BOK Working Paper

Uncertainty, Credit and Investment:
Evidence from Firm-Bank
Matched Data

Youngju Kim, Seohyun Lee, Hyunjoon Lim

2019. 11

BANK OF KOREA

Economic Research Institute
Bank of Korea

Publisher
Juyeol Lee
(Governor of Bank of Korea)

Editor
Woon Shin
(Director General of the Institute)

BOK Working Paper is occasionally published by the Economic Research Institute, Bank of Korea. This is circulated in order to stimulate discussion and comments. Articles include research achievement by the staff and visiting scholars, and selected works sponsored by the Institute.

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Economic Research Institute
Bank of Korea
39 Namdaemunno Jung-Gu
Seoul, 110-794, Korea

E-mail: eso@bok.or.kr

Fax: 82-2-759-5410

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Youngju Kim*, Seohyun Lee**, Hyunjoon Lim***

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* Corresponding author, Bank of Korea, Tel: +82-2-759-5283, E-mail: econoky@bok.or.kr

** Economist, The International Monetary Fund and Bank of Korea, E-mail: SLee6@imf.org

*** Senior Economist, Bank of Korea, Tel: +82-2-759-4137, E-mail: limhj1@bok.or.kr

We are grateful for all of the helpful comments from Bank of Korea seminar and Bank of Japan seminar. We also thank JaeBin Ahn, Sangyoon Song, Byungkwun Ahn, Wook Sohn, and Woon Shin for their useful comments. The views expressed in this paper are those of the authors and cannot be taken to represent those of Bank of Korea or the International Monetary Fund.

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Uncertainty, Credit and Investment: Evidence from Firm-Bank Matched Data

This paper studies how high uncertainty affects corporate bank loans, addressing the important identification issue. In times of high uncertainty, firms reduce their credit demand due to delayed investments or a deterioration in their credit worthiness, while at the same time banks are more exposed to negative shocks to their balance sheet and thereby reduce credit supply. To isolate the uncertainty effect from the credit supply effect, we employ matched bank-firm loan data covering all loans extended by all financial intermediaries to the universe of listed firms in Korea, a bank-centered economy. Our empirical results reveal that a failure to control for credit supply leads to overestimation of the negative effect of uncertainty on bank loans. In addition, we find that the negative effect is stronger for relatively larger firms or financially unconstrained firms with low leverage or financial slack, once credit supply is controlled for. We confirm the same results in the analysis of firm investment, suggesting that high uncertainty may transmit to investment and bank loans mainly through the real options effects.

Keywords: Firm-level uncertainty, Bank loan, Investment

JEL Classification: D84, E22

I . Introduction

Since the outbreak of the Global Financial Crisis in 2008, heightened uncertainty has been associated with slowdown in corporate bank loans, coupled with stagnant or even fallen corporate investments, in many countries. Theoretically, this negative correlation between uncertainty and bank loans can be due to a decline in firms' credit demand induced by the real options channel in which firms with non-convex adjustment costs postpone investment and hiring decisions when uncertainty increases (Bernanke, 1983; McDonald and Siegel, 1986; Dixit and Pindyck, 1994; Bloom, 2009). Or it can be attributable to a deterioration in firms' overall credit worthiness, as implied by the financial channel in which higher uncertainty can increase firms' default risk and their cost of external financing (Arellano et al., 2019; Christiano et al., 2014; Gilchrist et al., 2014).

However, empirically investigating the impact of uncertainty on corporate bank loans is challenging due to identification concerns because the negative correlation between uncertainty and corporate bank loans can also be affected by bank lending channel. For instance, typically in recessions or times of crises, firms face higher uncertainty (Bloom, 2014), and, at the same time, banks become more exposed to negative shocks to their balance sheet strength, thus unwilling to lend (Gertler and Kiyotaki, 2010). That is, in times of high uncertainty, reductions in bank loans can be consequences of both a decline in firms' credit demand or credit worthiness due to heightened uncertainty (firm balance sheet channel) and a decrease in banks' willingness to lend (bank balance sheet channel).

In this paper, we seek to explore how uncertainty shocks affect bank loans. To this end, we estimate the impact of firm-level uncertainty on bank loans while addressing the identification challenges. The difficulty in isolating the uncertainty effect from the credit supply effect in the variations of bank loans mainly comes from a lack of loan-level data that links banks to firms. In order to tackle this issue, we use the credit

registry of Korea that contains a comprehensive, matched, bank-firm dataset covering all loans extended by all financial intermediaries to the universe of listed Korean non-financial firms including delisted and newly listed ones over the period from 2006 to 2015.¹⁾ Through the firm identification numbers in the credit registry, the bank-firm loan data can be matched with comprehensive firm balance sheet data, which is then used to control for other firm-side determinants of bank loans. Our loan measure is the total borrowing from a given bank in a year. We observe the amount of outstanding loans to firms identified by each bank as well as rich information on firms' balance sheet. Our main firm-level uncertainty measure is the realized yearly volatility of stock returns, computed by the standard deviation of daily stock returns over the year (which typically spans 252 trading days).

We highlight that our analysis using Korean data is ideal for the study of uncertainty and its impact on bank loans in several ways. First, Korea's financial system is dominated by banks and thereby even listed firms rely heavily on bank loans for external financing for investment. Korean firms' dependence on bank financing is even greater than those in Japan and Germany. Furthermore, Korea's economy is a highly liberalized small open economy with its firms differently exposed to numerous external shocks such as global interest rate and commodity price volatility, and geopolitical risk from North Korea's nuclear threats. Such various exogenous sources of uncertainty provide us appropriate environment for investigating firms' responses to firm-level variations in uncertainty.

With the firm-level uncertainty measure, matched bank-firm loan data and firm balance sheet data in hand, we follow the identification methodology in Khawaja and Mian (2008), who investigate the impact of bank liquidity shocks on credit supply to firms, controlling for

1) Henceforth our definition of a "bank" covers all kinds of private and public financial intermediaries including private and government owned banks, foreign bank branches, saving banks, insurance companies, asset management companies, guarantee insurance companies and others. Also, our definition of "loan" covers all business loans and bond purchases by all financial institutions.

firm-specific changes in credit demand.²⁾ However, we depart from Khawaja and Mian (2008) in that we focus on banks' loans to multiple firms facing different levels of uncertainty while they focus on firms' borrowing from multiple banks differently exposed to liquidity shocks. Our bank-year fixed effects show how different banks change the quantity of loans extended to a given firm and thereby capture shocks to bank loan supply. Using bank-year fixed effects along with firm fixed effects and time-varying firm-side control variables, we compare the growth of loans from a bank that is extended to a firm relative to the growth of loans from the same bank to other firms facing higher uncertainty. As much as this within bank comparison fully absorbs bank-specific changes in credit supply, the estimated difference in loan growth across firms can be imputed to differences in the effects of firm-level uncertainty, controlling time-varying observed and unobserved bank heterogeneity with bank-year fixed effects.

Next, we attempt to uncover which one, between the real option channel and the financial channel, is more dominant as a transmission mechanism through which uncertainty shocks operate. To do so, we use the matched bank-loan data to control for bank credit supply effects and investigate whether the negative impact of uncertainty on bank loans exhibits heterogeneity across firms. The real options channel predicts that the negative effect of uncertainty on bank loans is stronger for firms with more irreversible investments since they have more incentive to delay investments and thus reduce more of their credit demand. In order to test this prediction, we exploit two different proxies for investment irreversibility as in Gulan and Ion (2015): the ratio of fixed to total assets and an indicator variable for whether the firm operates in a durables industry.

2) Related literature that uses Khwaza and Mian (2008) estimator to control for firm-specific credit demand includes Paravisini (2008), Ivashina and Scharfstein (2010), Schanbl (2012), Bercker and Ivashina (2016), among others. It mainly focuses on analyzing changes in credit supply to the same borrower by multiple banks with different balance sheet strength.

The financial channel, on the other hand, predicts that the negative effect of uncertainty on bank loans is greater for less creditworthy and more financially constrained firms since uncertainty increases the default risk of these firms to a greater extent and thereby raises their costs of external financing more. We use three different proxies for firm credit worthiness and financing constraints: leverage (the ratio of total liabilities to total assets), an indicator variable for firm size (large versus small and medium sized firms) and credit line drawdown ratio (the ratio of utilized loan commitments to total loan commitments granted). First, firm leverage is positively correlated with credit risk (Merton, 1974; Campbell, 2008), and has been used as a proxy for financing constraints in the related literature. Second, small firms are likely to be more financially constrained and less creditworthy (Hadlock and Pierce, 2010). Lastly, the credit line drawdown ratio directly measures firms' financial slackness, with its lower value indicating that the firm has relatively larger amount of loan commitments from banks that can readily be tapped at its discretion. Thus, we use this ratio as a measure of financing constraints.

Interestingly, real options literature makes the opposite prediction on the effect of uncertainty for high leveraged and financially constrained firms to that made by the financial channel. Boyle and Guthrie (2003) analyze the optimal timing of investment decision subject to financing constraints and argue that a high leveraged firm faces a higher likelihood of experiencing the threat of future funding shortfalls. Therefore, higher leverage lowers the value of the firm's timing options and encourages acceleration of investment. This suggests that a high leveraged firm may be less affected by uncertainty shocks. With mixed theoretical predictions of uncertainty effects for financially constrained and high leveraged firms, we attempt to address this question empirically. In order to identify the dominant mechanism through which firm-level uncertainty shocks operate, we interact the firm-level uncertainty measure with the five proxies for firm characteristics separately in the estimation of loan equations.

So far, the underlying assumption of our identification to find the

dominant transmission channel is that the effects of uncertainty on bank loans are driven by firms' investment incentives. To confirm whether this assumption is indeed valid, we also estimate the impact of uncertainty on firms' capital expenditures exploiting the same sample of firms in the analysis of bank loans. Furthermore, to be robust in the identification of the dominant channel, we examine whether the negative impact of uncertainty on firms' investment exhibits heterogeneity across firms in the same way as its differential effects on firms' bank loans.

Our main findings are as below. First, we find that higher firm-level uncertainty leads to a reduction in bank loans, but the magnitude of its negative effect is underestimated without controlling for bank specific credit supply. Using bank-year fixed effects, bank-firm fixed effects and time-varying firm-side determinants of bank loans, our within-bank comparison shows that one percent increase in the realized volatility uncertainty leads to a 0.097 percent decline in bank loans. If we only use time fixed effects and firm fixed effects without controlling for bank-specific credit supply, one percent increase in the realized volatility uncertainty leads to a 1.541 percent decline in bank loans. The comparison between the two estimates reveals that the negative effect of uncertainty on bank loans can be overestimated without controlling bank specific credit supply, indicating that firm-level uncertainty is negatively correlated with bank credit supply.

Second, we find robust evidence that high uncertainty reduces firms' incentive to invest and therefore decreases bank loans mainly through the real options channel. The negative impact of uncertainty shocks on bank loans is stronger for firms that have a higher degree of investment irreversibility: firms with a higher ratio of fixed to total assets, and firms that operate in a durables industry. In addition, higher uncertainty diminishes the bank loans even more for the firms that are likely to be more creditworthy and financially unconstrained: lower leveraged and large firms, and firms with the lower credit line drawdown ratio. These results are consistent with the implications of the real options literature as

in Boyle and Guthrie (2003) and Wong (2010). With bank specific supply shocks controlled for, we cannot find sufficient evidence of the strong financial channel through which uncertainty affects bank loans. We recognize that using the matched bank-firm loan data is important for identifying the dominant transmission channel. A naïve estimation without accounting for bank credit supply shocks may result in estimation biases that lead us to reach inappropriate conclusions qualitatively.

We also confirm the same results for firms' investment. The negative effect of uncertainty is stronger for firms facing a higher degree of investment irreversibility, and more credit worthy firms.

In our robustness exercises, all our findings are robust to replacing the levels of the realized volatility with the growth of the realized volatility as a measure of uncertainty shocks or to limiting our sample to loans from private banks.

Our paper is related to several strands of literature on uncertainty. Uncertainty as a source of business cycle has been empirically investigated in various contexts at the aggregate level and the firm level.³⁾ However, existing literature on the relation between uncertainty and bank loans is very few, and has focused on the impacts of macroeconomic (Valencia, 2017), policy (Bordo, Duca, and Koch, 2016) and banking sector (Buch et al., 2015) uncertainty on bank credit supply using bank-level data. To the best of our knowledge, this paper is the first attempt to identify the effect of uncertainty on bank loans using a comprehensive, matched, bank-firm loan data, which allows us to control for bank-specific credit supply. Considering that banks may differ in exposure to shocks which are simultaneously correlated with high uncertainty, it is important to control for bank-specific credit supply to obtain unbiased estimates on the uncertainty induced effects. In this regard, Amiti and Weinstein (2018)

3) A large body of empirical literature has investigated the impacts of aggregate uncertainty on macroeconomic activities, such as investment, employment, consumption and capital flows (See, for example, Bloom, 2009; Jurado, Ludvigson and Ng (2015); Basu and Bundick (2017); Julio and Yook, 2016). The literature on how firm-level uncertainty affects investment and employment includes Leahy and Whited (1996), Bloom et al. (2007), and Panousi and Papanikolaou (2012), among many.

illuminate the importance of the bank specific credit supply shocks as a driving force of banking and real activity, by showing that they explain 30-40 percent of aggregate loan and investment fluctuations in Japan, a bank-centered economy like Korea.

This paper is also related to the empirical literature on the transmission channels through which uncertainty affects corporate investment and financing decisions. Gulen and Ion (2016) and Kim and Kung (2017) tested the predictions of the real options channel by investigating cross sectional heterogeneity in the negative effect of policy and aggregate uncertainty on corporate investment depending on the degree of investment irreversibility. They found evidence in support of the real options channel but did not investigate the role of the financial channel. More recently, Alfaro, Bloom, and Lin (2018), both theoretically and empirically, investigate the effect of firm-level uncertainty on firms' real and financial activities. Their empirical results show that higher uncertainty reduces corporate investment and debt, with these effects being the strongest in periods of financial distress and for financially constrained firms. Their results suggest that the real options effect of uncertainty can be amplified through financial frictions especially in crisis times. Our study is similar to Alfaro, Bloom, and Lin (2018) in that both study the impact of higher firm-level uncertainty on corporate real and financial activity. However, our work departs from them in several ways. First, we explicitly control for credit supply shocks using the matched bank-firm loan data to address the identification issues in investigating the impact of higher uncertainty on corporate bank loans. Second, in terms of empirical results, we find little evidence in support of the financial channel with credit supply shocks accounted for. The negative impact of high uncertainty on corporate bank loans and investment is stronger for more credit worthy firms, and financially unconstrained firms with financial slack. These results are consistent of those in Baum et al. (2010) which study the impact of debt on a panel of US firms' investment. They find that the negative impact of higher firm-level

uncertainty on investment is stronger for less leveraged firms.

The remainder of the paper is organized as follows. Section 2 illustrates empirical strategy. Section 3 describes data. Section 4 presents main and robustness results and Section 5 concludes.

II. Empirical Framework

1. Baseline Estimation

The effect of uncertainty on bank loans is estimated by

$$\ln(\text{loan})_{f,b,t} = \mu_{b,t} + \beta \ln(VU_{f,t}) + X'_{f,t}\gamma + \lambda_{f,b} + \varepsilon_{f,b,t} \quad (1)$$

where $\ln(\text{loan})_{f,b,t}$ is loan amount of bank b to firm f at time t expressed as a natural logarithm, $\ln(VU_{f,t})$ is natural log of firm-specific uncertainty index, $\mu_{b,t}$ is bank-time fixed effect, $\lambda_{f,b}$ is firm-bank fixed effect, and $X'_{f,t}$ is a vector of controls.

$$X_{f,t} = \left[\text{Tobin } Q_{f,t-1}, \left(\frac{\text{cash}}{\text{assets}} \right)_{f,t-1}, \text{ROA}_{f,t-1} \right] \quad (2)$$

All variables in $X_{f,t}$ are in levels and one period lagged to account for simultaneity. We note that the realized volatility uncertainty measure can be affected by changes in bank loans. However, endogeneity can be partly resolved because these two variables are measured at different levels and individual bank's lending cannot drive changes in firm level uncertainty. The volatility measure of uncertainty is included in levels following the literature.

Bank-time fixed effect absorbs time variant bank-specific credit supply shocks and aggregate shocks at the same time, thereby isolating credit demand shocks, which is expected to provide more reliable estimates of the impact of uncertainty in the credit demand side. Our data structure –

loans extended to a firm from multiple banks – allows us to include bank-time fixed effects that can control for any time-varying unobserved aggregate shocks in general as well as bank-specific supply shocks. Regressions are all weighted-least square, where weights are equal to the natural logarithm of the loan. Standard errors are all double clustered at the firm and year levels.

To investigate different transmission channels of uncertainty shocks, we include an interaction term of firm-specific uncertainty and time-invariant firm characteristics.

$$\ln(\text{loan})_{f,b,t} = \mu_{b,t} + \beta_0 \ln(VU_{f,t}) + \beta_1 FSC_f \times \ln(VU_{f,t}) + X'_{f,t} \gamma + \lambda_{f,b} + \varepsilon_{f,b,t} \quad (3)$$

where FSC_f is the value of firm specific characteristics. With bank credit supply controlled, the estimated β_1 enables us to test whether the effect of uncertainty shocks exhibit heterogeneity across firms. We consider various firm specific characteristics that explain dominant channels through which uncertainty affects firms' bank loan demand.

The sensibility of firms' investment and demand for lending may depend on the cost of reversing their investment decisions. Gulen and Ion (2015) and Kim and Kung (2016) find the evidence that the negative effect of uncertainty shocks on capital expenditures is strong for firms that have a higher degree of investment irreversibility. To test this hypothesis, we use two proxies for investment irreversibility: capital intensity and product durability. To measure capital intensity, we use the ratio of fixed to total assets since investment projects that require significant amount of fixed assets, such as property, plant, and equipment, are costly to revert. Also, firms may want to liquidate their fixed assets in times of difficulties and firms' asset liquidation value depends on the cyclicity of the industry they operate. Generally, the cyclicity of industry tends to be greater for firms that produce durable goods. Therefore, we use a dummy variable indicating whether a firm produced durable goods to capture firms' investment irreversibility.

Firms' financing conditions are also crucial factors for how uncertainty shocks transmit to firms' loan demand. Literature shows mixed views on how financial conditions affect the degree of uncertainty effects on firms' decision. In the model highlighting risk premium effects, higher uncertainty can increase firms' risk of financial distress and their cost of external financing, which leads to a decline in corporate credit (Arellano et al., 2019; Christiano et al., 2014; Gilchrist et al., 2014). On the contrary, the real option theories literature, such as Boyle and Guthrie (2003), predicts that firms with higher financing constraints are less influenced by uncertainty shocks. They analyze the optimal timing of investment decision subject to financing constraints. They suppose a firm owns the right to several investment projects and has the option to invest in the projects at any time. A financing constraint means a higher likelihood of experiencing the threat of future funding shortfalls. Therefore, it lowers the value of the firm's timing options and encourages acceleration of investment beyond the first best optimal level (now-or-never investments). If a firm with insufficient financial resources has several investment projects, investing now for a new project increases the likelihood of being able to subsequently launch the other. Therefore, a firm with binding financial constraints may be less affected by firm-specific uncertainty shocks.

In order to test the effect of financing constraints and firms credit worthiness, we use three variables: leverage (the ratio of total liabilities to total assets), an indicator variable for firm size (large versus small and medium sized firms) and credit line drawdown ratio (the ratio of utilized loan commitments to total loan commitments granted). First, we examine how leverage affects the degree of uncertainty effects on bank loans. It is well understood that high level of debts may discourage firms' investment and lending activities even more when uncertainty is higher than normal times. Among many studies, Byun and Jo (2018) find that the negative impact of aggregate uncertainty shocks on firms' capital expenditures is stronger for highly leveraged firms. There is other theoretical literature

(for instance, Boyle and Guthrie, 2003 and Wong, 2010) that examines the role of firm leverage on the uncertainty effect. They argue that highly leveraged firms facing profitable investment opportunities have less incentives to wait and see in times of high uncertainty since they might not be able to obtain external financing in the future. Indeed, Baum et al. (2010) find the empirical evidence of either stimulating or mitigating effects of leverage by investigating the impact of debt on a panel of U.S. manufacturing firms' capital investment behavior.

Second, firm size can also be a proxy for financial constraints that a firm may experience during the bad times. Larger firms may have easier access to external finance even when uncertainty around the future economic outlook is high. Existing literature provide evidence of differential effects of uncertainty shocks depending on the firm size. Ghosal and Loungani (2000) show that the negative impact of (aggregate) uncertainty on investment is greater for smaller firms. They explain this result by the financing-constraints hypothesis: greater uncertainty about future profits increase the information asymmetry between borrowers and lenders, especially for smaller firms. Therefore, the premium on external funds increases more for small firms and consequently they are more financially constrained. Byun and Jo (2018) find that the firm size and the degree of uncertainty effects have a nonlinear relationship where small and large firms have stronger negative effects of uncertainty than medium sized firms.

Third, we utilize credit drawdown ratio to examine heterogeneity of uncertainty effects depending on financial slackness. Credit line is a contract between a financial institution and a borrower that establishes the maximum amount of loan that can readily be tapped at the borrower's discretion. A drop in a firm's credit line drawdown (or usage) ratio suggests a decrease in the firm's credit demand, not a decrease in the bank's credit supply because the firm has the opportunity to borrow up to the maximum level laid out in the contract but decides to borrow less. Therefore, a lower credit line drawdown ratio is associated with decreased

loan demands by a firm. A positive sign for a coefficient on the interaction between credit line usage ratio and firm-level uncertainty implies that the negative effect of uncertainty shock is stronger for the firms that have lower level of credit line drawdown ratio. That is, the positive sign for the coefficient can be interpreted as evidence that the real option channel dominates the bank.

Similarly, we estimate investment regressions as follows.

$$\frac{Inv_{f,t}}{Asset_{f,t-1}} = \theta_f + \mu_t + \alpha \ln(VU)_{f,t} + X'_{f,t}\gamma + \varepsilon_{f,t} \quad (4)$$

where $Inv_{f,t}$ is investment, $Asset_{f,t-1}$ is firm's asset lagged by one period. θ_f is firm fixed effect, μ_t is time fixed effect, $\ln(VU)_{f,t}$ is natural log of firm-specific uncertainty index, and $X'_{f,t}$ is a vector of controls. The controls are Tobin's Q, cash flow rate, and ROA. All variables are in levels.

We consider firm characteristics to examine real option channel of uncertainty in investment.

$$\frac{Inv_{f,t}}{Asset_{f,t-1}} = \theta_f + \mu_t + \alpha_0 \ln(VU)_{f,t} + \alpha_1 FSC_f \times \ln(VU)_{f,t} + X'_{f,t}\gamma + \varepsilon_{f,t} \quad (5)$$

where FSC_f is the value of firm specific characteristics as in the loan regressions.

2. Robustness

This section explains additional robustness exercises. First, we examine whether the results are robust to the use of growth rates in our estimation instead of levels. Additionally, we investigate whether the results are robust to the type of banks, government-owned or private banks.

III. Data

Our matched firm-bank loan data comes from the Korea Enterprise Data (KED). KED is a leading provider of business credit reports of Korean businesses, specializing in credit information of small and medium sized enterprises in addition to the large corporations. It offers standard Business Information Reports, credit check reports, and compact reports. The contents of Business Information Reports are business profile, statutory information, historical and current credit rating, major suppliers and customers, banking relations, financial statements and key financial ratios. KED uses various sources of information: Korea Federation of Banks, Office of National Taxation, Registry Office, Financial Supervisory Service, Newspapers, and on-site investigation.⁴⁾

KED has access to the public credit register of Korea, which contains exclusive information on all business loans, guarantees and bond purchases by all financial institutions operating in Korea. The data includes the history of each loan with information on the amount of loan outstanding, maturity and type of loan and default amount from 2006 to 2015. The scope of our data at the firm-level is limited to Korea's non-financial listed firms only as our objective is to estimate the uncertainty effect on non-financial firms' bank credit demand and investment decisions. We have annual data on 96,009 loans to 2,175 non-financial listed firms from 563 financial institutions.

Our firm balance sheet data comes from KISVALUE database managed by the Korea Investors Service, Korean credit rating agency affiliated with Moody's. This database contains balance sheet and stock market information on all listed firms including those delisted operating in Korea. We match the firm balance sheet data in KISVALUE to the loan

4) KED was established in 2005 as a licensed credit bureau with investments from various public institutions and banks. In 2012, KED was privatized through expanding the private bank equity participation. Current shareholders include Korea Credit Guarantee Fund, Korea Technology Finance Corporation, Industrial Bank of Korea, Korea Federation of Banks and Korea SMEs and Startups Agency. KED has the largest credit database on small and medium sized in Korea.

data by the firms' business registration.

Our bank balance sheet data comes from on the Financial Analysis Information Retrieval System (FAIRS) of the Bank of Korea, central bank of Korea. FAIRS is a system created to help the Bank of Korea and the Financial Supervisory Service share financial supervisory data. It has balance sheet information for all financial institutions operating in Korea. We match this data to the loan data by the financial institutions' names. In case of mergers and acquisitions between firms, we treat the firms before and after as different entities.

Our measure of firm-level uncertainty is the realized volatility of firms' stock returns (VU, henceforth). The yearly realized volatility is computed using the following formula.⁵⁾

$$VU_{f,t} = \sigma_{f,t}^q \quad (6)$$

where $\sigma_{f,t}^s = \sqrt{\Sigma_d (\Delta r_{f,d} / \sqrt{\Delta \varphi_d})^2}$, $\Delta r_{f,d}$ is the first difference of a firm f 's daily returns, r , φ_d is the number of days intervening. s indicates frequency of data, taking the values of day (d), month (m) and quarter (q), respectively.

We present summary statistics in Table 1. Panel A shows the statistics of loan-level data and Panel B those of firm-level data. In Panel A, the total number of observations of loan data is 96,009. In Panel B, the total number of observations of investment ratio is 16,758.

5) We also consider an alternative measure, $VU_{f,t}^{2s} = \sum_{m=1}^3 \sigma_{f,m}^2 / 3$, the average of the monthly realized volatility of stock returns, while our main analysis focuses on VU. We find the change of uncertainty measures does not affect outcomes substantially. The results using VU2 are available upon request.

Table 1. Descriptive Statistics

Panel A. Loan-level						
Variables	Obs.	Mean	Median	SD	p25	p75
Loan	96,009	24,840	2,000	120,170	16	17,046
VU	96,888	0.015	0.013	0.009	0.010	0.018
CF rate	83,698	0.191	0.071	11.998	0.028	0.128
Tobin's Q	88,404	1.291	1.051	1.401	0.838	1.404
ROA	85,953	0.097	0.040	6.208	0.005	0.084
Lev ratio	67,112	0.516	0.517	0.273	0.363	0.643
Crline use ratio	53,262	42,550	23.842	1,006.174	0.000	71.932

Panel B. Firm-level						
Variables	Obs.	Mean	Median	SD	p25	p75
Inv rate	16,758	0.046	0.014	0.083	0.001	0.051
VU	13,440	0.016	0.014	0.011	0.011	0.019
CF rate	13,758	0.084	0.072	0.129	0.022	0.137
Tobin's Q	12,053	1.319	1.057	0.922	0.814	1.484
ROA	12,758	0.050	0.042	0.122	0.002	0.096
Lev ratio	11,713	0.441	0.432	0.226	0.265	0.589
Crline use ratio	10,823	0.372	0.322	0.431	0.079	0.596

Notes: Loans in Panel A is identified up to firm-bank-year level whereas loans in Panel B is the average amount of loans across banks. Investment ratio denotes the ratio of the investment of current year to the asset value lagged by one year. VU is the realized volatility uncertainty measure, computed by the standard deviation of daily stock returns over the year. Cash flow denotes the ratio of cash flows to the total assets, both lagged by one year. Tobin's Q is computed by the ratio of equity market value to total assets (book value) minus fixed assets (book value) plus real fixed assets (re-evaluation value). ROA is the return on assets.

IV. Results

1. Baseline results

1.1 Loan

Table 2 reports the results from our baseline estimation for loan-level data. The sample covers total 96,009 loans that have the volatility uncertainty index available. While Columns (1) and (2) present the results from the specification that includes both bank-year and firm-bank fixed effects, Columns (3) to (5) contain the estimation results with either of

Table 2. The Effect of Uncertainty on Loans

	(1)	(2)	(3)	(4)	(5)
VU	-0.0852*** (0.0248)	-0.0975*** (0.0278)	-1.541*** (0.0667)	-0.785*** (0.0427)	-0.0930*** (0.0272)
Cash Flow		-0.281*** (0.0694)	-0.807*** (0.194)	-0.209** (0.101)	-0.262*** (0.0688)
Tobin's Q		0.0480*** (0.0114)	0.104*** (0.0248)	0.0856*** (0.0160)	0.0443*** (0.0113)
ROA		0.312*** (0.0626)	0.667*** (0.208)	0.116*** (0.0216)	0.296*** (0.0618)
Constant	7.775*** (0.107)	7.832*** (0.123)	1.631*** (0.287)	4.818*** (0.186)	7.854*** (0.120)
Observations	82,802	63,647	63,647	63,647	63,647
R-squared	0.858	0.864	0.044	0.453	0.859
Firm FE	No	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Bank-Time FE	Yes	Yes	No	Yes	No
Firm-Bank FE	Yes	Yes	No	No	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) and (2) include bank-year and firm-bank fixed effects while Column (3) to (5) contains firm and year fixed effect terms. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, y $p < 0.15$. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

them or dual fixed effect terms. We utilize the bank-year fixed effect to control for time-varying supply shocks driven by banking sector and thereby to better disentangle the demand and supply-side shocks in a setting of a firm with borrowings from multiple banks. This effect also removes need for aggregate controls. The firm-bank fixed effect could capture time-invariant relationship between a firm and a bank.

Most importantly, we find that loan is reduced in response to higher firm-level uncertainty at statistically significant level regardless of whether the bank-year fixed effects are included. The estimation results without bank-year FEs in Column (2) to (4) show that the coefficients on the firm-level uncertainty are negative and relatively larger than those with bank-year FEs in Columns (1) and (5). This result suggests that failure to take proper account of matched bank-firm relationship may lead to biased estimation results. That is, unless the bank-lending shocks are relevantly controlled, the coefficients may be underestimated.⁶⁾

Meanwhile, the regressors such as Tobin's Q and ROA are positively associated with the loan while the coefficients on the cash flows as a share of total asset are significant and negative.

We now turn to including in the baseline specification the firm-specific variables in the form of interaction terms. First, we choose to use proxies of investment irreversibility in order to investigate how much the effect of firm-level uncertainty on loans depends on investment irreversibility. Investment irreversibility is proxied by two measures: the means of the ratio of fixed assets (Property, Plant and Equipment, hereafter "PPE") to total assets, and a dummy for whether a firm produces "durable" goods (hereafter "durables"). Columns (1)-(2) of Table 3 show that neither of the coefficients on volatility uncertainty interacted with PPE and durable

6) The underestimation of the coefficients on the firm-level uncertainty without controlling for the bank-time fixed effect terms inarguably appears to be attributable to the fact that financial shocks are negatively correlated with the uncertainty. This result is broadly consistent with previous studies (Most recently, IMF (2019)) which showed that the financial cycles are negatively correlated with the real cycles in the case of Korea.

industries are, albeit of negative signs, statistically significant. These results cannot find enough evidence that higher investment irreversibility is closely related to a more pronounced response to firm-specific uncertainty.

Column (3) reports the dependence of uncertainty effect on firm size by adding interactive terms of uncertainty and five quintiles by firm sizes. This result shows that the coefficients on the interactive terms of higher quintile have larger negative values. This is interpreted as evidence supporting presence of the real option channel, given that the larger the firm is, the highly responsive it is to the firm-level uncertainty shock.

Meanwhile, Column (4) shows that firms with higher leverage ratio are less affected by firm-specific uncertainty, which is consistent with Baum et al. (2010). These estimation results which use the interaction terms consistently confirm that the real option channel predominates in accounting for the channel through which the firm-level uncertainty shocks affect its lending.

In order to test for presence of the risk premium channel, we, in turn, include a ratio of actual usage to the credit line which is assigned to a firm interacted with the uncertainty. As a result, it is found that firms with more usage of its credit line are less responsive to changes in firm-level uncertainty, suggesting that the real option channel rather than risk premium channel appears predominant in Korea. That is, these results suggest that drops in lending in response to a spike in firm-level uncertainty may be attributable to the fact that firms do not choose to borrow rather than banks refuse to lend.

Table 3. Heterogeneity in the Effect of Uncertainty on Loans

	(1)	(2)	(3)	(4)	(5)	(6)
VU	-0.0761*** (0.0293)	-0.0945*** (0.0378)	0.0810** (0.0309)	-0.143*** (0.0335)	-0.112*** (0.0438)	-0.102*** (0.0315)
VU x PPE	-0.0766*** (0.0262)					
VU x Durables		-0.00619 (0.0473)				
VU x 2 nd FS Quintile			-0.0898*** (0.0116)			
VU x 3 rd FS Quintile			-0.151*** (0.0144)			
VU x 4 th FS Quintile			-0.223*** (0.0180)			
VU x 5 th FS Quintile			-0.263*** (0.0258)			
Leverage ratio				0.637*** (0.173)		
VU x Leverage ratio				0.0809*** (0.0270)		
Credit line					-0.00592 (0.0019)	
VU x Credit line					0.00284*** (0.00017)	
VU x Crisis						0.0247 (0.0425)
Cash flow	-0.304*** (0.0724)	-0.281*** (0.0694)	-0.184*** (0.0672)	-0.383* (0.215)	-0.476 (0.715)	-0.353** (0.166)
Tobin's Q	0.0514*** (0.0119)	0.0480*** (0.0114)	0.0321*** (0.0110)	0.0518*** (0.0165)	0.0437** (0.0197)	0.0453*** (0.0132)
ROA	0.338*** (0.0656)	0.312*** (0.0627)	0.215*** (0.0606)	0.412* (0.211)	0.361 (0.733)	0.386*** (0.162)
Constant	8.041*** (0.126)	7.832*** (0.122)	7.854*** (0.122)	7.677*** (0.161)	8.567*** (0.195)	7.857*** (0.126)
Observations	63,647	63,647	63,647	55,802	44,254	63,647
R-squared	0.861	0.864	0.864	0.867	0.744	0.865
Firm FE	No	No	No	No	No	No
Time FE	No	No	No	No	No	No
Bank-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Bank FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) through (6) includes bank-year and firm-bank fixed effects. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, y p<0.15. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

1.2 Investment

We attempt to quantify the effect of firm-specific uncertainty shocks on its investment by adopting a standard Tobin's Q model. Table 4 reports the baseline results. They confirm that the firm-level uncertainty has negative impacts on investment, supporting widespread belief that a hike in uncertainty may lead to drops in corporate investment and further to weaker activity. In Table 5, we furthermore find that firms with high degree of investment irreversibility react more strongly to firm-level uncertainty shocks. In Column (3) and (4) of the same table, we also find that firms that are larger in size or less leveraged are more affected by the shocks, which is in line with the estimation results of lending. Finally, in Column (5), we analyze the responsiveness of the coefficients of our

Table 4. The Effect of Uncertainty on Investment

	(1)	(2)
VU	-0.00372* (0.00202)	-0.00279*** (0.00086)
Cash flow		0.00565*** (0.00144)
Tobin's Q		-0.0993** (0.0460)
ROA		0.150*** (0.0470)
Constant	0.0294*** (0.00895)	0.0202** (0.00801)
Observations	13,440	12,018
R-squared	0.074	0.083
Number of fid	1,917	1,881
Time FE	Yes	Yes
Firm FE	Yes	Yes

Notes: This table reports regression results of annual firm-level investment rate on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. The investment rate is the ratio of current investment to firm's asset lagged by one period. These specifications include year and firm fixed effect terms and firm-level controls such as Tobin's Q, cash flow as a share of total asset, and ROA. We do not report the coefficients and standard errors on fixed effect terms in order to save space. The sample period is annual from 2006 to 2015. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Standard errors are clustered at the firm level and are reported in parentheses. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, y $p < 0.15$. See section 2 for data details.

Table 5. Heterogeneity in the Effect of Uncertainty on Investment

	(1)	(2)	(3)	(4)	(5)	(6)
VU	-0.00300* (0.00162)	-0.00168* (0.00095)	-0.00305 (0.00186)	-0.00554*** (0.00192)	-0.00349** (0.00167)	-0.00237* (0.00126)
VU x Durables	0.00348 (0.00358)					
VU x PPE		-0.0180*** (0.00226)				
VU x 2 nd FS Quintile			0.00909*** (0.00328)			
VU x 3 rd FS Quintile			-0.00415 (0.00402)			
VU x 4 th FS Quintile			-0.00962** (0.00389)			
VU x 5 th FS Quintile			-0.00758* (0.00391)			
Leverage ratio				-0.0564*** (0.00968)		
VU x Leverage ratio				0.00734*** (0.00159)		
Credit line					-0.00466 (0.00314)	
VU x Credit line					0.00157** (0.000726)	
VU x Crisis						-0.00780* (0.00434)
Cash flow	0.00549*** (0.00133)	0.00440*** (0.00139)	0.00483*** (0.00142)	0.00612*** (0.00146)	0.00550*** (0.00169)	0.00541*** (0.00132)
Tobin's Q	-0.0931** (0.0448)	-0.0393 (0.0399)	-0.0895* (0.0458)	-0.0818* (0.0467)	-0.133* (0.0679)	-0.0957** (0.0444)
ROA	0.142*** (0.0453)	0.0864** (0.0391)	0.135*** (0.0466)	0.129*** (0.0476)	0.192*** (0.0675)	0.145*** (0.0449)
Constant	0.0204** (0.00855)	0.0471*** (0.0103)	0.0134 (0.0196)	0.0414*** (0.00953)	0.0227** (0.00967)	0.0134* (0.00660)
Observations	12,018	12,018	12,018	12,018	9,812	12,018
R-squared	0.085	0.105	0.086	0.092	0.100	0.085
Number of fid	1,903	1,881	1,881	1,879	1,690	1,903
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regression results of annual firm-level investment rate on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. The investment rate is the ratio of current investment to firm's asset lagged by one period. These specifications include year and firm fixed effect terms and firm-level controls such as Tobin's Q, cash flow as a share of total asset, and ROA. We do not report the coefficients and standard errors on fixed effect terms in order to save space. The sample period is annual from 2006 to 2015. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Standard errors are clustered at the firm level and are reported in parentheses. Statistical significance: *** p < 0.01, ** p < 0.05, * p < 0.1, y p < 0.15. See section 2 for data details.

interest on the degree of usage of credit line. As a result, firms with higher degree of credit line usage are more likely to be less affected by the uncertainty shock, which is also consistent with the results above.

2. Robustness

2.1 Substituting the growth of uncertainty measures for the levels

In the baseline specification, we use the variables of main interest in the form of level. In this setting, we replace the variables in level by their growth. Following the methodology used in Alfaro, Bloom and Lin (2018), we define the growth of uncertainty as⁷⁾

$$\Delta X_t = \frac{X_t - X_{t-1}}{0.5X_t + 0.5X_{t-1}}$$

These values yield growth rates which range between -2 and 2.

The estimation results displayed in Tables 6 to 7 are broadly in line with those in the baseline estimation. In particular, the negative coefficient estimates in the Column (1) and (2) are more different from those without bank-year fixed effect term in Column (3) to (4), confirming that the triple panel estimation plays a crucial and more efficient role in accounting for the dynamics of the matched loan data. The magnitudes of the coefficients on the uncertainty growth, nevertheless, are estimated to be smaller than those on the level of uncertainty. Most interestingly, the coefficient on the uncertainty growth which contains the bank-year fixed effect terms is notably larger than those which do not, which is in line with the result of baseline estimation and reinforces the finding above that the triple

7) This definition of growth rate is applied in Alfaro, Bloom and Lin (2018). It enables us to avoid losing observations by log transformation. The growth rate is symmetric around zero and ranges from -2 to 2. See Davis and Haltiwanger (1992) for further explanation.

Table 6. The Effect of Uncertainty on Loans (differenced)

	(1)	(2)	(3)	(4)	(5)
VU	−0.0214** (0.0103)	−0.0320*** (0.0120)	−0.0425*** (0.0108)	−0.0414*** (0.0108)	−0.0343*** (0.0117)
Cash Flow		−0.0899** (0.0406)	−0.0754** (0.0317)	−0.0838** (0.0324)	−0.0909** (0.0395)
Tobin's Q		0.0159** (0.0066)	0.0135*** (0.0052)	0.0153*** (0.0053)	0.0160** (0.0065)
ROA		0.0213 (0.0391)	0.0136 (0.0305)	0.0193 (0.0329)	0.0221 (0.0380)
Constant	−0.0696*** (0.0036)	−0.0697*** (0.0042)	−0.0823*** (0.0040)	−0.0815*** (0.0039)	−0.0708*** (0.0042)
Observations	81,314	62,829	62,829	62,829	62,829
R-squared	0.188	0.193	0.005	0.054	0.167
Firm FE	No	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Bank–Time FE	Yes	Yes	No	Yes	No
Firm–Bank FE	Yes	Yes	No	No	Yes

Notes: This table reports regression results of the annual growth rate of firm-bank level loan on one year lagged volatility growth and a set of firm-level controls. Firm-level controls include the growth rates of Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) and (2) include bank-year and firm-bank fixed effects while Column (3) and (4) contain firm and year fixed effect terms. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, γ $p < 0.15$. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

panel specification provides much unbiased estimates. In turn, Table 7 also exhibits the results broadly consistent with those in the baseline estimation. The interaction term of the volatility growth with "PPE", however, shows a negative causal relationship with the loan growth while that with the indicators of the durables industries is still not statistically significant. This result conflicts with those in the baseline specification and presents possibility, albeit weak, in favor of relatively

Table 7. Heterogeneity in the Effect of Uncertainty on Loans (differenced)

	(1)	(2)	(3)	(4)	(5)	(6)
VU	-0.0347** (0.0142)	-0.0328** (0.0140)	-0.0365*** (0.0141)	-0.0252* (0.0138)	-0.0465** (0.0219)	-0.0428*** (0.0136)
VU x PPE	-0.0713* (0.0396)					
VU x Durables		-0.00976 (0.0184)				
VU x 2 nd FS Quintile			-0.0167 (0.0280)			
VU x 3 rd FS Quintile			-0.0032 (0.0280)			
VU x 4 th FS Quintile			-0.0576** (0.0290)			
VU x 5 th FS Quintile			-0.0574 (0.0459)			
Leverage ratio				-0.190*** (0.0630)		
VU x Leverage ratio				0.248** (0.1000)		
Credit line					-0.0028** (0.0014)	
VU x Credit line					0.0015** (0.0008)	
VU x Crisis						0.0531* (0.0313)
Cash flow	-0.0918*** (0.0201)	-0.0711*** (0.0119)	-0.0679*** (0.0177)	-0.0770* (0.0435)	-0.0259** (0.0109)	-0.0896** (0.0405)
Tobin's Q	0.0248** (0.0094)	0.0161** (0.0075)	0.0269*** (0.0090)	0.0124* (0.0071)	0.0323** (0.0142)	0.0158** (0.0066)
ROA	0.170 (0.203)	0.0849 (0.0984)	0.0133* (0.0079)	0.0958** (0.0396)	0.0358 (0.0305)	0.0208 (0.0392)
Constant	-0.0288 (0.0262)	-0.0725*** (0.0043)	-0.0847*** (0.0049)	-0.0817*** (0.0049)	-0.0841*** (0.0010)	-0.0673*** (0.0044)
Observations	62,829	62,829	62,829	52,581	41,785	62,829
R-squared	0.196	0.198	0.196	0.196	0.199	0.193
Firm FE	No	No	No	No	No	No
Time FE	No	No	No	No	No	No
Bank-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Bank FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regression results of the annual growth rate of firm-bank level loan on one year lagged volatility growth and a set of firm-level controls. Firm-level controls include the growth rates of Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) through (6) includes bank-year and firm-bank fixed effects. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, y $p < 0.15$. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

strong response of the industries with irreversible investment to uncertainty shock. Specifically, the finding that firms with larger size, higher leverage ratios and higher usage ratios of credit line are less responsive to firm-level uncertainty growth shocks is also in line with the estimation results above.

The interactive terms which were included to test for firms' heterogeneity have the same signs as in the previous estimations. We therefore recognize that, as well confirmed in the baseline estimations, the firms' investment is closely affected by the growth as well as the level of uncertainty.

2.2 Regression on private financial institutions

Now, given notable and sterling role of public sector in Korean financial market, we investigate whether the effect of firm-level uncertainty on loan holds when allowing for private financial institutions. Table 8 shows that higher uncertainty reduces the lending and moreover that the magnitudes of the coefficients are akin to those in the baseline specifications. Also, the coefficients on the uncertainty which are estimated containing the bank-year and firm-bank fixed effect terms are larger than those with year and firm fixed effects, which is in line with the estimation results hitherto. This result suggests that the private banks react to the firm's uncertainty in a similar manner to the public banks. In addition, the coefficients on the interaction terms in Table 9 are broadly of the same sign as in the estimations above, which also provides relevant implication that there is little divergence between public and private banks in the response of the loan to firm-level uncertainty.

**Table 8. The Effect of Uncertainty on Loans
(private financial institutions)**

	(1)	(2)	(3)	(4)	(5)
VU	-0.0736*** (0.0264)	-0.0851*** (0.0298)	-1.6465*** (0.0708)	-0.7765*** (0.0423)	-0.0814*** (0.0293)
Cash Flow		-0.285*** (0.0706)	-0.657*** (0.193)	-0.195** (0.105)	-0.262*** (0.070)
Tobin's Q		0.0485*** (0.0116)	0.0786*** (0.0253)	0.0491*** (0.0133)	0.0441*** (0.0115)
ROA		0.318*** (0.064)	0.548*** (0.201)	0.461*** (0.119)	0.298*** (0.063)
Constant	7.577*** (0.114)	7.629*** (0.131)	0.900*** (0.302)	4.607*** (0.183)	7.650*** (0.129)
Observations	70,930	53,982	53,982	53,982	53,982
R-squared	0.854	0.859	0.049	0.456	0.854
Firm FE	No	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Bank-Time FE	Yes	Yes	No	Yes	No
Firm-Bank FE	Yes	Yes	No	No	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) and (2) include bank-year and firm-bank fixed effects while Column (3) and (4) contain firm and year fixed effect terms. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, γ $p < 0.15$. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

2.3 Regression on banks

Lastly, we conduct the same estimation for the banking sector only in order to confirm whether uncertainty effect holds for banks in a similar manner. Basically, uncertainty effect on loan appears to be robust to banking sector. The result of this estimation is quite analogous to those above, but the parameter estimates of uncertainty are relatively larger. These results suggest that the banks may respond more notably and strongly to uncertainty shocks.

Table 9. Heterogeneity in the Effect of Uncertainty on Loans
(private financial institutions)

	(1)	(2)	(3)	(4)	(5)	(6)
VU	-0.0670** (0.0312)	-0.0832** (0.0404)	0.0926*** (0.0336)	-0.1329*** (0.0359)	-0.0993** (0.0435)	-0.0906*** (0.0338)
VU x PPE	-0.0728** (0.0285)					
VU x Durables		-0.0039 (0.0515)				
VU x 2 nd FS Quintile			-0.0946*** (0.0127)			
VU x 3 rd FS Quintile			-0.1548*** (0.0158)			
VU x 4 th FS Quintile			-0.2169*** (0.0194)			
VU x 5 th FS Quintile			-0.2719*** (0.0271)			
Leverage ratio				0.589*** (0.187)		
VU x Leverage ratio				0.0856*** (0.0269)		
Credit line					-0.0062 (0.0186)	
VU x Credit line					0.0029* (0.0017)	
VU x Crisis						0.0245 (0.0452)
Cash flow	-0.309*** (0.0745)	-0.285*** (0.0706)	-0.194*** (0.0686)	-0.414** (0.210)	-0.621*** (0.189)	-0.407** (0.164)
Tobin's Q	0.0521*** (0.0123)	0.0485*** (0.0116)	0.0335*** (0.0113)	0.0504*** (0.0168)	0.0446** (0.0195)	0.0478*** (0.0135)
ROA	0.344*** (0.0675)	0.317*** (0.0639)	0.226*** (0.0618)	0.446** (0.205)	0.481*** (0.111)	0.441*** (0.160)
Constant	7.838*** (0.134)	7.629*** (0.131)	7.639*** (0.131)	7.502*** (0.173)	8.572*** (0.194)	7.643*** (0.135)
Observations	53,982	53,982	53,982	39,242	28,882	53,982
R-squared	0.857	0.859	0.859	0.863	0.737	0.861
Firm FE	No	No	No	No	No	No
Time FE	No	No	No	No	No	No
Bank-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Bank FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) through (6) includes bank-year and firm-bank fixed effects. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** p<0.01, ** p<0.05, * p<0.1, y p<0.15. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

V. Conclusions

Uncertainty as a source of business cycle has been studied in various contexts. In examining the impact of firm-level uncertainty on corporate credit and investment, it is imperative to clarify whether the correlation between uncertainty and firms' investment or lending indeed captures causation. Identification problem may arise if events (factors) that increase firm-level uncertainty can be accompanied by changes in the balance sheet strength of the financial institutions that have established relationship with the firm. Moreover, firm-level uncertainty shocks can be associated with bank supply shocks. We study whether uncertainty reduces corporate credit and investment while addressing identification problems. Using a granular bank-firm loan level data of South Korea, we exploit the empirical scheme of Khwaza and Mian (2008) to control for bank specific credit supply effects. Matched bank-firm loan data allows us to control for financial institution shocks and identify the impact of uncertainty on corporate credit in more sophisticated manner.

Furthermore, higher uncertainty is usually associated with lower corporate credit and investment which can be driven by multiple alternative channels: real options effects (demand channel) and risk premium effects (financial channel). In an attempt to identify dominant transmission mechanisms, we investigate whether the negative impact of uncertainty on corporate credit and investment exhibits heterogeneity in firms' characteristics. In particular, we construct six proxies to capture investment irreversibility, financial constraints, firm's credit worthiness and times in a crisis. Overall, we find that firm-level uncertainty discourages bank lending and investment. The estimation results without controlling for bank credit supply shocks show evidence of underestimation as we expected. In addition, we find more evidence to support the real options effects as a dominant mechanism through which uncertainty shock affects firms' borrowing and investment. The adverse effect of uncertainty shocks on corporate credit and investment

is stronger for firms: that have higher degree of investment irreversibility; that are less likely to be financially constrained – larger firms, firms with sufficient financial slack or less leveraged.

Our results are robust to replacing the variables in levels with those in differences. Also, we show that the results do not significantly change if we limit the sample only for private financial institutions or banks.

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Appendix

Table A.1. The Effect of Uncertainty on Loans (banks)

	(1)	(2)	(3)	(4)	(5)
VU	-0.113*** (0.0301)	-0.127*** (0.0323)	-1.076*** (0.0588)	-0.828*** (0.0507)	-0.117*** (0.0322)
Cash Flow		-0.312*** (0.0858)	-0.508*** (0.162)	-0.382*** (0.125)	-0.305*** (0.0862)
Tobin's Q		0.0534*** (0.0143)	0.0660*** (0.0246)	0.0607*** (0.0221)	0.0517*** (0.0144)
ROA		0.365*** (0.080)	0.338* (0.185)	0.376** (0.173)	0.354*** (0.080)
Constant	8.217*** (0.130)	8.206*** (0.142)	4.173*** (0.255)	5.205*** (0.221)	8.249*** (0.142)
Observations	56,675	46,801	46,801	46,801	46,801
R-squared	0.778	0.793	0.029	0.167	0.790
Firm FE	No	No	Yes	Yes	Yes
Time FE	No	No	Yes	Yes	Yes
Bank-Time FE	Yes	Yes	No	Yes	No
Firm-Bank FE	Yes	Yes	No	No	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) and (2) include bank-year and firm-bank fixed effects while Column (3) and (4) contain firm and year fixed effect terms. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, γ $p < 0.15$. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

Table A.2. Heterogeneity in the Effect of Uncertainty on Loans (banks)

	(1)	(2)	(3)	(4)	(5)	(6)
VU	-0.101*** (0.0338)	-0.119*** (0.0448)	0.0790** (0.0362)	-0.184*** (0.0371)	-0.114*** (0.0440)	-0.131*** (0.0363)
VU x PPE	-0.095** (0.0293)					
VU x Durables		-0.0244 (0.0545)				
VU x 2 nd FS Quintile			-0.103*** (0.0132)			
VU x 3 rd FS Quintile			-0.170*** (0.0163)			
VU x 4 th FS Quintile			-0.252*** (0.0200)			
VU x 5 th FS Quintile			-0.293*** (0.0289)			
Leverage ratio				0.726*** (0.207)		
VU x Leverage ratio				0.0900*** (0.0320)		
Credit line					-0.00603 (0.01870)	
VU x Credit line					0.00285* (0.00172)	
VU x Crisis						0.0135 (0.0485)
Cash flow	-0.341*** (0.0886)	-0.323*** (0.0878)	-0.200** (0.0855)	-0.301*** (0.0621)	-0.425*** (0.0754)	-0.327*** (0.0572)
Tobin's Q	0.0578*** (0.0148)	0.0551*** (0.0146)	0.0350** (0.0142)	0.0493** (0.0199)	0.0438** (0.0197)	0.0490*** (0.0163)
ROA	0.397*** (0.1826)	0.372*** (0.0817)	0.243*** (0.0805)	0.330*** (0.0761)	0.335*** (0.0736)	0.274*** (0.0585)
Constant	8,378*** (0.146)	8,380*** (0.144)	8,451*** (0.142)	7,896*** (0.181)	8,559*** (0.196)	8,228*** (0.146)
Observations	46,801	46,801	46,801	35,888	26,228	46,801
R-squared	0.787	0.787	0.788	0.810	0.743	0.795
Firm FE	No	No	No	No	No	No
Time FE	No	No	No	No	No	No
Bank-Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm-Bank FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table reports regression results of annual firm-bank level loan as expressed in natural logarithm on one year lagged volatility as expressed in natural logarithm and a set of firm-level controls. Firm-level controls include Tobin's Q, cash flow as a share of total asset, and ROA. The sample period is annual from 2006 to 2015. Column (1) through (6) includes bank-year and firm-bank fixed effects. We do not report the coefficients and standard errors on fixed effect terms in order to save space. Firm-level uncertainty measure is the annual realized volatility of firms' stock returns. Statistical significance: *** p < 0.01, ** p < 0.05, * p < 0.1, γ p < 0.15. We use weighted least squares with weights equal to natural logarithm of loans. Standard errors are clustered at the firm and year levels and are reported in parentheses. See section 2 for data details.

<Abstract in Korean>

기업 불확실성이 기업 대출 및 투자에 미치는 영향

김영주*, 이서현**, 임현준***

본고는 기업 단위의 불확실성 확대가 기업의 금융기관 대출에 미치는 영향을 식별 문제를 개선하는 새로운 분석방법을 이용해 추정하였다. 기업의 불확실성이 확대되는 경우 해당 기업들은 신용능력 하락, 투자 지연 등에 따라 그들의 대출수요를 자발적으로 축소하는 한편 금융기관들은 대차대조표 악화 충격에 대응해 대출공급을 줄이게 된다. 불확실성의 효과를 신용공급 효과와 분리하기 위하여 본고는 우리나라 상장기업의 전 금융기관 대상 대출 정보를 포괄하는 금융기관-기업 결합 대출 데이터를 이용하였다. 분석 결과, 신용공급효과를 통제하지 않은 일반 패널분석의 경우 불확실성이 대출에 미치는 영향이 과대평가되는 것으로 나타났다. 아울러 신용공급 효과를 통제할 경우 불확실성이 대출에 미치는 효과는 대기업과 차입제약이 작은 기업에서 상대적으로 큰 것으로 분석되었다. 또한 불확실성이 설비투자에 미치는 영향에서도 이와 상응하는 결과가 도출되었는데 이는 기업의 불확실성 확대는 주로 실질옵션 경로를 통해서 기업 대출 및 투자에 영향을 미치는 것으로 풀이된다.

핵심 주제어: 기업단위 불확실성, 금융기관 대출, 설비투자

JEL Classification: D84, E22

* 한국은행 조사국 국제경제부 아태경제팀장 (전화: 02-759-5283, E-mail: econoky@bok.or.kr)

** 한국은행, 한국국제통화기금(IMF) 파견 (E-mail: SLee6@imf.org)

*** 한국은행 조사국 거시모형부 전망모형팀 차장 (전화: 02-759-4137, E-mail: limhj1@bok.or.kr)

본 연구내용은 집필자의 개인의견이며 한국은행 및 IMF의 공식견해와는 무관합니다. 따라서 본 논문의 내용을 보도하거나 인용할 경우에는 집필자명을 반드시 명시하여 주시기 바랍니다.

BOK 경제연구 발간목록

한국은행 경제연구원에서는 Working Paper인 『BOK 경제연구』를 수시로 발간하고 있습니다. 『BOK 경제연구』는 주요 경제 현상 및 정책 효과에 대한 직관적 설명 뿐 아니라 깊이 있는 이론 또는 실증 분석을 제공함으로써 엄밀한 논증에 초점을 두는 학술논문 형태의 연구이며 한국은행 직원 및 한국은행 연구용역사업의 연구 결과물이 수록되고 있습니다. 『BOK 경제연구』는 한국은행 경제연구원 홈페이지(<http://imer.bok.or.kr>)에서 다운로드하여 보실 수 있습니다.

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8	Rare Disasters and Exchange Rates: An Empirical Investigation of Korean Exchange Rates under Tension between the Two Koreas	Cheolbeom Park · Suyeon Park
9	통화정책과 기업 설비투자 - 자산가격경로와 대차대조표경로 분석 -	박상준 · 육승환
10	Upgrading Product Quality: The Impact of Tariffs and Standards	Jihyun Eum
11	북한이탈주민의 신용행태에 관한 연구	정승호 · 민병기 · 김주원
12	Uncertainty Shocks and Asymmetric Dynamics in Korea: A Nonlinear Approach	Kevin Larcher · Jaebeom Kim · Youngju Kim
13	북한경제의 대외개방에 따른 경제적 후생 변화 분석	정혁 · 최창용 · 최지영
14	Central Bank Reputation and Inflation-Unemployment Performance: Empirical Evidence from an Executive Survey of 62 Countries	In Do Hwang
15	Reserve Accumulation and Bank Lending: Evidence from Korea	Youngjin Yun
16	The Banks' Swansong: Banking and the Financial Markets under Asymmetric Information	Jungu Yang

제2018-17	E-money: Legal Restrictions Theory and Monetary Policy	Ohik Kwon · Jaevin Park
18	글로벌 금융위기 전·후 외국인의 채권투자 결정요인 변화 분석: 한국의 사례	유복근
19	설비자본재 기술진보가 근로유형별 임금 및 고용에 미치는 영향	김남주
20	Fixed-Rate Loans and the Effectiveness of Monetary Policy	Sung Ho Park
21	Leverage, Hand-to-Mouth Households, and MPC Heterogeneity: Evidence from Korea	Sang-yoon Song
22	선진국 수입수요가 우리나라 수출에 미치는 영향	최문정 · 김경근
23	Cross-Border Bank Flows through Foreign Branches: Evidence from Korea	Youngjin Yun
24	Accounting for the Sources of the Recent Decline in Korea's Exports to China	Moon Jung Choi · Kei-Mu Yi
25	The Effects of Export Diversification on Macroeconomic Stabilization: Evidence from Korea	Jinsoo Lee · Bok-Keun Yu
26	Identifying Uncertainty Shocks due to Geopolitical Swings in Korea	Seohyun Lee · Inhwan So · Jongrim Ha
27	Monetary Policy and Income Inequality in Korea	Jongwook Park
28	How the Financial Market Can Dampen the Effects of Commodity Price Shocks	Myunghyun Kim
29	Which External Shock Matters in Small Open Economies? US Economic Policy Uncertainty vs. Global Risk Aversion	Youngju Kim · Hyunjoon Lim
30	Do Korean Exports Have Different Patterns over Different Regimes?: New Evidence from STAR-VECM	Sei-Wan Kim · Moon Jung Choi
31	기술진보와 청년고용	심명규 · 양희승 · 이서현

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33	기업규모간 임금격차 원인 분석	송상윤
34	우리나라 고용구조의 특징과 과제	장근호
35	창업의 장기 고용효과: 시군구 자료 분석	조성철 · 김기호
36	수출입과 기업의 노동수요	음지현 · 박진호 · 최문정
37	청년실업의 이력현상 분석	김남주
38	노동시장 이중구조와 노동생산성: OECD 국가를 중심으로	최충 · 최광성 · 이지은
39	한국과 일본의 청년실업 비교분석 및 시사점	박상준 · 김남주 · 장근호
40	노동시장의 이중구조와 정책대응: 해외사례 및 시사점	전병유 · 황인도 · 박광용
41	최저임금이 고용구조에 미치는 영향	송헌재 · 임현준 · 신우리
42	최저임금과 생산성: 우리나라 제조업의 사례	김규일 · 육승환
43	Transmission of U.S. Monetary Policy to Commodity Exporters and Importers	Myunghyun Kim
44	Determinants of Capital Flows in the Korean Bond Market	Soohyon Kim
45	Central Bank Credibility and Monetary Policy	Kwangyong Park
46	통화정책이 자본유출입에 미치는 영향: 행태방정식 분석	이명수 · 송승주

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제2019 –1	Deciphering Monetary Policy Board Minutes through Text Mining Approach: The Case of Korea	Ki Young Park · Youngjoon Lee · Soohyon Kim
2	The Impacts of Macroeconomic News Announcements on Intraday Implied Volatility	Jieun Lee · Doojin Ryu
3	Taking a Bigger Slice of the Global Value Chain Pie: An Industry-level Analysis	Chong-Sup Kim · Seungho Lee · Jihyun Eum
4	Trend Growth Shocks and Asset Prices	Nam Gang Lee
5	Uncertainty, Attention Allocation and Monetary Policy Asymmetry	Kwangyong Park
6	Central Bank Digital Currency and Financial Stability	Young Sik Kim · Ohik Kwon
7	은행의 수익 및 자산구조를 반영한 통화정책 위험선호경로	김익진 · 정호성
8	혁신기업에 대한 산업금융 지원: 이론모형 분석	강경훈 · 양준구
9	가계부채 제약하의 통화정책: 2주체 거시모형(TANK)에서의 정량적 분석	정용승 · 송승주
10	Alchemy of Financial Innovation: Securitization, Liquidity and Optimal Monetary Policy	Jungu Yang
11	Measuring Monetary Policy Surprises Using Text Mining: The Case of Korea	Youngjoon Lee · Soohyon Kim · Ki Young Park
12	Tracking Uncertainty through the Relative Sentiment Shift Series	Seohyun Lee · Rickard Nyman
13	Intra-firm and Arm's Length Trade during the Global Financial Crisis: Evidence from Korean Manufacturing Firms	Moon Jung Choi · Ji Hyun Eum

제2019-14	특허자료를 이용한 우리나라 지식전파의 지역화 분석	이지홍 · 남윤미
15	Overhead Labour and Skill-Biased Technological Change: The Role of Product Diversification	Choong Hyun Nam
16	Does the Number of Countries in an International Business Cycle Model Matter?	Myunghyun Kim
17	High-Frequency Credit Spread Information and Macroeconomic Forecast Revision	Bruno Deschamps · Christos Ioannidis · Kook Ka
18	경제 분석을 위한 텍스트 마이닝	김수현 · 이영준 · 신진영 · 박기영
19	Takeover, Distress, and Equity Issuance: Evidence from Korea	Euna Cho
20	The Cash-Flow Channel of Monetary Policy: Evidence from Mortgage Borrowers	Sang-yoon Song
21	부의 효과의 분위 추정: 분위 정준 공적분회귀를 중심으로	김기호
22	Identifying Government Spending Shocks and Multipliers in Korea	Kwangyong Park · Eun Kyung Lee
23	Systemic Risk of the Consumer Credit Network across Financial Institutions	Hyun Hak Kim · Hosung Jung
24	Impact of Chinese Renminbi on Korean Exports: Does Quality Matter?	Jihyun Eum
25	Uncertainty, Credit and Investment: Evidence from Firm-Bank Matched Data	Youngju Kim · Seohyun Lee · Hyunjoon Lim