basis of 2015 standards.

*4： Economic Research Department, Nomura Securities Financial and Economic Research Institute. "Economic Outlook for FY2019-2021-Economic Recovery Facing Lagging Risk", March 19, 2020, p.36. Nomura Securities. "Japan: Revised Economic Outlook for 2019-2021", "Global Markets Research", March 27, 2020, p.3.

*5： As for companies for which some sales records could not be collected from 2007 to the third quarter of 2019 are not included in the modeling, expansion and industry-wide sales were estimated after the model was built.

*6： Please note that, because the explanatory variables that were ultimately inputted were adjusted by the analysts taking into consideration the rationality of the degree of influence, causal relationships, and other factors, not all 18 types of economic indicators have been inputted.

*7： Please note that this forecast uses the data of listed companies, and the impact would be greater if unlisted companies were included.

*8： No official report has been published yet (as of April 24, 2020), but a video presentation (held April 22, 2020) at https://www.fuqua.duke.edu/linkedin-live is available, so please check there for details.

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https://www.nri.com/en/keyword/proposal

Inquiries about the proposals:
Center for Strategic Management & Innovation
Nomura Research Institute, Ltd.
E-mail: miraisouhatsu@nri.co.jp

Media Inquiries:
Corporate Communication Department
Nomura Research Institute, Ltd.
TEL: +81-3-5877-7100
E-mail: kouhou@nri.co.jp