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Firms' Knightian Uncertainty During the COVID-19 Crisis*

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Abstract

This study uses panel data (2004Q2–2021Q2) from a large-scale official statistical survey of Japanese firms to document the trends and characteristics of Knightian uncertainty, focusing on the impact of the COVID-19 pandemic. In addition, we analyze the relationship between Knightian uncertainty and investment at the firm level. According to the results, first, unlike the global financial crisis, which was characterized by a definite negative projection, uncertainty increased significantly during the COVID-19 crisis. Second, there is a positive correlation between the uncertainty over firms' business conditions (micro uncertainty) and the uncertainty over domestic economic conditions (macro uncertainty), but there are many firms whose business outlooks are certain even if the macroeconomic outlook is uncertain. Third, uncertainty has a negative association with future investments at the firm level, and the role of micro uncertainty dominates that of macro uncertainty.

Keywords: Knightian uncertainty, risk, business outlook, COVID-19, global financial crisis, investment
JEL Classification: D84, E22

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Firms' Knightian Uncertainty During the COVID-19 Crisis

1. Introduction

In recent years, many unforeseen shocks such as the global financial crisis (GFC), large-scale natural disasters, the COVID-19 pandemic, and Russia's invasion of Ukraine have seriously affected the economy, partly because of the effect of increasing the uncertainty of economic agents.

Theoretically, the concept of uncertainty can be classified into 1) risk (or Bayesian uncertainty) when the probability is known and 2) ambiguity (or Knightian uncertainty) when the probability is unknown (see, for example, Fernández-Villaverde and Guerrón-Quintana, 2020; Ilut and Schnider, 2022). Frequently used measures of macroeconomic uncertainty, such as the volatility of the stock market (e.g., VIX), ex-post prediction errors of econometric models, and uncertainty measures constructed from newspaper article texts (e.g., the EPU index), reflect both risk and ambiguity. Uncertainty is subjective in nature; therefore, recent studies have used surveys that directly collect subjective probability distributions of individuals or firms to capture subjective uncertainty (e.g., Guiso and Parigi, 1999; Bontempi *et al*., 2010; Ben-David *et al*., 2013; Morikawa, 2016b; Coibion *et al*., 2018; Altig *et al*., 2021; Bloom *et al*., 2021; Chen *et al*., 2021; Coibion *et al*., 2021; Faccini and Palombo, 2021; Barrero 2022; Dietrich *et al*., 2022; Kumar *et al*., 2022). The subjective uncertainty measure used in these studies is an ideal measure of risk. In contrast, studies measuring Knightian uncertainty or ambiguity using statistical data are limited.

This study uses panel data (2004Q2–2021Q2) of a large-scale official statistical survey of Japanese firms, documents trends and characteristics of Knightian uncertainty, focusing on the difference between the GFC and the COVID-19 crisis. In addition, we analyze the relationship between Knightian uncertainty and investment at the firm level. A simple uncertainty measure has been used in this study that focuses on firms that responded that the outlook for their own business and domestic economic conditions is "unsure," which strongly reflects Knightian uncertainty. As the data are available for a relatively long period of time, we show the characteristics of the COVID-19 crisis by comparing it to the GFC, a representative large-scale shock before the pandemic. We also examine the relationship between uncertainty over one's own business conditions (micro uncertainty) and uncertainty over domestic economic conditions (macro uncertainty).

The study makes multiple contributions to the literature. First, it presents a new firm-level uncertainty measure that reflects Knightian uncertainty. Second, it compares the GFC with the COVID-19 crisis by taking advantage of long time-series data. Third, it reports the relationship between micro- and macro-level uncertainty. Fourth, the study analyzes the relationship between

Knightian uncertainty and investment at the firm level.

The results are summarized as follows: First, uncertainty fluctuated significantly over time, and especially during the COVID-19 pandemic, the number of firms that answered that they are unsure about the direction of their business and macroeconomic conditions (improve/no change/deteriorate) increased significantly. This is unlike the GFC, where the number of firms confidently expected business and economic conditions to deteriorate significantly. Therefore, the COVID-19 crisis is characterized as a Knightian uncertainty shock. This is not captured by other uncertainty measures, which increased significantly during the GFC. Second, when the outlook for economic conditions is uncertain, the outlook for the firm's own business condition tends to be uncertain as well, but there are a significant number of cases where the outlook for the firm's own business condition is not uncertain, even when economic conditions are uncertain. Third, uncertainty at the firm level is negatively associated with future investment, and the effect of micro uncertainty plays a more dominant role in firms' investment than macroeconomic uncertainty.

The remainder of this paper is organized as follows. Section 2 briefly surveys the literature on uncertainty, including a recent analysis of uncertainty during the COVID-19 pandemic. Section 3 explains the Business Outlook Survey (BOS), which is the main dataset used in this study, as well as the method of analysis. Section 4 presents evidence of the movements of aggregate-level uncertainty, with a focus on the period of the COVID-19 crisis. Section 5 estimates the relationship between Knightian uncertainty and investment using a linked firm-level quarterly panel dataset constructed from the BOS and the Financial Statements Statistics of Corporations. Finally, the conclusions are summarized in Section 6.

2. Literature Review

Studies on the relationship between uncertainty and real economic activity have a long history. In particular, the negative impact of uncertainty on investments through the real-option effect or "wait-and-see" mechanism has been pointed out theoretically (e.g., Bernanke, 1983; McDonald and Siegel, 1986; Pindyck, 1991). When the cost of investments is irreversible, economic uncertainty reduces the amount of these investments because firms have an incentive to avoid taking action until uncertainty disappears. Empirical studies largely support the theoretical prediction that uncertainty negatively affects investments (e.g., Leahy and Whited, 1996; Guiso and Parigi, 1999; Ghosal and Loungani, 2000; Bloom *et al*., 2007; Bontempi *et al*., 2010; Morikawa, 2016a).

The COVID-19 pandemic has increased uncertainty among individuals and businesses

regarding trends in infection control policies, the timing of vaccine development and dissemination, and the end of the pandemic. In response, there has also been a surge of research on the uncertainty and its impact under the unexpected shock of the COVID-19 crisis: Altig *et al*. (2020), Armantier *et al*. (2021), Chen *et al*. (2021), Ahir *et al*. (2022), Arbatli *et al*. (2022), Baker *et al*. (2022), Dietrich *et al.* (2022), Meyer *et al*. (2022), Moran *et al*. (2022) are examples of such studies. The COVID-19 crisis caused a significant decrease in demand in industries with interpersonal contact, such as restaurants, lodging, passenger transportation, and entertainment, while demand increased in some industries, including information, telecommunications, and delivery services. Many firms found it difficult to determine whether demand would rise or fall since they could not foresee trends in the number of cases, the future of government measures to restrict business activity, or the timing of vaccine development and dissemination. Indeed, many studies have indicated that there was increased uncertainty during the COVID-19 crisis. However, studies comparing the GFC and the COVID-19 crisis in terms of firm-level uncertainty have been scarce.

Since uncertainty is not directly observable, various proxies have been developed and used in past studies (see Bloom, 2014 and Shinohara *et al*., 2021, for surveys). Representative macroeconomic uncertainty measures include the volatility of stock prices (e.g., VIX), prediction errors derived from econometric models (e.g., Jurado *et al*., 2015), disagreement or subjective probability distribution among professional forecasters (e.g., Survey of Professional Forecasters in the United States), and the frequency of newspaper articles on uncertainty (Baker *et al*., 2016). Recent studies often employ multiple uncertainty measures to compare differences (e.g., Caldara *et al*., 2016; Meinen and Roehe, 2017; Born *et al*., 2018; Kozeniauskas *et al*., 2018; Dery *et al.*, 2021; Nam *et al*., 2021; Shinohara *et al.*, 2021; Suh and Yang, 2021; Meyer *et al*., 2022).

Microeconomic uncertainty measures at the firm-level used in past studies include 1) volatility of production or stock prices (e.g., Kang *et al*., 2014; Castro *et al*., 2015; Bachmann *et al*., 2019), 2) forecast errors of firms' business outlooks (e.g., Bachmann *et al*., 2013; Arslan *et al*., 2015; Morikawa, 2016a, 2019; Bachmann *et al*., 2017), and 3) subjective uncertainty captured through surveys of the probability distribution of firms' forecasts (e.g., Guiso and Parigi, 1999; Bontempi *et al*., 2010; Ben-David *et al*., 2013; Morikawa, 2016b; Coibion *et al*., 2018; Altig *et al*., 2021; Bloom *et al*., 2021; Chen *et al*., 2021; Coibion *et al.*, 2021; Faccini and Palombo, 2021, Barrero, 2022; Dietrich *et al*., 2022; Kumar *et al*., 2022).

Manski (2004, 2018) stressed that risk (Bayesian uncertainty) can be best captured by directly surveying the subjective probability distributions (probabilistic expectations) of firms or individuals. The third category of the abovementioned research employs this strategy. However, although this approach can accurately capture risk, ambiguity (Knightian uncertainty), for which there is no subjective probability distribution, is out of range. In addition, since many surveys

have recently begun, time-series data available to compare the GFC with the COVID-19 crisis are rare.

Except for laboratory experiments, studies measuring Knightian uncertainty have been very limited. For example, Ilut and Schneider (2014) use the dispersion of the economic growth forecasts of professional forecasters (Survey of Professional Forecasters in the United States) as a shock affecting the ambiguity of economic agents.[1] Bachmann *et al*. (2020) use unique German firm survey data (ifo Business Tendency Survey), in which the probability that a firm's sales will increase in the next quarter is surveyed in the form of a single probability response or a choice of responses in intervals of probability, which is a rare example of analyzing ambiguity at the firm level. They treat the case of choosing to answer in intervals as a measure of Knightian uncertainty. However, whether this is a valid proxy variable for Knightian uncertainty is debatable.

Against this background, this study proposes a measure of Knightian uncertainty using an official statistical survey. The BOS used in this study is a business survey conducted by the government and, as described in the next section, asks about the outlook regarding the firms' business and overall economic condition (one- and two-quarters-ahead). A unique feature of this survey is that, in contrast to other business surveys, the respondents have an option to choose "unsure," in addition to "improve," "no change," and "deteriorate." Since the choice "unsure" means that the respondent firms are unable to predict even the direction (sign) of the change in business/economic condition, it can be interpreted as a proxy of Knightian uncertainty.

3. Data and Methodology

This study uses firm-level microdata of the BOS compiled jointly by the Ministry of Finance and the Cabinet Office of Japan. Under the Statistics Act, the BOS commenced in the second quarter (April-June) of 2004 and has been conducted quarterly. The survey covers incorporated firms with a capital of 10 million yen or more in all sectors of the economy, including both manufacturing and non-manufacturing firms. The sample has been chosen from the population of the Financial Statements Statistics of Corporations (Ministry of Finance). Recently, approximately 14,000 firms were sampled in each survey, of which approximately 11,000 responded (the response rate was between 70-80%). The survey was conducted on February 15th (Q1 survey), May 15th (Q2 survey), August 15th (Q3 survey), and November 15th (Q4 survey), and the aggregation results were released approximately one month later.

[1] Rossi *et al*. (2016) attempt to decompose uncertainty into ambiguity and risk based on the distributional information from the Survey of Professional Forecasters.

This study uses quarterly micro data on the BOS from 2004Q2 to 2021Q2. The number of observations is approximately 830 thousand. The BOS sends questionnaires to all firms with a capital of 3 billion yen or more, but the sample of smaller firms is periodically reshuffled. Therefore, the number of firms that responded throughout the sample period is small (1,145 large firms). The survey questions included both qualitative and quantitative questions.[2] This study uses the qualitative outlook of the firms' own business and domestic macroeconomic conditions. In contrast to the Tankan survey conducted by the Bank of Japan, which is a representative business survey in Japan, the BOS requires a two-quarters-ahead outlook in addition to a one-quarter-ahead outlook. While the Tankan survey asks about the expected *level* of business condition ("favorable," "not so favorable," or "unfavorable"), the BOS asks about the expected *change* in business/economic condition ("improve," "no change," or "deteriorate") from the current quarter. As mentioned earlier, an important difference is that the BOS includes "unsure" as a potential response.

It is worth mentioning that the BOS questionnaire asks the respondents that judgments should be made by removing seasonal factors. The Business Survey Index (BSI), which indicates business confidence based on the percentage of "improve," "no change," and "deteriorate" responses, is compiled and published by firm size (large, medium, and small companies) and industry (manufacturing and non-manufacturing).[3] The BSI is calculated as the percentage of firms that responded "improve" minus the percentage of firms that responded "deteriorate."

In this study, we use the response "unsure" for own business outlook and domestic economic outlook as a measure of uncertainty faced by firms and document its movements over time and differences by industry and firm size. When distinguishing between "unsure" for own business outlook and domestic economic outlook, we use the notation *BC_unsure* and *EC_unsure*. Since firms responding "unsure" cannot predict the direction of change in their own business condition or domestic economic condition one- or two-quarters-ahead, the response can be interpreted as being faced with Knightian uncertainty (ambiguity). Strictly speaking, Knightian uncertainty, where the (subjective) probability distribution is not known, is broader than the situation in which the direction is unsure. For example, it includes the case in which the direction of future business conditions is expected to "improve," but the probability distribution is not known. Therefore, we would like to state that the uncertainty in this study is narrowly defined as Knightian uncertainty.

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[2] The outline of the BOS is described on the website of the Ministry of Finance (http://www.mof.go.jp/english/pri/reference/bos/outline.htm#02). Although not used in this study, the quantitative items include actual and projected sales, current profit, and capital expenditures on a fiscal year basis.

[3] Large firms are those with a capital of at least 1 billion yen, medium-sized firms are those with a capital of at least 100 million yen but less than 1 billion yen, and small firms are those with a capital of at least 10 million yen but less than 100 million yen.

Section 4 documents the historical movements of BSI and uncertainty and compares them during the GFC and the COVID-19 crisis to clarify the different natures of the two shocks. We also observe the relationship between our Knightian uncertainty measure and other frequently used uncertainty measures (stock price volatility, the macro uncertainty (MU) index, and the economic policy uncertainty (EPU) index). Section 5 estimates the relationship between uncertainty and investment at the firm level. The BOS collects information about firms' sales and investments, but only annually (not quarterly). However, the firms surveyed in the BOS are selected from those surveyed in the quarterly survey of the Financial Statements Statistics of Corporations. Since the Financial Statements Statistics of Corporations surveys quarterly sales and capital expenditures, we can construct a 69-quarter panel data (2004Q2-2021Q2) by linking these two statistics at the firm level and using it to estimate investments.

When explaining the actual amount of investment ($ln(INV)_{i,\ t+1}$) in the next quarter, using a dummy for the uncertainty ($BC\_unsure_{it,\ t+1}$) of the firm's business condition (micro uncertainty) one-quarter-ahead as an explanatory variable, the baseline equation to be estimated is as follows: The subscripts i and t represent the firm and time, respectively. λ_t is the time dummy (t=1, 2, ・・・, 68, 69), and η_i is the firm fixed effect.

$$ln(INV)_{it+1} = \beta\, BC\_unsure_{it,\ t+1} + \gamma\, ln(Sales)_{it+1} + \lambda_t + \eta_i + \varepsilon_{it} \qquad (1)$$

Since the estimation includes firm-fixed effects, the effects of time-invariant unobservable firm characteristics, such as industry and capital intensity, are eliminated. Time-fixed effects control for macroeconomic factors common across firms as well as seasonal fluctuations. When estimating a two-quarters-ahead investment, the subscript is t+2 instead of t+1. In addition to estimating the firm's own business condition, we use the uncertainty (*EC_unsure*) of domestic economic conditions (macro uncertainty) as an explanatory variable and compare the results. Furthermore, we estimate using both micro (*BC_unsure*) and macro (*EC_unsure*) uncertainty as explanatory variables and compare the explanatory power of the two uncertainty measures.

4. Movement of the Uncertainty Measure

Figure 1 shows the movements of the BSI for the firm's own (micro) business and macroeconomic conditions for the next one and two quarters. The horizontal axis indicates the time of the survey, and the BSIs are shown one- and two-quarters-ahead as of the time of the survey. The BSI of the outlook deteriorated significantly during the GFC. The BSIs deteriorated significantly for the two-quarters-ahead in the 2013Q4 survey and the one-quarter-ahead in the

2014Q1 survey before the consumption tax rate increased from 5% to 8% in April 2014. The BSI deteriorated significantly for the one-quarter-ahead in the 2020Q2 survey when the COVID-19 infection spread and the first "State of Emergency" was declared. The deterioration in business sentiment was much greater during the GFC than during the COVID-19 crisis. Overall, the fluctuation of the BSI for macroeconomic conditions was larger than that of the BSI for the firm's own business conditions.

Table 1 summarizes the mean, minimum, and maximum percentages of "unsure" responses during the sample period, which is the focus of this study. The mean percentages of uncertainty over the firm's business condition are 15.6% for the one-quarter-ahead and 27.8% for the two-quarters-ahead outlooks. The mean percentages of uncertainty over macroeconomic conditions are 18.6% for the one-quarter-ahead and 31.7% for the two-quarters-ahead outlooks. This uncertainty measure has a large time-series variation, with large gaps between the minimum and maximum values.[4] **Figure 2** depicts the movements of the uncertainty measures, which rose during the GFCs compared to earlier periods, then declined slowly, but rose significantly during the COVID-19 pandemic.[5] The uncertainty level remained high in 2021Q2 at the end of the sample period.

Throughout the sample period, the level of "unsure" responses was higher for the two-quarters-ahead outlook than for the one-quarter-ahead outlook, indicating that subjective uncertainty is higher in the more distant future. In addition, the percentage of "unsure" responses was higher for macroeconomic conditions than for firms' business conditions. The "unsure" responses regarding the firm's own business condition and the macroeconomic condition have a fairly strong correlation at the firm level, with a correlation coefficient of 0.959 for the one-quarter-ahead and 0.983 for the two-quarters-ahead.

As seen in **Figure 2**, there is a seasonality in the percentage of "unsure" responses, with higher responses in Q1 for the one-quarter-ahead outlook and in Q4 for the two-quarters-ahead outlook. Seasonality is stronger for a firm's own business conditions than for macroeconomic conditions. **Appendix Table 2** compares the percentage of firms that responded "unsure" for each quarter, indicating that the percentages of firms that responded "unsure" for one-quarter-ahead of their

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[4] The mean percentages of "unsure" responses by industry and firm size are shown in **Appendix Table 1**. Although the rate of "unsure" responses tends to be higher among small and medium-sized firms, it is higher among large firms than among medium-sized firms, indicating that the relationship with the firm size is not monotonic.

[5] The pattern of the transition of judgment, that is, how firms that answered that their business condition was "unsure" one-quarter-ahead at the beginning of the COVID-19 Crisis (2020Q2) expected their business condition one-quarter-ahead in the previous survey (2020Q1), shows that 6.4% of the firms answered "improve," 42.9% "no change," 9.8% "deteriorate" and 40.9% "unsure." The pattern of the transition in the outlook for the two-quarters-ahead was generally the same.

own business and macroeconomic conditions in the Q1 survey are 2.8 percentage points and 2.2 percentage points higher, respectively, compared with the other quarters' survey. In the case of the two-quarters-ahead outlook in the Q4 survey, the percentages of firms that responded "unsure" regarding their own business condition and macroeconomic condition are 4.8 percentage points and 3.7 percentage points higher, respectively. This seasonal pattern is likely related to the accounting year. The accounting year for Japanese firms is generally one year, from April to March of the following year. The forecasts for Q2 (April-June) business condition crosses the accounting year; therefore, we conjecture that this may be because many firms find it difficult to respond based on their finalized annual business plans and earnings forecasts (and the economic outlook on which they are premised), as of Q1 (January-March) or Q4 (October-December) of the previous year.

The BOS includes a sample of firms with small capitalization, and the movements of uncertainty may be affected by the change in the sampled firms. To check for possible bias, although the sample is limited to large firms, **Appendix Figure 1** shows the movements of uncertainty only for the subsample of firms that continuously responded to the BOS throughout the sample period ("continuous respondents"). The general pattern is the same as for the full sample, but the increase in uncertainty during the COVID-19 crisis is more pronounced for the subsample of continuous respondents.

Table 2 shows a cross-tabulation of the relationship between the uncertainty of one's own business condition (*BC_unsure*) and the uncertainty of macroeconomic conditions (*EC_unsure*). For both one-quarter-ahead and two-quarters-ahead outlooks, firms that are uncertain about the outlook for macroeconomic conditions tend to be uncertain about their own business condition (12.0% and 23.0%, respectively), but a significant number of firms were certain about their own business condition but were uncertain about the macroeconomic condition: 6.5% in the one-quarter-ahead and 8.5% in the two-quarters-ahead outlooks. In contrast, the percentages of firms uncertain about their own business condition but not about macroeconomic conditions are small: 2.7% in the one-quarter-ahead and 4.1% in the two-quarters-ahead outlooks.

Table 3 shows a cross-tabulation of the relationship between uncertainty for the one-quarter-ahead and two-quarters-ahead outlooks. The results show that the percentages of firms that are uncertain about the one-quarter-ahead outlook tend to be uncertain about the two-quarters-ahead outlook (15.4% for the business condition and 18.3% for the macroeconomic condition). However, there are a significant number of firms that are not uncertain about the one-quarter-ahead outlook but are uncertain about the two-quarters-ahead outlook (12.4% and 13.2%, respectively). In contrast, there are very few cases where the outlook for two-quarters-ahead is certain, but the outlook for one-quarter-ahead is uncertain (0.2% for both the business and macroeconomic conditions). As one might expect, the more distant the future, the more uncertain it is.

Table 4 compares the BSI and uncertainty during the GFC and the COVID-19 crisis. The figures for the GFC period are simple averages for the four quarters from the 2008Q3 to 2009Q2 surveys, whereas the figures for the COVID-19 crisis period are simple averages for the five quarters from the 2020Q2 to 2021Q2 surveys. The averages for the entire sample period are shown for comparison.

Looking at the one-quarter-ahead BSI of business conditions (Panel A, Column (1) of **Table 4**), while the deterioration of the BSI was significant (-0.219) during the GFC, the uncertainty ("unsure" response rate) was 0.151, similar to the average for the entire period. During the GFC, many firms were less uncertain about the direction of their business conditions and expected them to deteriorate with confidence. In contrast, the deterioration in the BSI of business conditions during the COVID-19 crisis was relatively small (-0.051), but uncertainty increased significantly (0.299). Owing to the difficulty of predicting when the COVID-19 pandemic will end, and uncertainty over government policies such as restrictions on activities and requests for self-restraint, the number of firms that are unsure of the direction of their future business condition has increased significantly.[6]

In terms of the outlook for macroeconomic conditions (Panel B, Column (1) of **Table 4**), the BSI deteriorated more during the GFC and the COVID-19 crisis periods than for the firm's own business condition, but the increase in uncertainty was about the same as that for the firm's own business condition. The GFC was a negative shock with a strong "certainty of deterioration," whereas the COVID-19 crisis was a Knightian uncertainty shock in the sense that even the future direction was unpredictable, similar to the observation of a firm's business condition.

In the case of the two-quarters-ahead outlook (Column (2) of **Table 4**), the deterioration of BSI in both the firm's own business condition and macroeconomic condition during the GFC was smaller than that of the one-quarter-ahead outlook, but the basic pattern is the same as the one-quarter-ahead outlook. During the GFC, the deterioration in the BSI was larger, but the increase in uncertainty was smaller, whereas, during the COVID-19 crisis, the deterioration of BSI was smaller, but the increase in uncertainty was larger.

The tabulation results restricted to the subsample of firms that respond continuously are shown in **Appendix Table 3**. The pattern for both the firms' own business conditions and macroeconomic conditions is similar to that of the tabulation results for the entire sample, but the uncertainty shock feature of the COVID-19 crisis is more prominent in this subsample.

Next, we compare the uncertainty measure in this study with other frequently used measures of economic uncertainty. **Appendix Figure 2** compares the stock market volatility (Nikkei 225

[6] By industry, the increase in uncertainty during the COVID-19 pandemic was slightly larger in the transportation, wholesale, and retail sectors.

Volatility Index: abbreviated as Nikkei VI), **Appendix Figure 3** compares the MU index, and **Appendix Figure 4** compares the EPU index with the percentage of "unsure" responses for the firm's business condition one-quarter-ahead.[7] In the case of Nikkei VI, the rise at the time of the GFC (2008Q4) was remarkable, and the index has been relatively stable since then, although it reached a slightly higher figure in 2020Q1 at the beginning of the COVID-19 pandemic. The MU index was high during the GFC period (2009Q2), after the Great East Japan Earthquake (2011Q2), and during the recent COVID-19 pandemic (2020Q2). The EPU index had many peaks in 2008Q4, 2010Q2, 2011Q3, and 2016Q2 and was at its highest in the 2020Q2 survey but is comparable to previous peaks.

The correlation coefficients with the uncertainty of one's own business condition (one-quarter-ahead) are calculated to be 0.157 for the Nikkei 225 VI, 0.473 for the MU index, and 0.470 for the EPU index. The correlation coefficients with the uncertainty of macroeconomic conditions (one-quarter-ahead) are 0.066 for the Nikkei 225 VI, 0.334 for the MU index, and 0.486 for the EPU index. The uncertainty measure in this study is more pronounced and higher during the COVID-19 crisis than in other representative indices. We interpret that the difficulty in foreseeing the trends of infection and the timing of the end of the pandemic have led to a persistent increase in Knightian uncertainty, in the sense that the future direction of the business and economic conditions is difficult to predict.

5. Uncertainty and Investment

In this section, we estimate the relationship between uncertainty and investment at the firm level. For this purpose, quarterly data from the BOS and the Financial Statements Statistics of Corporations are linked at the firm level and used in the analysis. Since the BOS uses the Financial Statements Statistics of Corporations as its population registry, approximately 79.6% of the BOS observations can be matched with the Financial Statements Statistics of Corporations. The information used from the Financial Statements Statistics of Corporations is investment and sales, both of which are log-transformed and used for estimations.[8]

As explained in Section 3, we estimate whether the uncertainty over the one-quarter-ahead

[7] The Nikkei 225 Volatility Index, MU Index, and EPU Index are all simple averages of monthly data to produce quarterly figures. The MU Index was created for Japan in a manner similar to Jurado *et al*. (2015) in the U.S. For details, see Shinohara *et al*. (2020) and Nakajima (2022). EPU index is taken from http://www.policyuncertainty.com/.

[8] In addition, the fixed asset value taken from the Financial Statements Statistics of Corporations is used in the estimations to check the robustness.

(t+1) or two-quarters-ahead (t+2) outlook (*BC_unsure* or *EC_unsure*) dummy at the time of the survey (t) is associated with the realized value of investment (expressed in log) in the relevant quarter (t+1 or t+2). Sales (log) of the same quarter as investment, firm fixed-effects and time-fixed effects are used as control variables. **Table 5** presents the summary statistics for the variables.

Table 6 presents the results of the baseline estimation. The coefficients for the uncertainty of business condition (*BC_unsure*) are negative and statistically significant at the 1% level for both one-quarter-ahead (Column (1)) and two-quarters-ahead investment (Column (4)). [9] Quantitatively, when a firm's business outlook is uncertain, the firm's investment is 3-4% lower. The result suggests that when Knightian uncertainty is high, that is, when the future direction of business conditions is uncertain, firms are cautious about investment. As shown in the previous section, the percentage of firms that answered "unsure" about the future business condition under the COVID-19 pandemic was 14.3% higher for one-quarter-ahead and 11.9% higher for two-quarters-ahead than the mean of the sample period. A mechanical calculation suggests that the increase in uncertainty reduced aggregate investment by approximately 0.5% during the COVID-19 crisis.

The size of the coefficient for sales (*ln(Sales)*) is approximately 0.4, meaning that a 1% decrease in sales is associated with a 0.4% lower capital investment. Uncertainty may also be related to future sales. When we estimate the relationship between "unsure" responses and realized sales, uncertainty is negatively associated with sales one- or two-quarters-ahead. Since the estimations reported above control for sales, the result implies that uncertainty leads to cautious investment behavior independent of a decrease in investment due to a negative impact of uncertainty on sales.

In contrast, when domestic macroeconomic uncertainty (*EC_unsure*) is used as an explanatory variable, the relationship with one-quarter-ahead investment is statistically insignificant (Column (2)). The relationship with the two-quarters-ahead investment is significantly negative at the 1% level (Column (5)), but the absolute value of the coefficient is nearly half that of the uncertainty over the firm's business condition. Furthermore, when both the uncertainty of the firm's business condition and the uncertainty of macroeconomic conditions are simultaneously used as explanatory variables (Columns (3) and (6)), the coefficient of uncertainty of macroeconomic conditions loses statistical significance. Naturally, the role of uncertainty about the future of a

[9] Considering the possibility that uncertainty over the outlook for business conditions in the next and subsequent periods may affect investment in the current period (t), that is, at the time of the survey, we also conducted an estimation with investment in the current period as the dependent variable. In this case, the coefficient of "unsure" was insignificant. The reason why uncertainty about business conditions has no significant effect on investment in the current quarter can be attributed to the fact that there is a certain lag in the decision-making and execution of investment.

firm's own business condition (micro uncertainty) in investment behavior is more dominant than that of macro uncertainty.

In the following, we conduct several robustness checks: Since the uncertainty measure in this study rose sharply after the COVID-19 pandemic, this may have had a significant impact on the overall estimation results. Therefore, we estimate the period by excluding the quarters from 2020Q2 (see **Appendix Table 4**). The coefficient of "unsure" is slightly larger, but the basic pattern is the same as that of the baseline estimation results, including the COVID-19 period. Our interpretation is that the relationship between uncertainty and investment itself has not been significantly affected by the COVID-19 pandemic, but the relationship that originally existed still occurred during the pandemic.

Next, to eliminate the effect of the reshuffling of sample firms in the BOS, we use a subsample of large firms that continue to respond to the survey throughout the sample period (see **Appendix Table A5**). In this case, the coefficient of *BC_unsure* is still significant, and the absolute value is somewhat larger, but the basic pattern is the same as in the estimation results for the full sample.

Finally, instead of investment (expressed in log), an estimation is conducted using the value of investment divided by the amount of capital stock at the end of the previous period (INV_{it+1}/K_t, INV_{it+2}/K_{t+1}) as the dependent variable. This specification is often used in the estimation of investment functions, and because it is not log-transformed, it is possible to include zero investment in the observations. The estimation results are presented in **Appendix Table 6**.[10] Compared to the baseline estimates, the pattern is almost the same, except that the coefficient of "unsure" for the one-quarter-ahead domestic macroeconomic condition is statistically significant (Column (2)). Overall, the coefficient for "unsure" is smaller than the baseline estimations, but this is due to the difference in the dependent variable, and the quantitative magnitude is similar to or somewhat larger than the baseline estimations.

To summarize, these results suggest that uncertainty over the business outlook at the firm level has a negative impact on investment behavior. This result is consistent with previous studies showing a negative relationship between uncertainty and investment and is not in itself a surprising result. However, the uncertainty measure in this study is strongly characterized as a proxy for Knightian uncertainty in the sense that even the future direction is uncertain. The novelty of this study lies in its clarification of the relationship between uncertainty and investment at the firm level. In addition, the different associations of micro- and macro-uncertainty with investment behavior is a new finding in the literature.

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[10] Since there are cases where *INV/K* is an extremely large figure, we excluded observations where it is greater than unity (cases where more than the amount of capital stock is invested in a single quarter) as an outlier.

6. Conclusion

This study uses panel data from a large-scale official survey of Japanese firms (2004Q2–2021Q2) to document long-run trends in uncertainty and analyze the relationship between uncertainty and investment. The main contributions of this paper are as follows: 1) we presented a new uncertainty measure at the firm level that strongly reflects Knightian uncertainty; 2) we clarified the characteristics of the COVID-19 crisis relative to the GFC, a major shock in the past; and 3) we compared uncertainty in the firm's own business condition (micro uncertainty) and uncertainty in the macroeconomic condition (macro uncertainty) and their relative importance on investment behavior.

The major findings are as follows: First, uncertainty has varied considerably over time, and the number of firms that were unsure of the direction of the business and macroeconomic conditions during the COVID-19 crisis increased significantly. In other words, unlike the GFC, where the number of firms that confidently expected business conditions and the macroeconomy to deteriorate increased significantly, the COVID-19 crisis had the unique characteristic of the Knightian uncertainty shock. In this respect, it differs from the movements of other frequently used uncertainty measures, which rose significantly during the GFC. Second, when the outlook for domestic business conditions is uncertain, the outlook for the firm's own business condition tends to be uncertain as well, but there are quite a few cases where the outlook for the firm's own business condition is certain, even though macroeconomic conditions are uncertain. Third, uncertainty at the firm level has a negative relationship with investment, and the role of micro uncertainty in the firm's own business condition is more dominant than macroeconomic uncertainty.

The "unsure" response used in this study is a very simple measure, but it contains valuable information for understanding the subjective uncertainty of firms. It is also advantageous to capture uncertainty at the individual firm level as well as at the macro level. Furthermore, unlike the *ex-post* forecast errors often used in firm-level uncertainty analysis, it is useful in policy practice in that it can be used without having to wait for the next release of realized data.

The limitations of this uncertainty measure include 1) unlike the subjective probability distribution that has recently been used to capture the subjective risk of firms or households, it is not a quantitative measure at the firm level, and 2) although it is government statistical data with a high response rate, it cannot completely eliminate bias due to non-responses. Finally, we would like to note that we have not been able to simultaneously identify risk (Bayesian uncertainty) and ambiguity (Knightian uncertainty). Such a decomposition is a difficult task, but it is an important

subject for future research.

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Table 1. Summary Statistics of Micro and Macro Uncertainty

	Mean	Std. Dev.	Min.	Max.
BC_unsure (1Q ahead)	15.6%	5.1%	8.5%	34.7%
BC_unsure (2Q ahead)	27.8%	5.9%	19.2%	47.6%
EC_unsure (1Q ahead)	18.6%	4.7%	11.0%	31.8%
EC_unsure (2Q ahead)	31.7%	5.8%	22.3%	49.1%

Note: The percentage of firms that responded "unsure" is tabulated for each quarter, and the period mean, standard deviation, minimum, and maximum values are reported.

Table 2. Relationship between Business and Macroeconomic Outlook Uncertainty

		Macroeconomic outlook	
	Business outlook	Uncertain	Certain
1Q ahead	Uncertain	12.0%	2.7%
	Certain	6.5%	78.8%
2Q ahead	Uncertain	23.0%	4.1%
	Certain	8.5%	64.4%

Note: Uncertain refers to firms that chose "unsure'." Certain refers to firms that chose "improve," "no change," or "deteriorate."

Table 3. One-Quarter-Ahead and Two-Quarters-Ahead Uncertainty

		2Q ahead	
	1Q ahead	Uncertain	Certain
Business outlook	Uncertain	15.4%	0.2%
	Certain	12.4%	72.0%
Macroeconomic outlook	Uncertain	18.3%	0.2%
	Certain	13.2%	68.3%

Note: Uncertain refers to firms that chose "unsure.' Certain refers to firms that chose "improve," "no change," or "deteriorate."

Table 4. BSI and Uncertainty During the Global Financial Crisis and the COVID-19 Crisis

	(1) 1Q ahead		(2) 2Q ahead	
	BSI	Uncertainty	BSI	Uncertainty
A. Business outlook				
Whole period	-0.017	0.156	0.013	0.278
GFC period	-0.219	0.151	-0.099	0.310
COVID-19 period	-0.051	0.299	0.007	0.420
B. Macroeconomic outlook				
Whole period	-0.039	0.184	-0.001	0.315
GFC period	-0.379	0.162	-0.189	0.339
COVID-19 period	-0.154	0.303	-0.028	0.454

Note: The simple average of 2008Q3-2009Q2 for the GFC period and 2020Q2-2021Q2 for the COVID-19 period.

Table 5. Summary Statistics of Variables

	Mean	SD (overall)	SD (within)	N
BC_unsure_{t+1}	0.1442	0.3513	0.2594	660,349
BC_unsure_{t+2}	0.2706	0.4443	0.3219	661,690
EC_unsure_{t+1}	0.1772	0.3818	0.2802	632,097
EC_unsure_{t+2}	0.3133	0.4638	0.3354	632,097
ln(INV)	4.1837	2.3571	1.0952	397,988
ln(Sales)	4.5762	2.1388	0.3044	614,354

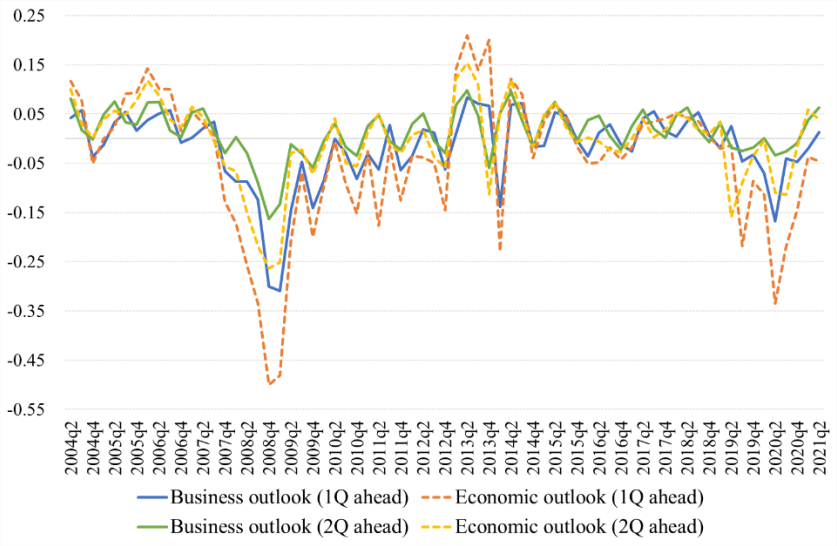
Note: The figures are calculated from the linked dataset of the BOS and Financial Statements Statistics of Corporations.

Table 6. Uncertainty and Investment

	(1)	(2)	(3)	(4)	(5)	(6)
	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$
BC_unsure	-0.0320 ***		-0.0429 ***	-0.0408 ***		-0.0415 ***
	(0.0078)		(0.0102)	(0.0065)		(0.0086)
EC_unsure		-0.0114	0.0125		-0.0224 ***	0.0024
		(0.0072)	(0.0091)		(0.0063)	(0.0081)
ln(Sales)	0.4023 ***	0.4073 ***	0.4073 ***	0.4082 ***	0.4127 ***	0.4125 ***
	(0.0050)	(0.0051)	(0.0051)	(0.0053)	(0.0054)	(0.0054)
Firm FE	yes	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes	yes
Nobs.	342,782	333,851	333,733	307,088	298,803	298,803
R^2 (within)	0.0460	0.0465	0.0466	0.0490	0.0493	0.0494

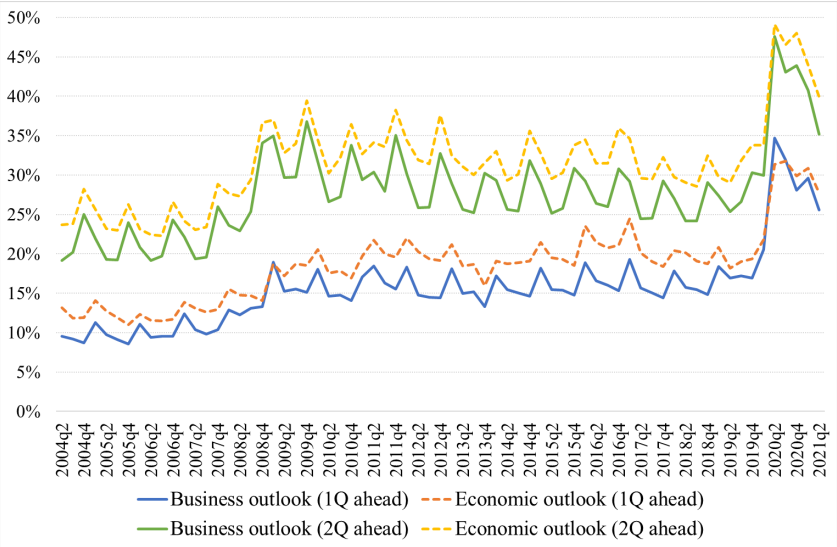
Notes: Fixed-effects estimations with robust standard errors are in parentheses. ***: p<0.01.

Figure 1. Movements of Micro and Macro Business Survey Index (BSI)



Note: The BSI is calculated as the percentage of firms that responded "improve" minus the percentage of firms that responded "deteriorate."

Figure 2. Movements of Micro and Macro Uncertainty



Note: The figures indicate the percentages of firms choosing "unsure."

Appendix Tables

Table A1. Uncertainty by Industry and Firm Size

	BC_unsure (1Q ahead)	*BC_unsure* (2Q ahead)	*EC_unsure* (1Q ahead)	*EC_unsure* (2Q ahead)
All	15.6%	27.8%	18.4%	31.5%
Construction	20.2%	36.2%	22.1%	37.5%
Manufacturing	14.9%	30.4%	17.0%	33.2%
Wholesale	15.9%	28.8%	17.9%	31.7%
Retail	14.9%	25.1%	17.2%	28.6%
Real estate	11.3%	18.6%	16.8%	26.2%
I&C	14.8%	26.4%	18.7%	31.1%
Transport	16.2%	26.9%	19.8%	31.1%
Electricity and Gas	17.8%	22.4%	26.6%	31.8%
Services	15.6%	26.2%	19.0%	30.6%
Bank and insurance	16.6%	23.4%	18.7%	26.9%
Others	17.2%	23.5%	22.1%	29.8%
Small	18.3%	31.6%	20.5%	34.2%
Medium	12.2%	23.5%	16.1%	28.8%
Large	15.1%	26.7%	17.9%	30.7%

Note: The figures indicate the mean percentage of firms that responded “unsure” about business and macroeconomic outlooks. I & C denotes the information and communications industry. Small firms are capitalized at less than 100 million yen, medium-sized firms at between 100 million yen and 1 billion yen, and large firms at 1 billion yen or more.

Table A2. Seasonality of the Uncertainty Measure

Survey quarter	*BC_unsure* (1Q ahead)	*BC_unsure* (2Q ahead)	*EC_unsure* (1Q ahead)	*EC_unsure* (2Q ahead)
Q1	16.5%	27.8%	19.3%	31.8%
Q2	14.4%	25.1%	17.7%	29.8%
Q3	13.8%	24.8%	17.2%	29.7%
Q4	13.1%	30.7%	16.7%	34.1%
All	14.4%	27.1%	17.7%	31.3%

Note: The percentages are firms that responded “unsure” about business and macroeconomic outlooks.

Table A3. BSI and Uncertainty During the Global Financial Crisis and the COVID-19 Crisis (Panel Firms)

	(1) 1Q ahead		(2) 2Q ahead	
	BSI	Uncertainty	BSI	Uncertainty
A. Business outlook				
Whole period	0.036	0.146	0.043	0.284
GFC period	-0.111	0.131	-0.012	0.291
COVID-19 period	0.026	0.344	0.046	0.471
B. Macroeconomic outlook				
Whole period	0.025	0.173	0.040	0.320
GFC period	-0.237	0.148	-0.076	0.329
COVID-19 period	-0.006	0.381	0.046	0.522

Note: Panel firms are a sample of firms that responded to all surveys from the 2004Q2 survey to the 2021Q2 survey (1,145 firms).

Table A4. Uncertainty and Investment Excluding the COVID-19 Period

	(1)	(2)	(3)	(4)	(5)	(6)
	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$
BC_unsure	-0.0356 ***		-0.0475 ***	-0.0419 ***		-0.0446 ***
	(0.0084)		(0.0108)	(0.0068)		(0.0089)
EC_unsure		(0.0079)	0.0179 *		-0.0195 ***	0.0068
		(0.0077)	(0.0096)		(0.0066)	(0.0084)
ln(Sales)	0.4068 ***	0.4116 ***	0.4115 ***	0.4107 ***	0.4164 ***	0.4162 ***
	(0.0053)	(0.0054)	(0.0054)	(0.0055)	(0.0056)	(0.0056)
Firm FE	yes	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes	yes
Nobs.	321,861	313,971	313,853	290,980	283,511	283,511
R^2 (within)	0.0465	0.0469	0.047	0.0494	0.0497	0.0498

Notes: Fixed-effects estimations with robust standard errors are in parentheses. ***: p<0.01, *: p<0.1.

Table A5. Uncertainty and Investment (Estimations of Panel Firms)

	(1)	(2)	(3)	(4)	(5)	(6)
	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+1}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$	$ln(INV)_{it+2}$
BC_unsure	-0.0429 **		-0.0562 **	-0.0438 ***		-0.0506 ***
	(0.0167)		(0.0217)	(0.0137)		(0.0179)
EC_unsure		-0.0091			-0.0139	0.0172
		(0.0156)			(0.0133)	(0.0172)
ln(Sales)	0.4731 ***	0.4742 ***	0.4737 ***	0.4697 ***	0.4679 ***	0.4677 ***
	(0.0123)	(0.0123)	(0.0123)	(0.0124)	(0.0125)	(0.0125)
Firm FE	yes	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes	yes
Nobs.	55,893	55,274	55,264	55,130	54,467	54,467
R^2 (within)	0.0671	0.0673	0.0673	0.0672	0.0667	0.0669

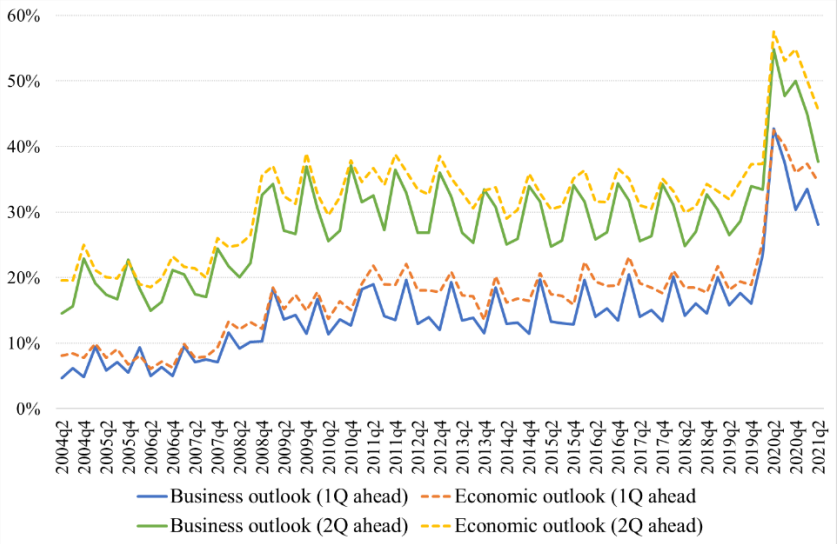
Notes: Fixed-effects estimations with robust standard errors are in parentheses. ***: p<0.01, **: p<0.05.

Table A6. Uncertainty and Investment (Investment Divided by Capital Stock as the Dependent Variable)

	(1)	(2)	(3)	(4)	(5)	(6)
	INV_{it+1}/K_{it}	INV_{it+1}/K_{it}	INV_{it+1}/K_{it}	INV_{it+2}/K_{it+1}	INV_{it+2}/K_{it+1}	INV_{it+2}/K_{it+1}
BC_unsure	-0.0008 **		-0.0007 *	-0.0012 ***		-0.0012 ***
	(0.0003)		(0.0004)	(0.0002)		(0.0003)
EC_unsure		-0.0007 **	(0.0003)		-0.0006 ***	0.0000
		(0.0072)	(0.0003)		(0.0002)	(0.0003)
ln(Sales)	0.0019 ***	0.0020 ***	0.0020 ***	0.0021 ***	0.0022 ***	0.0022 ***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Firm FE	yes	yes	yes	yes	yes	yes
Time FE	yes	yes	yes	yes	yes	yes
Nobs.	467,811	451,470	451,288	392,995	379,839	379,839
R^2 (within)	0.0039	0.0040	0.0040	0.0049	0.0050	0.0050

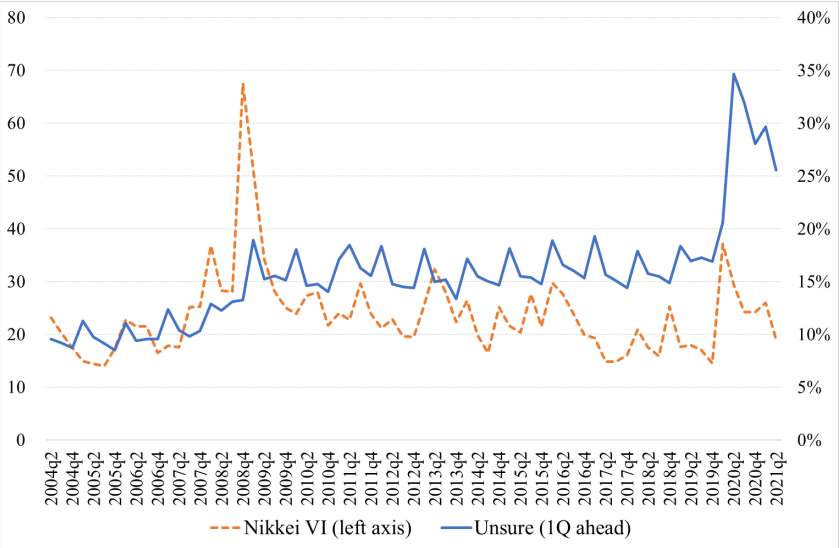
Notes: The dependent variable is investment divided by capital stock (INV_{t+1}/K_t, INV_{t+2}/K_t). Fixed-effect estimations with robust standard errors are given in parentheses. ***: p<0.01, **: p<0.05, *: p<0.1.

Appendix Figure A1. Movements of Micro and Macro Uncertainty (Panel Firms)



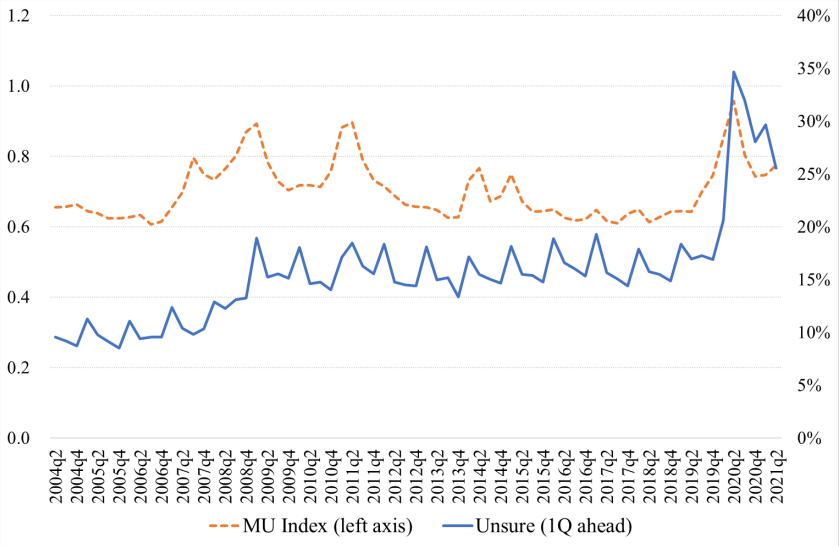
Note: The figures indicate the percentages of firms choosing "unsure." The panel firms are a sample of firms that responded to all surveys, from the 2004Q2 survey to the 2021Q2 survey (1,145 firms).

Appendix Figure A2. Stock Market Volatility and Knightian Uncertainty



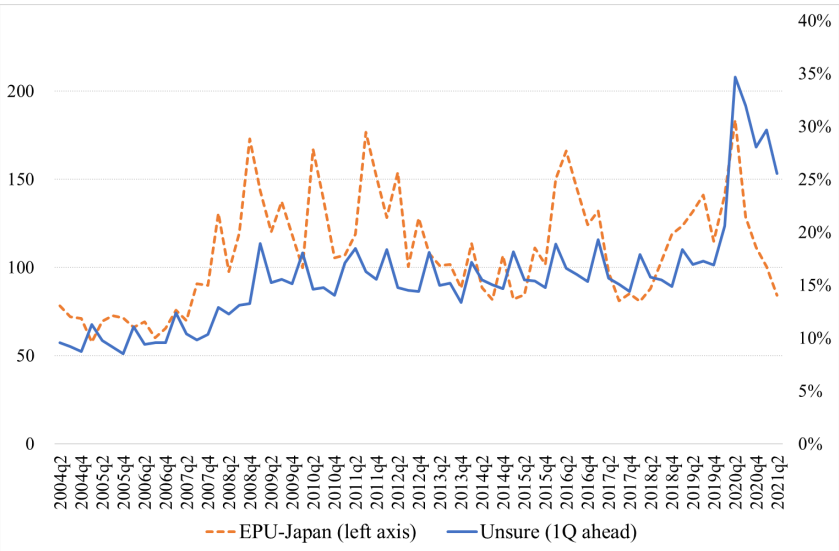
Note: The Nikkei 225 volatility index is a simple average of monthly data used to produce quarterly figures.

Appendix Figure A3. Macroeconomic Uncertainty (MU) Index and Knightian Uncertainty



Note: The MU Index is a simple average of monthly data used to produce quarterly figures. For details on the MU index, see Shinohara *et al*. (2020) and Nakajima (2022).

Appendix Figure A4. EPU Index and Knightian Uncertainty



Note: The EPU Index is a simple average of monthly data used to produce quarterly figures.