Rate of extent to which crude oil prices are passed through to gasoline prices

Estimating recent conditions using neural network

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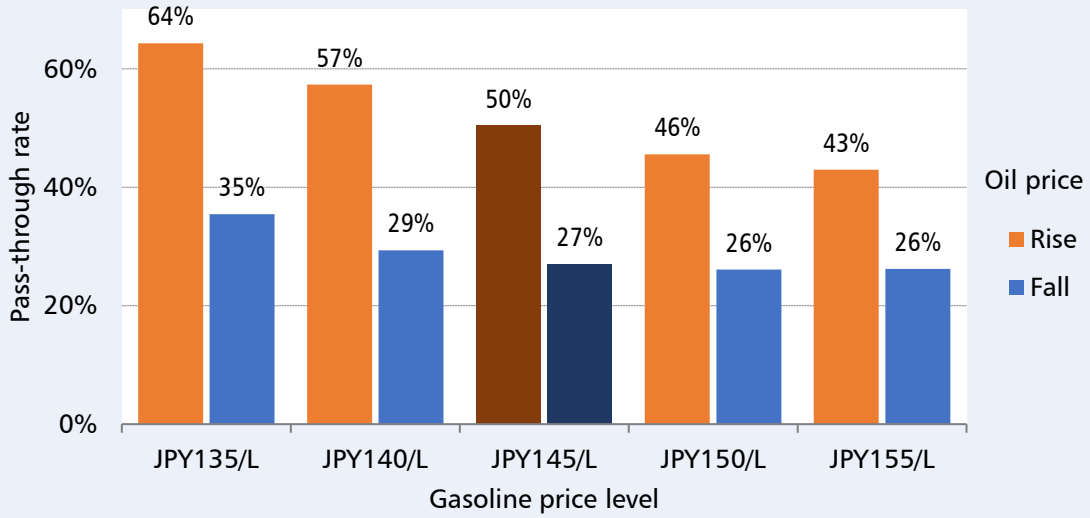
Summary

Gasoline prices are rising in Japan. This is because crude oil prices are increasing on a joint oil production cut by OPEC and other oil producing countries and the fluid Middle Eastern situation, with the Japanese yen's depreciation inflating yen-denominated oil prices. As bullish views about oil prices have spread further on the United States' withdrawal from the Iran nuclear deal and other developments, public concerns on future gasoline prices are growing. The recent conditions of multiple factors that price gasoline are modelled for this paper.

Generally, model analyses assume model structures such as linear. Such assumption could occasionally have great effects on analysis results. In a bid to mitigate such potential effects, we used an artificial neural network model, a kind of artificial intelligence. The developed model is as accurate as the Oil Information Center, an oil price expert, in predicting the direction of gasoline prices one week ahead.

The rate of the extent to which oil price changes are passed through to gasoline prices is important for predicting future gasoline prices. The pass-through rate is now at low levels. This apparently indicates that gasoline prices are adjusted not only to the crude oil cost but also to supply and demand fundamentals in the gasoline market. Pass-through rate levels for oil price hikes differ from those for price drops, indicating their asymmetric relationship. Their gap may be greater when gasoline prices are lower.

Figure | Rate of extent to which oil prices are passed through to gasoline prices (by price level)



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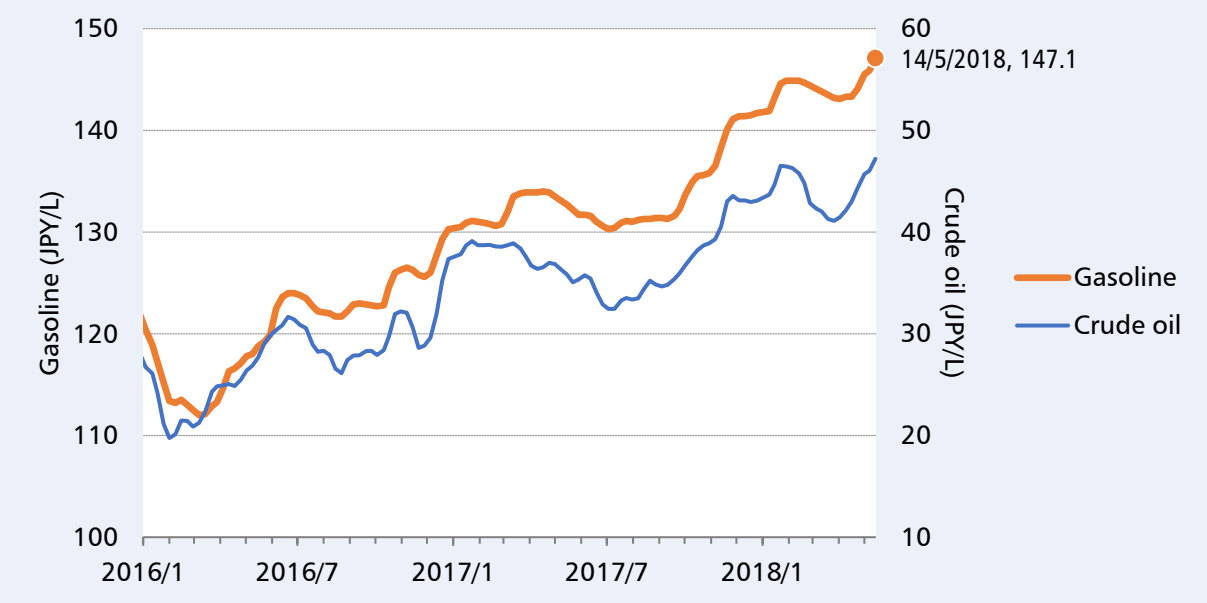
Pass-through rate differences are caused by other factors as well. For example, oil price hikes on Wednesday lead to gasoline price increases more easily than on any other day of the week. Meanwhile, oil price falls on Wednesday are more difficult to be reflected in gasoline prices than on any other day of the week.

Rising gasoline prices

Gasoline prices are rising in Japan (Figure 1). The average retail price of regular gasoline in May 2018 hit a 41-month high (Agency for Natural Resources and Energy "Petroleum Products Price Survey"). This is because crude oil prices are increasing in the international market on a joint production cut by OPEC and other oil producing countries, a rapid fall in Venezuelan crude oil production, the Middle Eastern situation including Syria and Iran problems, and other factors, with the yen's depreciation inflating yen-denominated oil prices. Also contributing to gasoline price hikes is a rise in oil refining and distribution margins in recent years that has come as supply to the spot gasoline market decreased due to measures taken by the March 2017 deadline under the Act on the Promotion of Use of Non-fossil Energy Sources and Effective Use of Fossil Energy Materials by Energy Suppliers and the establishment of JXTG Nippon Oil & Energy Corporation in April 2017.

Figure 1 | Gasoline and crude oil prices



Note: The gasoline price represents the average gas station retail price. The crude oil price represents the moving average of settlement prices seven to 20 days ago for the front-month futures contract on the Platts Dubai crude oil.
Source: Agency for Natural Resources and Energy "Petroleum Products Price Survey" [gasoline prices], Tokyo Commodity Exchange [crude oil prices]

As bullish views about oil prices have spread on the United States' withdrawal from the Iran nuclear deal and other developments, public concerns on the future course of gasoline prices are growing. Multiple factors that price gasoline are modelled quantitatively for this paper to determine each factor's contribution to gasoline prices, enabling an analysis that is deeper than the simple comparison between prices at different times saying that oil and gasoline prices rose by xx yen/L and yy yen/L, respectively, from last week.

Developing and assessing neural network model

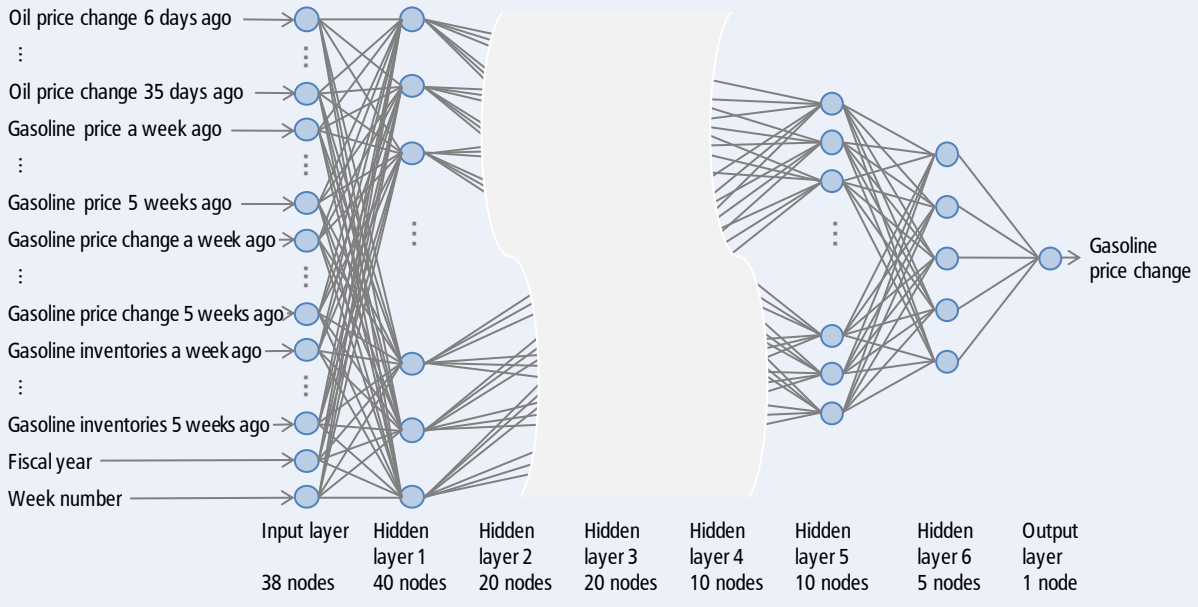
We took up the relationship between crude oil and gasoline prices in the past, based on a single equation model developed through a multiple linear regression analysis. The orthodox approach is advantageous in that it is highly transparent and easy to understand. However, assumed model structures (such as linear ones), degree of freedom (the number of parameters is limited to that of samples), multicollinearity (unstable estimation results emerging from the use of similarly moving explanatory variables), changes in structures and other problems may become constraints on analyses[1].

In a bid to mitigate these constraints and consider the situational changes in the spring of 2017, we have developed an artificial neural network model, a kind of artificial intelligence, for analysing the relationship between oil and gasoline prices. The neural network represents a combination of mathematical models of human brain neurons. While each neuron works simply, a multi-layer network of numerous neurons can provide complicated expressions. Although neural networks have been used most for pattern matching including image recognition processing, it can be applied to issues for which regression analyses are used frequently. Given its structure and size, however, a neural network can become a black box, making it difficult occasionally for humans to understand or interpret the network's behaviours.

The neural network used for this paper produces a weekly gasoline price[2] change as an output from 38 inputs: daily oil price[3] changes on trading days six to 35 days ago, gasoline price levels one to five weeks ago, weekly gasoline price changes one to five weeks ago, gasoline inventories[4] one to five weeks ago, the fiscal year and the week number (1 to 53). The number of hidden layers stands at six, with the maximum number of nodes reaching 40. The neural network is thus relatively small[5] (Figure 2).

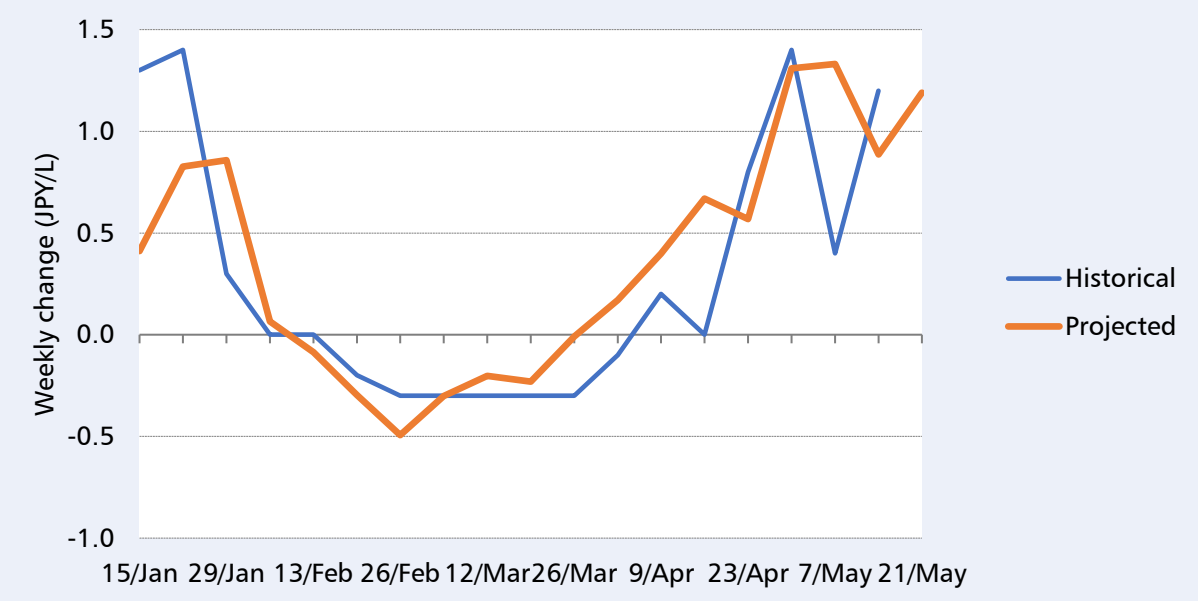
[1] Statistical methods to counter such constraints have been developed.
[2] The retail price of regular gasoline (Monday) in the "Petroleum Products Price Survey" by the Agency for Natural Resources and Energy.
[3] Settlement prices for the front-month futures contract on the Platts Dubai crude oil on the Tokyo Commodity Exchange (Monday through Friday)
[4] Inventories (Saturday) in "Weekly Crude Oil and Petroleum Products Supply Statistics" by the Petroleum Association of Japan
[5] This is because the number of data samples for model estimation is limited to around 200. For comparison, the policy network to explore the next move in Google's AlphaGo, which impressed the world with its AI/neural network capabilities by defeating a top Go player in 2016, had 17,328 nodes for the input layer, 69,312 nodes for each of the 12 hidden layers and 361 nodes for the output layer. A total of 28.4 million game records were used for learning (H. Yoshida, N. Itoh "AlphaGo no shikumi [AlphaGo composition]").

Figure 2 | Model flow



Under this formula, we first estimated the model for gasoline price changes between April 2014 and December 2017. To assess the accuracy of the estimated model, we projected weekly gasoline price changes for the period from January 2018 that was not covered by the model estimation. Figure 3 shows the projection results. Given that differences are projected, the projection results are apparently good.

Figure 3 | Projected weekly gasoline price changes [January - May 2018]



Source: Agency for Natural Resources and Energy "Petroleum Products Price Survey" [historical]

Box 1 | Accuracy of projection

The Oil Information Center (OIC), which undertakes the petroleum products price survey, gives a gasoline price outlook for the next week in a manner to respond to questions from mass media. Instead of predicting any quantitative price change, however, OIC indicates price directions such as a rise and a level-off for the next week. Here, we assess the performance of the developed model by comparing its projection with the OIC outlook under the following approach:

[1] Weekly gasoline price outlook comments by OIC over the past half year are classified into five categories – a fall, a slight fall, a level-off, a slight rise and a rise.

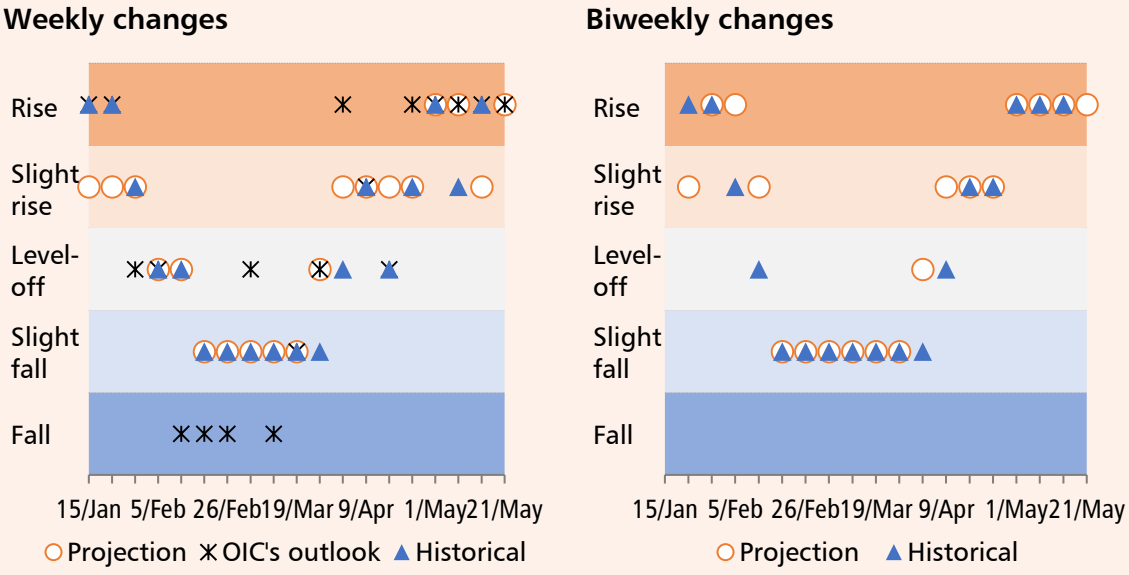
[2] Historical weekly gasoline price changes are classified into the above five categories.

The threshold between categories is set to allow OIC outlook comments to meet the results most[7]. Then, a fall stands for a fall of more than JPY1.1/L, a slight fall for a fall of JPY0.15/L - JPY1.1/L, a level-off for a fall or rise of up to JPY0.15/L, a slight rise for a rise of JPY0.15/L - JPY1.1/L and a rise for a rise of more than JPY1.1/L.

[3] Weekly price changes projected by the developed model are also classified into the categories as specified in [2].

The left side of Figure 4 indicates the classification results, showing that the model's projection is as accurate as or more accurate than the oil price expert's prediction. The model's projection of biweekly gasoline price changes is given in the right side of Figure 4. The biweekly price change projection is slightly less accurate than the weekly change projection. In forecasting biweekly price changes in the absence of OIC's outlook for such changes, however, the neural network model can be expected to play a role.

Figure 4 | Projected gasoline price changes [January - May 2018]



Note: a fall stands for a fall of more than JPY1.1/L, a slight fall for a fall of JPY0.15/L - JPY1.1/L, a level-off for a fall or rise of up to JPY0.15/L, a slight rise for a rise of JPY0.15/L - JPY1.1/L and a rise for a rise of more than JPY1.1/L.
Sources: Media reports about Oil Information Center outlook, Agency for Natural Resources and Energy "Petroleum Products Price Survey" [historical]

[7] For the sake of convenience, price changes are given in JPY0.05/L increments and made symmetrical about JPY0/L.

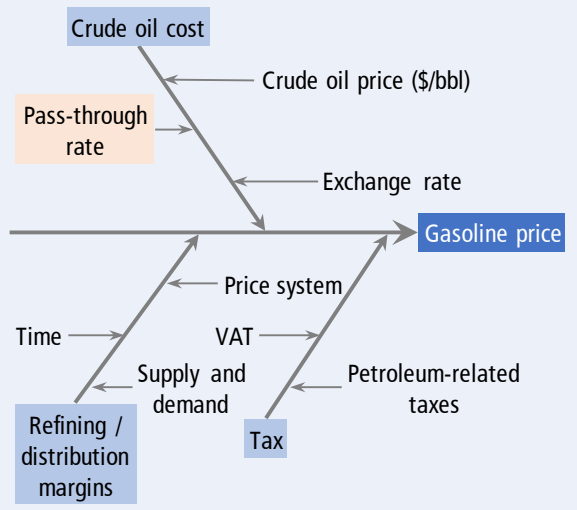
Present oil price pass-through rates for gasoline prices

Given the assessment in the previous chapter, it is deemed that the neural network model can be used for a gasoline price analysis at a certain degree of accuracy. So, we use the neural network model for analysing the rate of the extent to which the crude oil price as a key determinant of the gasoline price is passed through to the gasoline price – the rate of a oil price change's contribution to a gasoline price change.

A gasoline price is influenced by various factors. Representative factors include the crude oil cost, refining and distribution margins and tax (Figure 5). In the developed model, the yen-denominated oil price as an explanatory variable can be deemed as the crude oil cost factor. Refining and distribution margins can be deemed as explained by gasoline inventories as a proxy variable for supply and demand conditions, the fiscal year and the week number. The crude oil cost pass-through rate represents an oil price change's contribution to a gasoline price change in the absence of changes in the other variables, or the oil price's influence on the gasoline price. Given that the crude oil cost accounts for a large share of total costs for petroleum products, the oil price pass-through rate is an indicator worthy of attention.

To assess the latest situation, the model re-estimated covering up-to-date data under the formulation as described in the previous chapter is used.

Figure 5 | Examples of factors influencing gasoline prices



In the following single equation model, parameter β indicates the pass-through rate.

ΔGasoline price = α + β ΔCrude oil price + …

For a neural network, however, the number of parameters tends to be enormous, with parameters being arranged complicatedly[8]. This means that it is difficult to directly pick up the pass-through rate from parameters in a neural network. So, a sensitivity analysis is used to estimate the pass-through rate. Then, up-to-date data (for March-April 2018) are used for parameters other than variables, with the weekly oil price fluctuation put at JPY2/L.

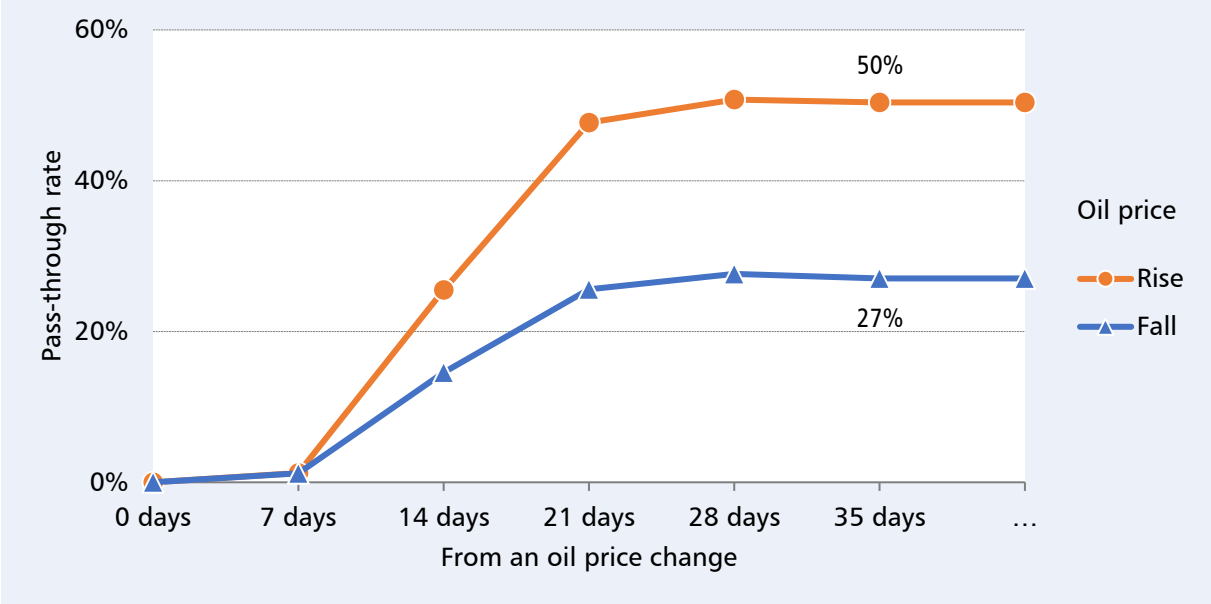
Current pass-through rates are low

It is known that the pass-through of crude oil price changes to gasoline prices is accompanied by a time lag. Currently, some one month is required for the pass-through. Final pass-through rates are not so high, slipping far below 100% (Figure 6). The rate stands at 50%[9] when oil prices rise, against 27% when oil prices fall. The gap of more than 23 percentage points indicates that the pass-through is asymmetric.

[8] The model developed for this paper is a relatively small neural network. Even so, the number of parameters exceeds 3,000.

[9] The pass-through rate of 50% means that 50% of an oil price hike contributes to a gasoline price increase. Gasoline prices change depending not only on oil price changes but also other factors. Faster gasoline price increases than oil price hikes since the spring of 2017 indicate the presence of factors other than the pass-through rather than a pass-through rate of more than 100%.

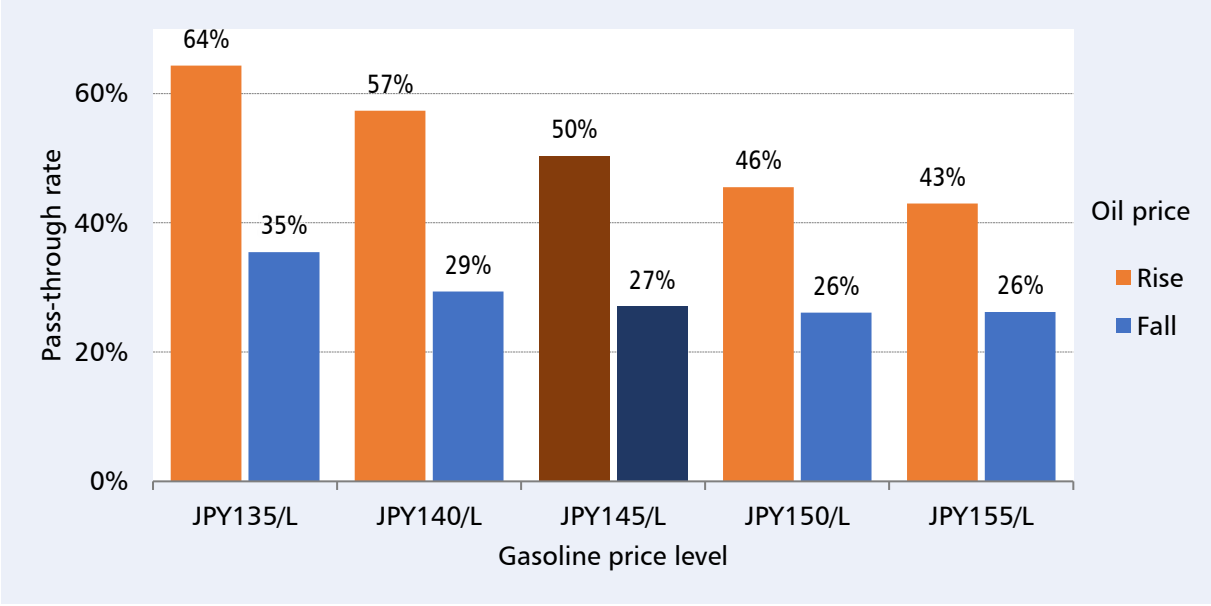
Figure 6 | Oil price pass-through rates for gasoline prices



Gasoline price levels and pass-through rates – Slower gasoline price hikes at higher price levels

"We hesitate to implement a gasoline price increase at high price levels that could lead to customer losses," gas station operators say occasionally. To analyse such comment, we computed a pass-through rate (a theoretical model value) by gasoline price level.

Figure 7 | Oil price pass-through rates for gasoline prices (by gasoline price level)



In fact, the pass-through rate differs by price level (Figure 7). The pass-through rate for an increase at the price level of JPY155/L is more than 20 points lower than that at the level of JPY135/L. The pass-through rate for a price cut is also low at higher price levels. This apparently indicates that an oil price hike portion failing to be passed through to gasoline prices at high

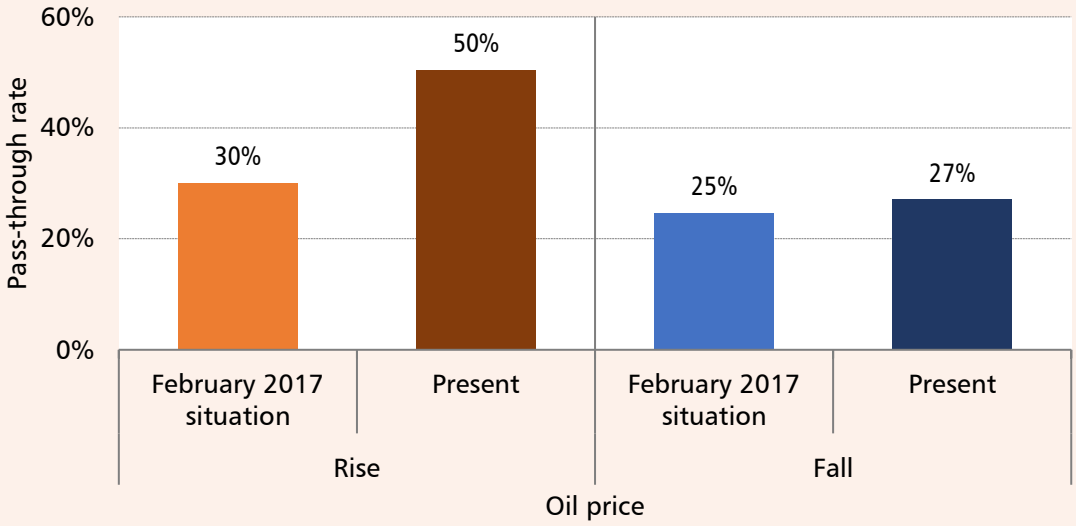
price levels is covered with a restriction on a price cut. At any price level, the pass-through rate for a price hike differs from that for a price cut. The difference is greater at lower price levels.

Box 2 | Difference from a year-earlier situation

The second notice under the Act on the Promotion of Use of Non-Fossil Energy Sources and Effective Use of Fossil Energy Materials by Energy Suppliers called for the residual oil processing equipment installation rate to be raised to 50% by March 2017. In response, oil refiners took atmospheric distillation capacity reduction and other measures. Their atmospheric distillation capacity declined by 7.8% from 3.82 Mb/d at the end of April 2016 to 3.52 Mb/d at the end of April 2017 (Petroleum Association of Japan "Monthly Oil Statistics"). This development coincided with a merger of petroleum products wholesalers that led some supply and demand adjustment transactions in the spot petroleum products market to become inhouse transactions, leading to a major oil industry situation change in the spring of 2017.

In February 2017 before the situational change[10], the pass-through rate for a price hike was far lower than at present, with the asymmetry between the rates for a price hike and for a price cut less remarkable than at present (Figure 8). Some of the refining and distribution margin expansion through the present has been induced by a rise in the pass-through rate for a price hike.

Figure 8 | Oil price pass-through rates for gasoline prices [February 2017 situation]



Oil price fluctuations and pass-thorough rates – Greater oil price hikes lead to higher pass-through rates

From this section, we analyse the pass-through rate by oil price fluctuation.

"Gasoline price hikes cannot catch up with too fast oil price increases," gas station operators say

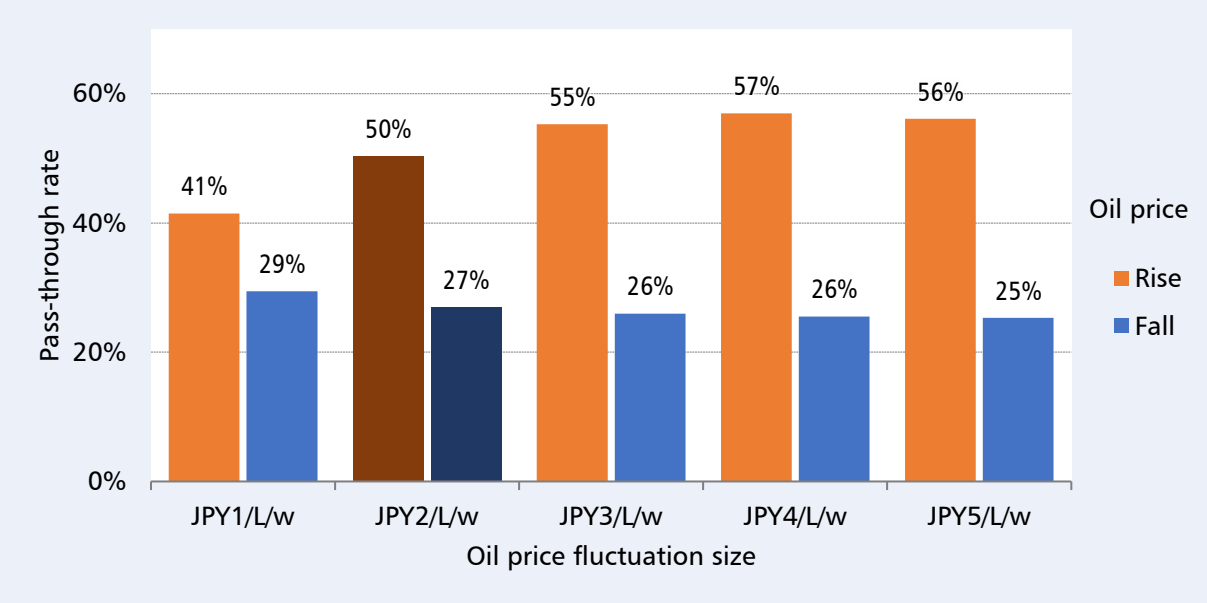
[10] The fiscal year and week number were set for February 2017.

occasionally. So, we estimated the oil price pass-through rate by oil price fluctuation size.

The estimation results differ from the situation represented by the comment by gas station operators, indicating that the pass-through rate increases as an oil price fluctuation grows wider (Figure 9). Nevertheless, the rate still slips far below 100%[11].

This may be because it is difficult to restrict a retail price hike by cutting refining and distribution margins that are still thin even after a recent increase. Given that the pass-through rate for a price cut depends little on an oil price fluctuation, wild oil price fluctuations could lead to a tough situation for consumers. However, recent weekly oil price fluctuations have remained narrow within JPY2/L. When a weekly oil price fluctuation remains within JPY1/L, the gap between the pass-through rate for a price hike and that for a cut is limited to 12 points. When oil prices are stable with fluctuations limited, the asymmetry between the pass-through rates for a price hike and a cut is not any serious problem.

Figure 9 | Oil price pass-through rates for gasoline prices (by oil price fluctuation size)



Oil price fluctuation duration and pass-through rate – pass-through rate remains stable even during long duration of oil price fluctuations

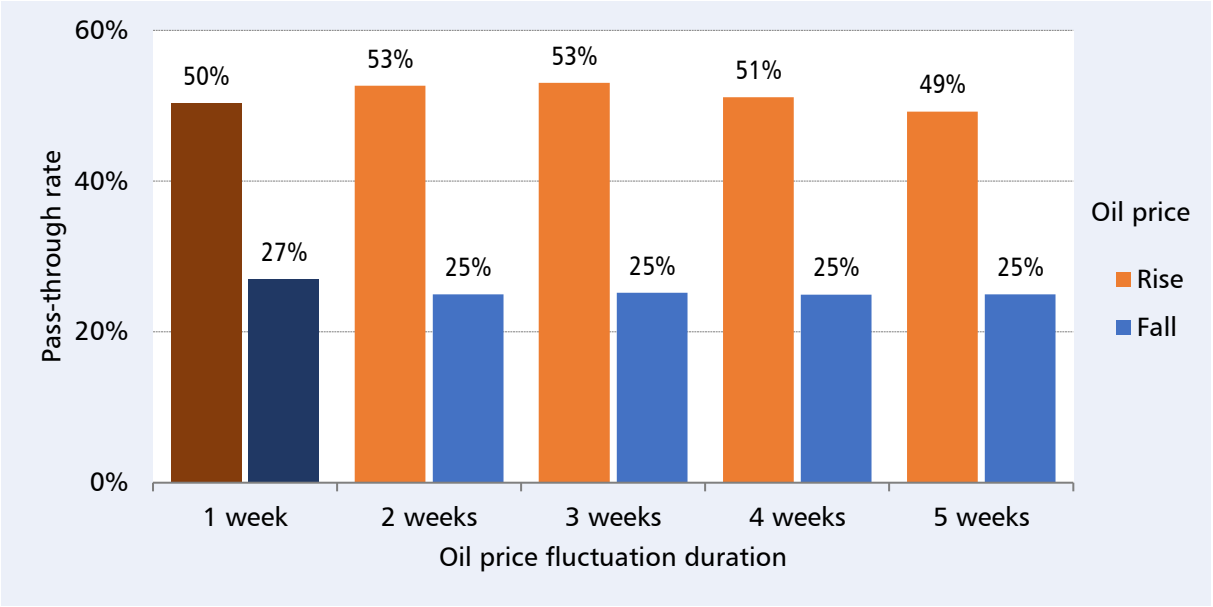
The abovementioned tendency in which the pass-through rate for a price hike gradually increases as an oil fluctuation size expands may lead to an expectation that the pass-through rate could increase as oil prices continue to rise. To verify the expectation, we projected the pass-through rate for a case in which oil prices continue increasing for two to five weeks beyond one week.

The projection results betray the expectation, indicating that such oil price fluctuation duration exerts little impact on the pass-through rate (Figure 10). Given the results combined with the previous section's results, a slow fluctuation in which the oil price increases by

[11] This means that gasoline price hikes cannot catch up with oil price increases irrespective of fluctuation sizes. Gas stations that can decelerate gasoline price hikes when oil price increases accelerate may be commensurately strong.

JPY1/L per week over three weeks may be more favourable for consumers than a rapid fluctuation in which the oil price rises by JPY3/L in one week.

Figure 10 | Oil price pass-through rates for gasoline prices (by oil price fluctuation duration)



Day of week and pass-through rate – Pay attention to Wednesday

As oil prices influence petroleum products wholesalers' prices, the price of an energy good frequently influences that of another good. In some cases, the prices of the two goods are revised at different frequencies. For example, the Saudi Arabian crude oil price is revised once a month, based on the monthly average of daily spot prices for Dubai/Oman crude oil. Here, spot prices for all days are treated equally. The price for a long-term steam coal contract is revised once a year, based on spot prices and other factors. Exerting great influence on the revision is a trend just before revision negotiations, rather than the one-year average of daily spot prices. In this case, it is important for negotiators to carefully ascertain the latest conditions. In business, particularly, it is significant to become aware of the time at which prices have the greatest influence on negotiations.

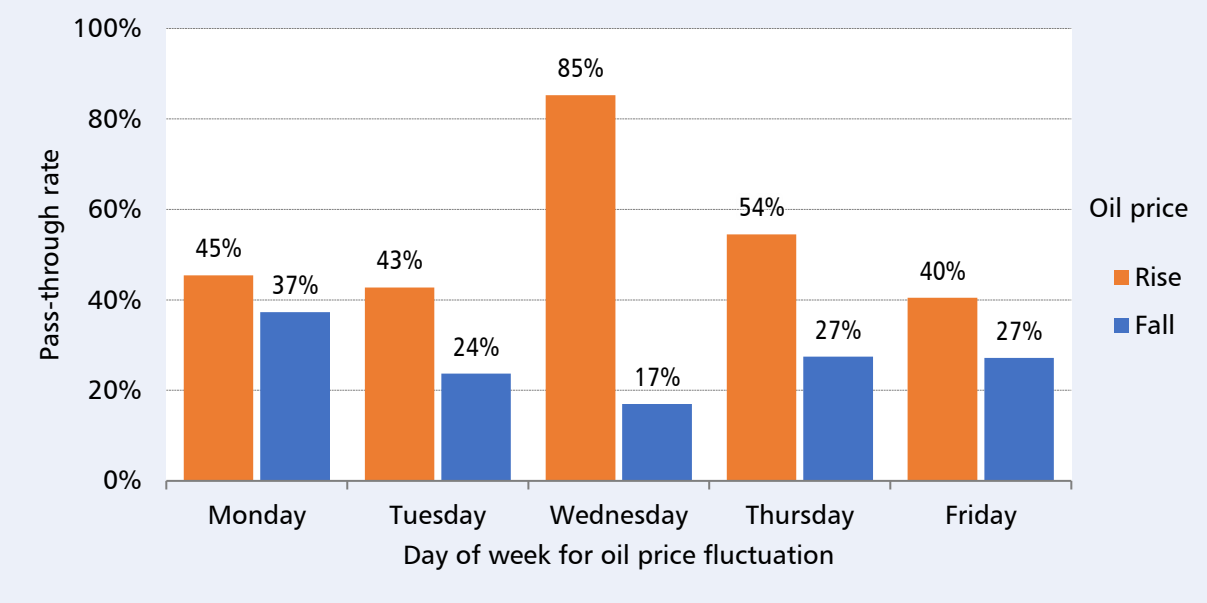
Wholesale prices are revised once a week in principle. Retail gasoline prices, which depend heavily on such wholesale prices, are observed once a week[13]. While oil prices change every day, gasoline prices are revised every week, though roughly. How do daily oil prices influence gasoline prices? Is the pricing approach for gasoline close to the time-neutral Saudi Arabian crude oil approach, the steam coal approach giving priority to latest conditions or any other one? If the approach is not time-neutral, an oil price fluctuation on Monday for a weekly petroleum products price survey or the previous trading day of Friday may mainly be passed through to gasoline prices.

The projection results indicate that the pass-through rate for a price cut roughly reflects the hypothesis, showing a concave shape in the graph (Figure 11). Conversely, however, the pass-through rate for a price hike shows a convex shape, indicating a remarkably high level for Wednesday in the middle of the week. While the finding is interesting, it is regrettably difficult for this analysis scheme to decide whether the projection result represents an

[13] Actually, gasoline prices are revised more frequently.

anomaly[14] or any good reason. A potential reason would be that many wholesalers announce their wholesale price revisions on Wednesday. It is also difficult to decide whether the high pass-through rate for Wednesday is attributable to wholesale prices or gas stations' decisions[15].

Figure 11 | Oil price pass-through rates for gasoline prices (by day of week for oil price fluctuation)



Conclusion

The oil price pass-through rate for gasoline prices is currently limited to low levels – 50% for a hike and 27% for a cut. This may indicate that gasoline prices reflect gasoline market supply and demand conditions as well as crude oil cost.

The neural network model has problems with transparency and the uniqueness of solutions due to its structure, while having the potential to provide new findings or analyses. However, AI is not almighty. We hope that AI will be developed as a means to increase the scope of analyses while suitable areas for AI application are explored.

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[14] An anomaly represents an empirical rule that frequently meets the results while lacking clear theories or reasons. One example is "Sell in May" for U.S. stock trading.

[15] While oil prices change in JPY0.01/L increments, wholesale prices fluctuate only in JPY0.5/L increments usually. Therefore, the oil price pass-through rate for wholesale prices is unstable, having a low affinity for the analysis in this paper.