論　文

Firm-level Uncertainty and Cash Holding: ＊

Theory and Firm-level Empirical Evidence

By Aubhik KHAN and Tatsuro SENGA＊＊

Abstract

We document three facts for publicly listed firms in Japan: (1) a secular decline in the debt-to-asset ratio between 1993 and 2017; (2) a U-shaped pattern in the cash-to-asset ratio, with a secular increase since 2000; (3) an upward shift in the volatility of sales growth after 2000 which has remained high until recently. To account for these facts, we build a general equilibrium model with heterogeneous firms that face uncertainty over idiosyncratic productivity and default risk. We calibrate the model using a panel data of Japanese public firms constructed using the Compustat database. The model predicts that uncertainty faced by firms is positively associated with cash holdings and negatively correlated with borrowings. These model predictions are empirically validated by a panel regression using our data.

JEL Classification Codes: E44, G33, E20

Keywords: Uncertainty; Cash Holding; Idiosyncratic Productivity; Financial Frictions

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企業が直面する不確実性と現金保有

－理論分析と企業データからのエビデンス－

Aubhik Khan・千賀 達朗

＜要旨＞

本稿ではまず日本の上場企業について以下の 3 つの事実を示す。①1993 年から 2017 年にかけて総資産に対する負債の比率が趨勢的に低下している一方、②総資産に対する現金の比率は U 字型を描き、特に 2000 年以降の増加が顕著であるほか、③2000 年以降は売上増加率のボラティリティが上昇し、最近まで高位に推移している。こうした事実を踏まえて、生産性が異なる企業が多数存在し、各企業が将来の生産性についての不確実性に直面し、また企業による債務不履行が内生的に発生するよう金融制約を取り込んだ一般均衡モデルを構築して、企業が直面する不確実性と現金保有との間における負の関係を理論的に示した。こうした不確実性と現金保有に関する負の関係は、日本の上場企業を対象にしたパネルデータ分析からも示された。

JEL Classification Codes：E44, G33, E20

Keywords：不確実性、現金保有、個別の生産性ショック、金融制約

1 Introduction

There is widespread concern among researchers and policymakers over the increase in cash holdings among Japanese firms.[1] In this paper, we document the following facts: (1) a continuous decline in the debt-to-asset ratio of Japanese firms after the burst of the asset price bubble in the early 1990s; (2) a U-shaped trend in the ratio of cash to assets of Japanese firms, declining before 2000 and then increasing until 2017; (3) a significant upward shift in the level of uncertainty faced by Japanese firms since 2000, as captured by the high volatility of sales growth. In light of these facts, we build a macroeconomic model with heterogeneous firms that finance investment via a mix of retained earnings and debt in the presence of uncertainty over idiosyncratic productivity. We find that our model predicts a positive association between uncertainty faced by firms and their cash holdings and a negative association between this uncertainty and their borrowing. We test our model's predictions against data on publicly traded Japanese firms taken from the Compustat database.

Why are Japanese firms holding so much more cash than they used to? What factors explain why Japanese firms are continuously reducing their leverage ratio? Our focus is on the role of uncertainty facing each individual firm in driving financial behavior. We construct a macroeconomic model with heterogeneous firms that face uncertainty over idiosyncratic productivity, where investment may be constrained by financial frictions. We begin with the model of Khan, Senga, and Thomas (2016), in which firm-level investment is financed by retained earnings and non-contingent debt. Firms may default on debt after being hit by idiosyncratic productivity shocks. Lenders cannot fully recover the value of debt in such cases. One feature of such models with heterogeneous firms and financial frictions is that firms will accumulate capital to avoid financial constraints and undertake the optimal scale of production consistent with idiosyncratic productivity without incurring borrowing costs.[2] In our model, the optimal capital choice reflects firms' expected productivity and the optimal funding rules ensure that default risk can never again affect their choice of capital. Firms with high productivity maintain a higher level of leverage to finance their capital stock, while firms with low productivity de-leverage by reducing debt and even building a positive cash position. When uncertainty rises, indicated by an increase in the variance of idiosyncratic productivity shocks, firms hold more cash to shield themselves from an increase in the cost of borrowing required

[1] This is an economic concern over achieving growth, but it is also a political matter as it appears that economic stimulus packages are failing to trickle down beyond big businesses. Not surprisingly, policymakers have become increasingly concerned with this: "The situation went much too far. We must think of ways for that money to be spent on capital spending and wages." (Finance Minister Taro Aso, October 2017)

[2] While we take firm-level default as a model ingredient to derive the optimal borrowing and cash-holding rules at the firm level, there are other approaches to obtain such financial rules. See the model by Khan and Thomas (2013), which uses collateral constraints.

to achieve the optimal investment. We focus on firms that have outgrown default risk but whose optimal borrowing and cash-holding behaviors are nonetheless still shaped by default risk.

Quantitative analysis involves calibrating the model parameters, targeting the aggregate debt-to-asset ratio, the aggregate cash-to-asset ratio, and other salient moments both at the micro and macro level. We conduct sensitivity analysis by varying the parameters that govern the level of uncertainty faced by firms and their costs of operation around the calibrated values. We then show that the aggregate debt-to-asset ratio decreases and the cash-to-asset ratio increases when uncertainty rises and the costs of operation increase.

Importantly, we empirically validate our model's predictions using panel data on Japanese public firms taken from the Compustat database. We construct a measure of volatility of sales growth following Comin and Philippon (2005) as a proxy of uncertainty faced by each individual firm. We regress the debt-to-asset ratio and the cash-to-asset ratio on the firm-level uncertainty measure and other various observables using the panel dataset. Our panel regressions confirm our theoretical predictions, yielding a significant positive association between uncertainty and cash holdings. We also find that other factors, including research and development expenses and intangible assets intensity, have explanatory power with regard to cash holdings of Japanese businesses.

Related work

Opler, Pinkowitz, Stulz, and Williamson (1999) and Bates, Kahle, and Stulz (2009) showed that the greater the level of uncertainty regarding cash flow, the more cash firms will hold as firms may at times have more outlays than expected. In particular, the latter study connects such precautionary motives with the recent rise in the cash holdings of U.S. firms. Almeida, Campello, and Weisbach (2004) model the precautionary demand for cash and find that financially constrained firms invest in cash out of cash flow, while unconstrained firms do not. Riddick and Whited (2009) re-examine existing studies on firms' propensities to invest in cash out of cash flow, mainly on measurement error in Tobin's q. Their model still shows a positive relation between a firm's risk and cash. Finally, Acharya, Almeida, and Campello (2007) develop a model showing that firms accumulate cash instead of reducing debt when the correlation between operating income and investment opportunities is low. In their model, firms that issue debt and hold cash transfer and smooth out income from high cash flow states to low cash states.

The impact of uncertainty on cash holdings of Japanese firms is understudied. Recent studies by Nakamuara (2017) and Tominaga (2016) examined the importance of precautionary motives in shaping firms' cash-holding patterns, although there is no direct investigation of uncertainty faced by these firms.

Despite considerable attention paid by policymakers to the low investment spending and high levels of cash holding of Japanese firms, theoretical underpinnings are scarce. This paper is the first to show a simple structural macroeconomic framework that allows us to study implications of uncertainty on firm's financial behaviors such as borrowing and cash holdings simultaneously together with their aggregate implications.

Organization

The rest of the paper is organized as follows. We first document a set of key facts on Japanese businesses in Section 2. In Section 3, the model of heterogeneous firms is developed. Section 4 presents the results as well as parameterization of the model. Section 5 shows empirical results from our panel data. Section 6 concludes.

2 Facts

2.1 Data construction

The data source that we use is Compustat, which contains a database of profit and loss statements and balance sheet information on publicly traded companies throughout the world. We restrict our sample to firms with headquarters located in Japan by restricting the data set to firms whose fic and loc codes are equal to JPN. We exclude oil-related companies (SIC codes 2911, 5172, 1311, 4922, 4923, 4924, and 1389), energy-related companies (SIC codes between 4900 and 4940), and financial firms (SIC codes between 6000 and 6999), as in other papers that use the firm-level data from the Compustat database (see, for example, Gabaix 2011, among others).[3]

The data consists of year by firm observations, with fiscal years ending in March, of the following variables: (1) SALE – net sales, (2) AT – total assets, (3) CHE – cash and short-term investments, (4) CAPX – capital expenditures, (5) DLTT – long-term debt, (6) INTAN – intangible assets, (7) XRD – research and development expense, and (8) EBITA – earnings before interest, tax, depreciation, and amortization. By dropping unusual data such as negative values for sales, we reach around 54,000 firm-fiscal year observations, with 2,971 Japanese companies averaging 18 observations each from 1987 to 2017.[4] Based on this sample, we examine the financial behavior of Japanese firms over the sample period as follows.

[3] This sample selection by sector does not alter the results presented in this paper.
[4] We exclude non-positive values of sales and assets, negative values of capital expenditures, intangible assets, and research and development expenses from our sample.

Fact 1: A Secular reduction in leverage

In Table 1, column (4) reports the average leverage — debt (DLTT in Compustat) divided by total assets (AT in Compustat) for each firm in the sample. Column (5) shows the aggregate leverage, which is the sum of debt divided by the sum of total assets for all the sample firms. These leverage measures increase during two periods: the financial crisis in Japan from 1997 to 1998 and the global financial crisis from 2007 to 2008; however, one obvious implication that emerges from Table 1 is that Japanese businesses have been deleveraging over the two decades since the burst of asset prices in 1991.[5] These measures of leverage peaked in 1993 and have been falling from 1993 until 2017. As seen in column (4), the average leverage falls from 16.2 percent in 1993 to 8.8 percent in 2017; the aggregate leverage, in column (5), also falls from 22.7 percent in 1993 to 17.1 percent in 2017.

Table 1: Average and Mean Cash and Leverage Ratios and Sales Volatility from 1991 to 2017

	Average Cash Ratio	Aggregate Cash Ratio	Average Leverage	Aggregate Leverage	Average Net Leverage	Aggregate Net Leverage	Sales Growth Volatility
1991	0.181	0.173	0.157	0.215	–0.024	0.041	0.050
1992	0.177	0.166	0.158	0.215	–0.018	0.049	0.048
1993	0.179	0.162	0.162	0.227	–0.016	0.065	0.047
1994	0.177	0.157	0.145	0.219	–0.032	0.061	0.048
1995	0.167	0.148	0.131	0.205	–0.035	0.057	0.048
1996	0.164	0.143	0.123	0.199	–0.041	0.057	0.048
1997	0.156	0.139	0.118	0.200	–0.039	0.062	0.050
1998	0.163	0.141	0.127	0.216	–0.037	0.075	0.051
1999	0.168	0.137	0.113	0.198	–0.056	0.061	0.055
2000	0.142	0.105	0.104	0.182	–0.039	0.077	0.055
2001	0.141	0.104	0.099	0.184	–0.042	0.080	0.055
2002	0.143	0.105	0.099	0.188	–0.045	0.083	0.055
2003	0.146	0.111	0.099	0.179	–0.048	0.068	0.056
2004	0.151	0.113	0.093	0.168	–0.059	0.055	0.058
2005	0.149	0.109	0.087	0.154	–0.062	0.045	0.058
2006	0.145	0.104	0.082	0.150	–0.063	0.046	0.058
2007	0.149	0.102	0.080	0.153	–0.067	0.050	0.057
2008	0.161	0.111	0.093	0.181	–0.067	0.070	0.057
2009	0.176	0.124	0.095	0.187	–0.080	0.063	0.056
2010	0.181	0.130	0.093	0.178	–0.087	0.048	0.054
2011	0.182	0.123	0.090	0.175	–0.091	0.052	0.055
2012	0.186	0.121	0.090	0.174	–0.097	0.052	0.055
2013	0.188	0.123	0.090	0.176	–0.099	0.054	0.055
2014	0.190	0.124	0.090	0.175	–0.100	0.051	0.054
2015	0.195	0.130	0.091	0.174	–0.104	0.045	0.053
2016	0.201	0.133	0.092	0.176	–0.107	0.043	0.053
2017	0.202	0.133	0.088	0.171	–0.114	0.037	0.054

[5] In 1997, Sanyo Securities, Hokkaido Takushoku Bank, and Yamaichi Securities failed. Long Term Credit Bank of Japan failed in 1998. See Nakaso (2001) for a chronological summary of this chain of events.

In columns (6) and (7) in Table 1, we report the average net leverage and the aggregate net leverage, which are other ways of measuring leverage where we subtract cash (CHE in Compustat) from debt (DLTT in Compustat) and then divide it by total assets (AT in Compustat). As seen in column (6), the average net leverage falls from −1.6 percent in 1993 to −11.4 percent in 2017; the aggregate net leverage, in column (7), exhibits a similar time trend, falling from 6.5 percent in 1993 to 3.7 percent in 2017.

For Japanese firms, the leverage and net leverage ratios have a declining trend in common. In fact, this is different from the pattern observed in data for U.S. public firms. In the U.S., while the net leverage ratio exhibits a secular downward trend similar to that seen in Japan, there is little evidence of a decrease in leverage (without subtracting cash). Bates, Kahle, and Stulz (2009) argue that most of the decrease in net leverage can be explained by the increase in cash holdings, with the level of debt fixed. While the secular decrease in both leverage and net leverage measures for Japanese firms suggests that there are other factors in Japan driving these leverage ratios, we first examine cash holdings of Japanese firms and subsequently explore the role of uncertainty.

Fact 2: The increase in cash-to-asset ratio

In column (2) of Table 1, we report the average cash-to-asset ratio, defined as cash (CHE in Compustat) divided by total assets (AT in Compustat). This ratio decreases from 18.1 percent in 1991 to 14.1 percent in 2001. Since 2001, however, it has increased to 20.2 percent in 2017, an acceleration of cash holdings among Japanese firms. A similar pattern is found for the aggregate cash-to-asset ratio, which is reported in column (3). This measure is defined as the sum of cash (CHE in Compustat) divided by the sum of total assets (AT in Compustat) for all sample firms. As can be seen, this ratio is 17.3 percent in 1991 and decreases to 10.4 percent by 2001, bouncing back to 13.3 percent in 2017.

Between 1991 and 2017, while the leverage of Japanese firms decreased continuously, the level of cash holdings exhibits a U-shaped trend. This time trend for leverage and cash holdings among Japanese firms is different from the one for U.S. firms. As discussed above, the time trend of cash holdings does not seem to explain the decrease in net leverage well. In Japan, both leverage and net leverage fell continuously from 1991, while only the net leverage ratio fell in the U.S. Below, we further examine an additional factor that may explain the Japanese experience.

Fact 3: The increase in firm-level volatility

Why did Japanese firms accumulate so much cash and reduce their debt? It is commonly understood that a precautionary motive may influence how firms manage their financial position. For example, firms may hold cash as they anticipate adverse shocks. If access to external finance is costly, firms avoid situations in which they need to raise additional funds after being hit by shocks. The precautionary motive may also imply that firms with better investment opportunities hold more cash, as argued by Bates, Kahle, and Stulz (2009). This is also related to the fact that it is costly to raise funds externally. In fact, Opler, Pinkowitz, Stulz, and Williamson (1999) use market-to-book ratios and research and development expenses as proxies for investment opportunities and find that firms with better investment opportunities hold more cash.

Is the precautionary motive held by Japanese firms stronger than before? Comin and Philippon (2005) document a recent increase in firm-level volatility in publicly traded U.S. firms. Following Comin and Philippon (2005), we construct a proxy of uncertainty faced by Japanese firms and then examine the trend over time from 1991 to 2017 in Japan. In particular, we compute the volatility of sales growth rate and take the cross-sectional mean across all the firms in the sample. While Comin and Philippon (2005) document the time trend of firm-level volatility for the U.S. economy in the post-war period before 2000, our sample extends until 2017.

First, we define sales growth as

$$g_{i,t} = \log(sales_{i,t}) - \log(sales_{i,t-1}),$$

where *sales* is taken as net sales (SALE in Compustat). We then calculate

$$\sigma_{i,t} = \frac{1}{10}[\sum_{\tau=-4}^{\tau=+5}(g_{i,t+\tau} - \bar{g}_{i,t})^2]^{\frac{1}{2}}$$

for firm *i* and year *t*, where $\bar{g}_{i,t}$ is the average growth rate between $t-4$ and $t+5$. Finally, we take a cross-sectional average of sales volatility as

$$\sigma_t^{mean} = \text{mean}\{\sigma_{i,t}\}_{\text{over } i}.$$

In Table 1, column (8) reports the cross-sectional average of sales volatility over the sample period between 1991 and 2017. This measure hits its bottom in 1993 at 4.7 percent. It then increases sharply to 5.5 percent in 1999 during the financial crisis in Japan. The measure continues to rise after 2000, peaking in 2006 at 5.8 percent; it remains high during and after the global financial crisis. In 2017, the measure is still at 5.4 percent, with no sign of returning to the level seen in the 1990s.

Does greater uncertainty reduce leverage and increase cash holdings at the firm level? We provide a theoretical framework to examine this in the following section and test our model's implications using the constructed panel dataset.

3 Model

In this section, we use a structural model to draw theoretical implications about the relationship between uncertainty and the fall in debt as well as the rise in cash holdings among Japanese firms. Such theoretical implications will be empirically validated via data on a panel of Japanese firms in later sections.

To this end, we take a model of Khan, Senga, and Thomas (2016), who studied an economy in which firms are heterogeneous in their capital, debt, and firm-specific productivity and default risk on non-contingent loans. One important implication of the model is that firms can permanently outgrow the implications of financial frictions. That is, firms can accumulate capital out of their retained earnings and debt issuance over time. Such firms will have sufficient resources to implement their optimal investment plan without borrowing that involves non-zero default probability in the next period. In this paper, we focus on such *unconstrained firms* that have accumulated enough net wealth to be able to finance efficient levels of investment at the risk-free interest rate in every possible future state.[6] Khan, Senga, and Thomas (2016) derive the optimal saving rule for unconstrained firms, called *the minimum saving rule*, to determine the optimal investment plan and associated rules for either borrowing or cash holdings. Focusing on *the minimum saving policy*, we draw implications for the stylized facts on Japanese firms with respect to uncertainty and borrowing and cash holdings. Instead of laying out the whole model from Khan, Senga, and Thomas (2016), what follows is a description of the ingredients of their model that are necessary to understand the minimum saving policy.[7]

3.1 Firms

There are a large number of firms with unit mass. Firms finance investment with retained earnings and non-contingent one-period debt provided by a financial intermediary at loan rates determined by each firm's characteristics. We allow persistent heterogeneity in firm-level productivity. Firms' idiosyncratic productivity, ε, follows a Markov chain $\varepsilon \in \{\varepsilon_1, ..., \varepsilon_{N_\varepsilon}\}$ and the transition matrix is denoted by Π^ε, with each element of $\pi^\varepsilon_{i,j} = \Pr(\varepsilon' = \varepsilon_j \mid \varepsilon = \varepsilon_i) \geq 0$ and $\sum_{j=1}^{N_\varepsilon} \pi^\varepsilon_{i,j} = 1$.

At the beginning of each period, a firm is identified by its predetermined stock of capital, k, the level of debt it took on in the previous period, $b > 0$, or the level of cash it saved in the previous period, $b < 0$, and its current productivity level, ε.[8] Each firm may default after ob-

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6 Unconstrained firms are only a subset of the entire distribution of firms studied by Khan, Senga, and Thomas (2016).

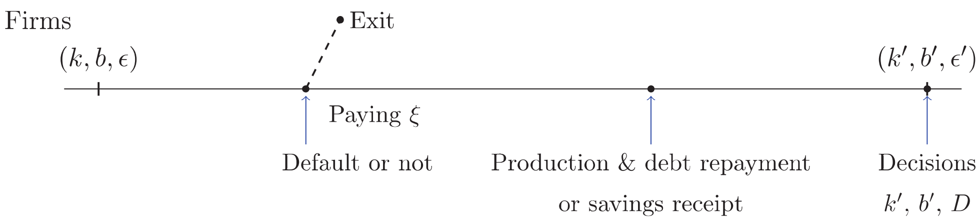
7 While we treat the minimum saving policy as the primitive, we refer the reader to Khan, Senga, and Thomas (2016) for the description of the whole model.

8 Negative values of b may capature any financial assets, which are liquid and expected to mature within one year. We lebel this as cash holdings, which the empirical literature defines as cash and cash equivalents following generally accepted accounting principles (GAAP).

serving this set of state variables (k, b, ε). If the firm chooses to default, it does not repay any of the obligation b and exits from the economy permanently. If instead it chooses to continue and repay, a firm must pay the fixed cost of operation, ξ, to produce. Each firm then produces a homogeneous good using its predetermined capital stock k and labor n via an increasing and concave production function, $y = \varepsilon F(k, n)$.

After production, firms determine their future capital, k', future debt or cash, b', along current dividends, D.[9] As firms undertake investment at the end of the period after production, the capital stock accumulates as $k' = (1 - \delta) k + i$, where $\delta \in (0, 1)$ is the rate of depreciation of the capital stock.

Timing within a Period



For each unit of debt it issues for the next period $b' > 0$, the firm receives $q(k', b', \varepsilon)$ units of output, which it uses to invest or pay out dividends; b' is to be repaid in the next period. The loan discount factor, $q(k', b', \varepsilon)$, reflects the firm's repayment probability. Competitive lending equates the financial intermediary's expected return on each of its loans to the risk-free real interest rate. Among firms selecting a common (k', b'), those realizing higher ε' in the next period will be less likely to default. Thus, given persistence in the firm productivity process, $q(k', b', \varepsilon)$ weakly rises in ε. $q(k', b', \varepsilon)$ also rises in k' and falls in b'.[10] When the firm saves cash flows $b' < 0$, it saves $-b'q(k', b', \varepsilon)$ and receives $-b'$ in the next period. As savings carries no default risk, $q(k', b', \varepsilon)$ will be the risk-free interest rate.

The continuing firm's current dividends, given the wage rate ω, are $D = x - k' + q(k', b', \epsilon) b'$, where x is its net wealth including current profits, $\pi(k, \epsilon)$, and the value of undepreciated capital stock, after repaying its debt or receiving cash, and the fixed operating cost:

$$x = \pi(k, \varepsilon) + (1 - \delta)k - b - \xi \quad (1)$$

$$\pi(k, \epsilon) = y(k, \epsilon) - \omega n(k, \epsilon). \quad (2)$$

[9] Because our focus is on firms that accumulate sufficient resources to overgrow the implications of financial frictions, we do not impose exogenous exit in this economy, unlike Khan, Senga, and Thomas (2016).
[10] See Khan, Senga, and Thomas (2016) for loan rate schedules arising from financial intermediary's zero-profit condition.

3.2 Minimum Saving Policy

One implication of the model is that firms can outgrow the implications of financial frictions and firms ultimately achieve a capital level consistent with a frictionless choice given their expected productivity. As such, $k^*(\varepsilon)$ is chosen by firms in a model without loan risk premia, which is the efficient level of capital firms with costless to equity financing would choose. Thus, through the optimal allocation of profits, they reduce their debt and build financial savings. We focus on such firms' financial behavior and use it to study how uncertainty is related to firms' borrowing and cash holdings.

Here, we formulate firms' optimal financial rules for allocating profits across dividends and retained earnings along with investment decisions, debt issuance, and cash accumulation. The formulation of such optimal financial rules is as follows.

Let $B^W(\varepsilon)$ define the minimum savings policy that ensures that unconstrained firms of type ε adopting the frictionless capital level consistent with their expected productivity, $k^*(\varepsilon)$, will remain unconstrained and will never default. Let $\widetilde{B}\,(k^*(\varepsilon),\ \varepsilon_j)$ define the maximum level of debt at which a firm entering the next period with $k^*(\varepsilon)$ and realizing ε_j will be unconstrained.

$$B^w(\varepsilon) = \min_{\{\varepsilon_j|\pi^{\varepsilon}_{ij}>0\}} \widetilde{B}\Big(k^*\left(\varepsilon\right), \varepsilon_j\Big), \tag{3}$$

where

$$\widetilde{B}(k,\varepsilon) \ \equiv \ \pi(k,\varepsilon) - \xi + (1-\delta)\,k - \min\Big\{-k^*\left(\varepsilon\right) + q_0 B^w\left(\varepsilon\right), 0\Big\}. \tag{4}$$

$\widetilde{B}\,(k,\,\varepsilon)$ is the largest b that a type $(k,\ \varepsilon_i)$ firm can owe this period by implementing $k^*(\varepsilon_i)$ and $bI = Bw\,(\varepsilon_i)$ while satisfying $D \geq 0$, where q_0 is the risk-free real rate, and thus $q_0 = \beta$ in the stationary equilibrium.

As will be clear below, $k^*(\varepsilon)$ increases in ε. At the same time, the higher ε, the higher $B^W(\varepsilon)$, with some firms holding positive levels of debt $B^W(\varepsilon) > 0$ and other firms holding positive levels of cash, which translates as negative debt: $B^W(\varepsilon) < 0$, depending on firm-level productivity ε. Considering the balance sheets of firms in this economy, it follows that firms never hold positive levels of debt and cash simultaneously. For a firm with positive levels of debt $B^W(\varepsilon) > 0$, the asset side of the balance sheet at the beginning of each period is $k^*(\varepsilon)$, whereas $B^W(\varepsilon)$ appears on the liability side of the balance sheet. For a firm with positive levels of cash, $B^W(\varepsilon) < 0$, the asset side of the balance sheets at the beginning of each period is $k^*(\varepsilon) - B^W(\varepsilon)$, which is mirrored by the equity of the firm, the only component of the beginning-of-period liability on the balance sheet.

This model economy reflects the view that cash is negative debt. Here, shareholders are indifferent between an extra unit of cash and one less unit of debt in the balance sheet. While the interplay between cash and debt policies may be relevant for financially constrained firms, the type of firm we study satisfies the Modigliani Miller Theorem, thus making the gross position of financial assets and liabilities irrelevant for real outcomes like investment. Given complete markets, risk-neutral firms have little incentive to hold multiple assets in the absence of additional frictions, such as differences in their maturity and liquidity, which add further challenges to solving the quantitative model. One way to have both cash and debt coexist within a firm is to assume debt is less liquid than cash. However, liquidity is difficult to model in quantitative models when we allow for stochastic equilbria with time-varying asset prices. One way forward is to assume firms face fixed costs of issuing new debt. In such a setting, firms, holding debt, may choose to hedge against unexpected expenditures using cash.[11]

Below, using a parameterized version of our model, we will examine the relationship between the volatility faced by firms, σ, and the capital and financial rules, $k^*(\varepsilon)$ and $B^W(\varepsilon)$. To this end, we will close the model with a description of the households problem.

3.3 Households

We close the model with a unit measure of identical households. In each period, households earn their labor income by supplying a fraction of their time endowment. Period utility is given by $U(C, 1-N)$, and households discount future utility by a subjective discount factor, β. The representative household holds a comprehensive portfolio of as- sets containing a number of shares λ and non-contingent discount bonds φ. It maximizes lifetime expected discounted utility by choosing the quantities of aggregate consumption demand, C^h, and labor supply, N^h, while adjusting its asset portfolio.[12] The lifetime expected utility maximization problem of the representative household is:

$$V^h(\lambda, \phi) = \max_{C^h, N^h, \lambda', \phi'} \left[U(C^h, 1-N^h) + \beta V^h(\lambda', \phi') \right] \tag{5}$$

subject to

$$C^h + q\phi' + \int_S \rho_1(x', \epsilon')\lambda'(d[x \times \epsilon]) \leq wN^h + \phi + \int_S \rho_0(x, \epsilon)\lambda(d[x \times \epsilon])$$

We apply the following notation for stock price. In (5), $\rho_1(k', b', \epsilon')$ denotes the exdividend prices of firm shares in the current period, and $\rho_0(k, b, \epsilon)$ is the dividend-inclusive value for current shareholding, λ. Let $\Phi^h(\lambda, \varphi)$ be the household's decision for bonds and $\Lambda^h(k', b', \epsilon', \lambda, \varphi)$ its choice of firm shares corresponding to the future state (k', b', ϵ').

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[11] See, for example, Acharya, Almeida, and Campello (2007), among others, for studies that look at cash-holding and deleveraging behaviors for financially constrained firms.

[12] Households also have access to a complete set of state-contingent claims. These are in zero net supply in equilibrium.

4 Quantitative Analysis

4.1 Parameterization

First, we set the length of a period in the model to be one year. For preferences and technology, we assume that the representative household's period utility is $u(c, L) = \log c + \eta L$, as in models of indivisible labor (Hansen, 1985; Rogerson, 1988). Second, we assume that each firm's production technology is Cobb-Douglas production. This function describes technology set: $\varepsilon k^{\alpha} n^{\nu}$. Third, we assume that the idiosyncratic productivity process follows a mean zero AR(1) process in logs: $\log \varepsilon' = \rho \log \varepsilon + \eta'$ with $\eta' \sim \mathbf{N}(0, \sigma^2)$.

We calibrate the model parameters so that the model's steady state can match several salient moments from both micro and macro data in Japan. First, we take the household discount factor, $\beta = 0.976$, from Hayashi and Prescott (2002), who also assume indivisible labor in the study of Japanese economy. Second, the depreciation rate, $\delta = 0.089$, is also taken from Hayashi and Prescott (2002), which yields the average value of the ratio of depreciation of the capital stock for the Japanese economy the period from 1984 to 1989. Third, we calibrate the labor share, ν, to obtain an average labor share of income at 0.64, which corresponds to the average value of the ratio of compensation of employees to national disposable income between 1994 and 2016. Finally, we set the persistence of the idiosyncratic productivity process, ρ, at 0.90. With these parameters set in advance, we calibrate the remaining parameters by indirect inference; solving the model's stationary equilibrium repeatedly over the parameter space defined below.

Table 2: Parameter values

β	ν	δ	ρ	σ	ξ	α	η
0.976	0.64	0.089	0.90	0.0335	0.0203	0.227	2.472

The remaining parameters are in $\mathbf{\Omega}$, involving (1) the capital share, α, (2) the prefer- ence parameter, η, (3) the fixed operation cost parameter, ξ, and (4) the standard deviation of the idiosyncratic productivity process, σ. These parameters are calibrated against the data moment vector, $\mathbf{m}$, which contains (1) the average private capital-to-output ratio between 1994 and 2016 (= 1.98), (2) aggregate total hours worked (= 1/3), (3) the average debt-to-asset ratio of Japanese nonfarm nonfinancial businesses over 1991-2017 (= 0.18), (4) the average cash-to-asset ratio of Japanese nonfarm nonfinancial businesses over 1991-2017 (= 0.13).[13]

[13] These moments are obtained from our panel dataset constructed from the Compustat database as presented above.

This will pick the set of calibrated parameters, $\widehat{\mathbf{m}}(\boldsymbol{\Omega})$, by minimizing the distance between the set of moments generated by the model, $\widehat{\mathbf{m}}$ $(\boldsymbol{\Omega})$ and those from data $\mathbf{m}$.[14] The resulting parameter values are listed below in Table 2 and the comparison between the moments in the data and the model is presented in Table 3.

Table 3: Moments: target and Model

Description	Target	Model
The discount factor	0.025	0.025
Labor share	0.637	0.637
Depreciation of capital	0.089	0.089
Persistence of productivity	-	0.900
Capital-to-output ratio	1.98	2.00
Average hours worked	0.33	0.326
Debt-to-capital ratio	0.18	0.182
Cash-to-capital ratio	0.13	0.131

4.2 Model results

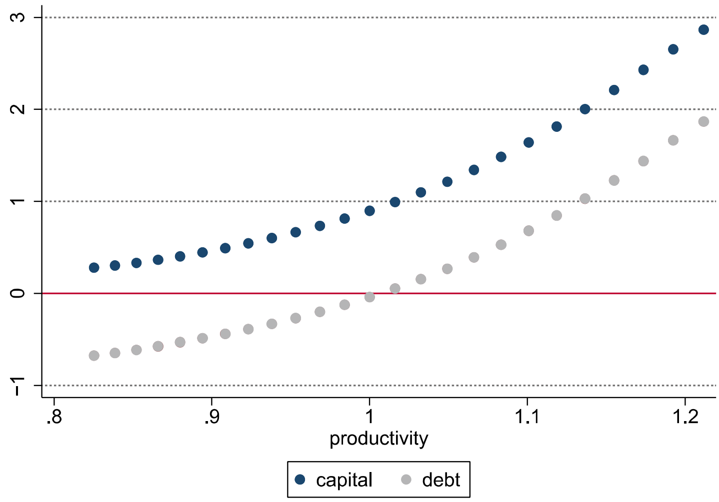
The primary mechanism in the model may be seen in Figure 1, which depicts the decision rule of individual firms. Firstly, as in standard firm dynamics models with decreasing returns to scale production technology, firms' optimal capital choice (k') is convex in firm-level productivity (ε). As firm-level productivity increases, the optimal capital stock grows faster. This is simply because firms undertake higher levels of investment with a rise in the distribution of future productivity. Here, firm-level productivity is persistent and thus this implies that the current productivity levels is positively related to the distribution of future productivity, leading to the positive association between the current firm-level productivity and k'. Secondly, the optimal debt choice also increases with firm- level productivity, and is convex in firm-level productivity (ε). This reflects the convexity of capital choice in firm-level productivity (ε) in that firms need more net wealth to afford a higher level of capital stock. Additionally, as expected productivity is high, they can repay such larger levels of borrowing using profits generated from operation in the following period, which is expected to be high as well. As such, firms with high productivity keep positive levels of debt.

Turning to firms with low productivity, as seen in Figure 1, they hold cash. Such firms' expected productivity, and thus their capital choice, is low. With low levels of future capital stock, expected net wealth in the next period is also low, implying that the probability of de-

[14] Formally, we state this minimization problem as follows: $\widehat{\mathbf{m}}(\Omega) = \arg\min_{\Omega} (\mathbf{m} - \widehat{\mathbf{m}}(\Omega))' W (\mathbf{m} - \widehat{\mathbf{m}}(\Omega))$, where W is an identity matrix we use as the weighting matrix.

fault is positive, all else equal. Therefore, instead of continuing with positive debt holding, they build sufficient precautionary financial assets to ensure that they will not default. Moreover, they hold cash to finance investment if they experience a large rise in productivity next period.

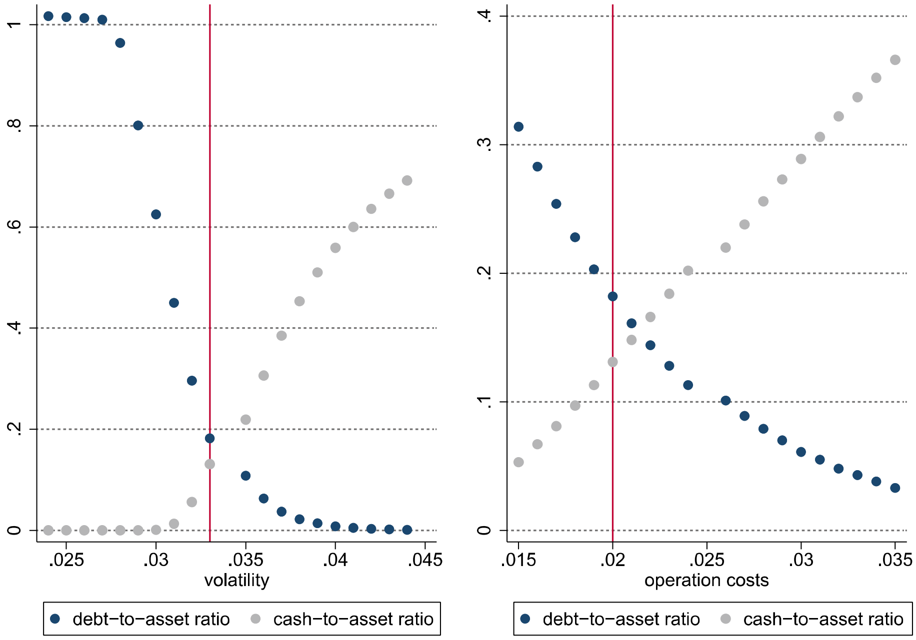
Figure 1: Decision rules of each firm



As seen above, our model reproduces the coexistence of debt and cash in the economy, a distinct feature that a heterogeneous firm model like ours with rich cross-sectional variation of financial positions can generate. Interestingly, even though firms that we examine are those have outgrown default risks permanently, their borrowing and cash- holding behaviors are crucially related to the size of the uncertainty they face. Here, we investigate debt and cash-holding behavior of firms and their aggregate implications by varying the parameters that govern the volatility of firm-level productivity process (σ) and the size of operation costs (ξ).

In Figure 2, we show how the aggregate debt-to-asset ratio and cash-to-asset ratio are affected when we vary the volatility parameter (σ) and the operation cost parameter (ξ). We start with the calibrated parameters and then change the parameter relative to its calibrated value, holding all other parameters fixed, and find the new general equilibrium of each model to compute the aggregate equilibrium quantities. The left panel of Figure 2 shows how the aggregate debt-to-asset ratio and the aggregate cash-to-asset ratio change when we vary the volatility parameter (σ). The major observation is that the aggregate debt-to-asset ratio decreases as the volatility parameter increases, while the aggregate cash-to-asset ratio increases. Moreover, the results are highly non-linear in that the aggregate borrowing sharply increases as the volatility faced by firms decreases and the size of cash holding decreases quickly when the volatility gets smaller — reaching almost negligible cash holdings when the volatility is below 0.03.

Figure 2: Sensitivity of moments to productivity volatility and operation costs



Note: Red lines show the calibrated parameters.

The right panel of Figure 2 examines how the aggregate debt-to-asset ratio and the aggregate cash-to-asset ratio change when we vary the operation cost parameter (ξ). The main finding emerging from this exercise is that the aggregate debt-to-asset ratio decreases as the operation cost rises, while the aggregate cash-to-asset ratio increases. The mechanics are simple. The larger the cost of operation, the more resources firms hold to avoid potential default. Compared to the results for the case where we change the volatility parameter, in the current case, the changes in the aggregate debt-to-asset and cash-to-asset ratios are smoother; however, we still see substantial changes in these aggregate quantities in the general equilibrium.

As discussed above, the causes behind the recent trend of increasing levels of cash holdings in the Japanese business sector are not well understood. All in all, what we have found is that firms that have survived long enough and have thus outgrown default risks still change their borrowing and cash-holdings behaviors when the size of uncertainty changes. In particular, the size of uncertainty faced by firms is positively related to the aggregate cash-to-asset ratio, while the aggregate debt-to-asset ration is negatively related to the size of uncertainty. Our proposed theory shows that uncertainty may be playing an important role in driving the recent corporate cash-holdings patterns observed in the data. Our next step is to empirically test our model's prediction with regard to the uncertainty-cash nexus using Japanese business panel data.

5　Empirical test

5.1　Data construction

This section tests our model prediction. To this end, we use our Japanese firm panel data as described above. We construct measures of historic sales growth volatility and profit-to-sales ratio volatility. We take the standard deviation of every realization of annual sales growth and profit-to-sales ratio over the past five years prior to year *t* for firm *i* as *Sales volatility*$_{i,t}$ and *Profit volatility*$_{i,t}$. For sales, we use net sales taken as SALE from Compustat and then obtain the measure of sales growth as $g_{i,t} = \log(sales_{i,t}) - \log(sales_{i,t-1})$. For profits, we use earnings before interest, tax, depreciation, and amortization, taken as EBITA in Compustat. We then define the ratio of profit to sales.

As discussed above, the type of firms in the model economy is financially unconstrained and thus it is indifferent between an extra unit of cash and one less unit of debt. Therefore, our first test is whether we observe any relationship between net leverage and uncertainty empirically. We define net leverage by subtracting cash (CHE in Compustat) from debt (DLTT in Compustat) and divide it by total assets (AT in Compustat). We then use this as the left hand side variable.

We then investigate the impact of uncertainty on the cash-to-asset ratio and debt-to- asset ratio one by one. As above, we follow the literature in that we use cash and short- term investments (CHE in Compustat) to measure cash for the sample firms. Cash is defined the sum of currency, demand deposits, and cash equivalents such as term deposits and commercial paper that is near maturity, without risk of changes in value because of changes in interest rates. Short-term investments includes trading securities, available-for-sale securities, or held-to -maturity securities that are reported as current assets in the balance sheet. They are intended to be sold within one year or to be held until maturity if maturing within one year. We then define the ratio of cash-to-asset using total assets (AT in Compustat) as the denominator. The ratio of debt-to-asset is defined by dividing debt (DLTT in Compustat) by total assets (AT in Compustat).

5.2　Firm-level evidence

In this sub-section, we empirically validate the prediction of our model. Our first empirical test examines the relationship between our volatility measures and net leverage at the firm level within the Japanese business panel data described above. To this end, we regress net leverage of firms on the measures of historic sales growth volatility and profit-to-sales ratio volatility over prior years. Consistent with the theory, a firm's past realized sales growth volatility and profit ratio volatility are negatively associated with firm-level net leverage, as shown in columns (1) through (6) in Table 4, though the coefficient in column (5) is insignificant. Columns (1) and (2) show the results without fixed effects, while columns (3) and (4) show the results with year fixed effects and industry fixed effects. Finally, columns (5) and (6) show the results with year fixed effects and firm fixed effects. All in all, as shown in Table 4, the results are consistent with our theory across different specifications with different sets of fixed effects included.

Table 4: The relationship between uncertainty and net leverage at the firm level

	Net leverage					
	(1)	(2)	(3)	(4)	(5)	(6)
Sales volatility	-0.038***		-0.013**		0.006	
	(0.0173)		(0.0164)		(0.0126)	
Profit volatility		-0.092***		-0.072***		-0.010**
		(0.0530)		(0.0506)		(0.0405)
Year FE	N	N	Y	Y	Y	Y
Industry FE	N	N	Y	Y	N	N
Firm FE	N	N	N	N	Y	Y
Observations	24954	25406	24954	25406	24954	25406
R^2	0.142	0.148	0.401	0.401	0.829	0.827

While our theory predicts a financial behavior for financially unconstrained firms, the dataset may include financially constrained firms. Such firms will have different effects of cash and debt on their value. Because the dataset contains only publicly listed firms, the degree of financial frictions for those firms may be less severe than that for small and medium sized enterprises. To explore this issue empirically, we replace each firm's net leverage by the ratio of cash-to-asset and run the same regression, controlling for other variables that are found in the literature to be important in explaining cash holdings at the firm level. The results are summarized in Table 5. Columns (1) through (6) show that a firm's historic realized sales volatility and profit volatility are positively correlated with firm-level cash holdings. Columns (1) and (2) show the results for sales and profit ratio volatility with no fixed effects. All coefficients in these columns are positive and significant. Next, columns (3) and (4) show the results for sales and profit ratio volatility with year fixed effects and industry fixed effects. The coefficients get smaller as fixed effects pick up some of the effect; however, they are significant for both sales growth and profit ratio volatility. Columns (5) and (6) show the results for sales and profit ratio volatility with year fixed effects and firm fixed effects, instead of industry fixed effects. As can be seen in these coefficients, firm fixed effects capture a larger variation relative to industry fixed effects. Yet, these coefficients are still significantly positive, validating our model prediction and showing its robustness.

Table 5: Positive associations between uncertainty and cash holdings are robust

	Cash-to-asset ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
Sales volatility	0.094***		0.061***		0.028***	
	(0.0115)		(0.0109)		(0.00914)	
Capital exp.-to-asset	-0.302***	-0.298***	-0.216***	-0.215***	-0.112***	-0.112***
	(0.0233)	(0.0229)	(0.0232)	(0.0228)	(0.0181)	(0.0179)
Prof-it-to-sales ratio	0.299***	0.264***	0.283***	0.261***	0.120***	0.117***
	(0.0115)	(0.0114)	(0.0111)	(0.0110)	(0.0105)	(0.0104)
RandD-to-asset	0.089***	0.065***	0.017**	0.004	-0.043***	-0.041***
	(0.0312)	(0.0311)	(0.0367)	(0.0362)	(0.0528)	(0.0520)
Sales growth	-0.115***	-0.115***	-0.091***	-0.091***	-0.070***	-0.070***
	(0.00594)	(0.00583)	(0.00536)	(0.00528)	(0.00336)	(0.00334)
Intangible-to-asset ratio	0.021***	0.029***	-0.127***	-0.120***	-0.133***	-0.128***
	(0.0224)	(0.0219)	(0.0222)	(0.0218)	(0.0202)	(0.0200)
Profit volatility		0.159***		0.121***		0.030***
		(0.0353)		(0.0335)		(0.0294)
Year FE	N	N	Y	Y	Y	Y
Industry FE	N	N	Y	Y	N	N
Firm FE	N	N	N	N	Y	Y
Observations	25017	25473	25017	25473	25017	25473
R^2	0.156	0.169	0.418	0.422	0.802	0.799

Turning to other coefficients, the results are in line with our conventional view. For example, capital expenditures and research and development expenses are negatively correlated with cash holdings at the firm level. This is because the amount of cash that firms can keep in the balance sheet will be lower if such spending increases. At the same time, research and development expenses may lead to the accumulation of intangible assets. This can incentivize firms to hold cash as intangible assets are often considered to be less collateralizable, making it difficult to finance them externally.[15] Although this argument implies that intangible asset intensity may lead to high levels of cash holdings at the firm level, our results indicate the opposite, and the coefficients are negative once year and industry or firm fixed effects are included, as seen in columns (3) through (6). In sum, our empirical investigation shows a significant positive association between cash holdings and uncertainty faced by firms. The results are robust to the inclusion of various fixed effects and other firm-level controls, some of which are considered to be key factors explaining cash levels across firms.

Lastly, controlling for other variables as in the previous specification, we examine the relationship between uncertainty and the debt-to-asset ratio at the firm level. We replace the ratio of cash-to-asset by the ratio of debt-to-asset and revisit the regression. Table 6 summarizes the

15 See Hall and Lerner (2009) for the financing gap for innovation activities.

results. As shown in Table 6, the sign of the coefficients on the volatility measures are positive, showing that, contrary to our theoretical predictions, uncertainty is positively associated with leverage among the sample firms. The channel isolated from the model in this paper is consistent with cash holding, which drives net leverage as well. However, there are other omitted factors in the model when it comes to explaining debt.

Table 6: Uncertainty is positively related to leverage at the firm level

	Cash-to-asset ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
Sales volatility	0.052***		0.056***		0.046***	
	(0.00985)		(0.00980)		(0.00818)	
Capital exp.-to-asset	0.243***	0.243***	0.145***	0.145***	0.031***	0.033***
	(0.0199)	(0.0197)	(0.0209)	(0.0207)	(0.0163)	(0.0161)
Prof-it-to-sales ratio	-0.100***	-0.107***	-0.142***	-0.147***	-0.131***	-0.131***
	(0.00973)	(0.00978)	(0.00986)	(0.00983)	(0.00934)	(0.00926)
RandD-to-asset	-0.100***	-0.103***	-0.078***	-0.083***	-0.113***	-0.116***
	(0.0267)	(0.0268)	(0.0328)	(0.0326)	(0.0468)	(0.0460)
Sales growth	0.036***	0.037***	0.033***	0.035***	0.008**	0.009**
	(0.00508)	(0.00502)	(0.00481)	(0.00476)	(0.00300)	(0.00298)
Intangible-to-asset	0.110***	0.109***	0.165***	0.165***	0.131***	0.132***
ratio	(0.0192)	(0.0190)	(0.0200)	(0.0197)	(0.0181)	(0.0179)
Profit volatility		0.031***		0.021***		0.015***
		(0.0302)		(0.0300)		(0.0260)
Year FE	N	N	Y	Y	Y	Y
Industry FE	N	N	Y	Y	N	N
Firm FE	N	N	N	N	Y	Y
Observations	25066	25530	25066	25530	25066	25530
R^2	0.070	0.068	0.291	0.286	0.760	0.757

6 Conclusion

We have documented a set of stylized facts. First, the debt-to-asset ratio of Japanese firms continuously declined after the burst of asset price bubble up until 2017. Second, the ratio of cash-to-asset of Japanese firms declined from 1993 to 2000 and increased since then, until 2017. Third, the level of uncertainty faced by Japanese firms rose significantly after 2000.

In light of these stylized facts, we have developed a macroeconomic model with heterogeneous firms that face uncertainty over idiosyncratic productivity and default risk. Investment is financed by retained earnings and non-contingent debt, firms may find it optimal to default on loans when adverse shocks to productivity are large and their financial positions has deteriorated below the level required to cover fixed-costs of operation. One important implication of the model is that firms are heterogeneous in their idiosyncratic productivity and financial positions. Further, some firms with high productivity keep positive levels of debt issuance, while other firms with low productivity build financial savings to shield themselves from future funding needs. The coexistence of debt and cash requires a heterogeneous firm environment; a representative firm model cannot deliver it.

The implication of our model is that uncertainty, measured by the standard deviation of productivity shocks, is positively related to the size of cash holdings at the firm level, while the size of debt issuance is negatively correlated with uncertainty. The first pre diction of the model is empirically validated by panel regressions. In the data, firm-level cash-to-asset ratios are significantly positively correlated with the volatility of past sales growth. Firm-level debt-to-asset ratio is also significantly positively correlated with the volatility of past profit-to-sales ratio at the firm-level, even after we control for year, industry, and firm fixed effects as well as other firm-level control variables such as research and development expenses and intangible assets intensity.

Areas for further research include developing measures of uncertainty for Japanese businesses, isolating causal relationships between uncertainty and economic activity, and conducting structural analysis with Japanese business-level data. Domestically, the consumption tax is expected to increase to 10 percent in October 2019 and perhaps more urgent, the businesses environment is more uncertain globally; for example, the UK is leaving the European Union, U.S. trade policy has been and is expected to cause significant uncertainty: It appears to be difficult to make well-informed decisions. In such a setting, macroeconomic models with heterogeneous firms, tested against micro-level data, are expected to play an important role in economic research and policy analysis. Eliciting business level expectation using business surveys is also a crucial in providing interpretations of data.

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