DISCUSSION PAPER No.140

為替変動の不確実性と研究開発投資：日本の企業データによる実証分析

Exchange Rate Uncertainty and R&D Investment: Evidence from Japanese Firms

2017 年 2 月

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伊藤恵子・羽田尚子 (2017) 「為替変動の不確実性と研究開発投資：日本の企業データによる実証分析」, *NISTEP DISCUSSION PAPER*, No.140, 文部科学省科学技術・学術政策研究所.
DOI: http://doi.org/10.15108/dp140

Ito, Keiko and Haneda, Shoko (2017) “Exchange Rate Uncertainty and R&D Investment: Evidence from Japanese Firms,” *NISTEP DISCUSSION PAPER*, No.140, National Institute of Science and Technology Policy, Tokyo.
DOI: http://doi.org/10.15108/dp140

為替変動の不確実性と研究開発投資：日本の企業データによる実証分析

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要旨

日本の通貨「円」は、世界の主要先進国通貨の中でも最も変動の大きい通貨の一つである。本研究では、為替レートの不確実性が企業活動、特に研究開発活動にどのような影響を与えるかを 1994～2011 年の日本の製造業企業のパネルデータを用いて分析した。分析の結果、不確実性が高いと、間違った意思決定によって費用増加を招いてしまう可能性が高くなるので、為替レート変動により大きく晒されている企業（輸出から輸入を引いた純輸出が大きい企業）ほど、研究開発投資により慎重になることが示された。つまり、企業は需要の増加という好ましい環境下にあっても研究開発投資をあまり増やさず、最適な研究開発投資の増加率よりも低い増加にとどまることが示唆される。

我々の分析結果から、研究開発投資を刺激するためには、為替レートの不確実性を減らすことが重要であるといえる。また、企業の研究開発投資と輸出とを同時に促進していくためには、輸出促進政策と並行して、特許や研究開発補助金に関する制度の強化を図り、研究開発へのインセンティブを高めることも求められる。

Exchange Rate Uncertainty and R&D Investment: Evidence from Japanese Firms[†]

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ABSTRACT

The Japanese yen is one of the most volatile among developed country currencies. In this paper, we investigate how real effective exchange rate (REER) uncertainty affects firms' research and development (R&D) investment, using firm-level panel data for Japanese manufacturing firms for the period 1994-2011. Our results show that firms that are more exposed to REER uncertainty are less responsive to changes in demand conditions. Uncertainty makes firms more cautious when investing since high uncertainty increases the chances of making a costly mistake. Our finding thus provides evidence of the caution effect of uncertainty. The caution effect also increases the persistence of R&D, implying that R&D investment does not increase much even if firms face favorable demand conditions. Reducing REER uncertainty is important to stimulate R&D investment, especially for firms that are more exposed to international competition and REER uncertainty.

Keywords: R&D; Uncertainty; Real effective exchange rate
JEL classification: F14, F31, D92, E32, O30

[†]This research was conducted as part of research projects for the Economic Research Institute for ASEAN and East Asia (ERIA) and the National Institute for Science and Technology Policy (NISTEP). This work was supported by JSPS KAKENHI Grant Number 23683003. The opinions expressed and arguments employed in this paper are the sole responsibility of the authors and do not necessarily reflect those of ERIA, NISTEP, or any institution with which the authors are affiliated.

概要

［空白のページ］

1．研究の背景と目的

研究開発投資は新製品・技術の開発を実現することができるのか、そしてそれらが市場に受け入れられて商業的に成功するのかという意味での不確実性を引き受けなければならない投資である。研究開発投資には不可逆性があり、他への転用が難しいことから、不確実性が高い状況のもとで間違った意思決定をすることは、企業が損失や費用を被る確率を高めることになる。このため、不確実性は研究開発投資に負の影響を及ぼすと予想される。

不確実性が企業の研究開発投資に与える影響について、Bloom (2007) は「遅延効果」と「慎重効果」という用語を用いた説明をしている。投資の不確実性が高い時、企業は「投資をする」というオプションを行使せず、失敗を回避しようと「待って様子を見る」方を好むかもしれない。このように投資の意思決定を遅らせる「遅延効果」が働くと、研究開発の水準が最適水準より低い場合であっても高い場合であっても、企業は投資の調整により時間をかけるようになる。

また、誤った判断による損失や費用を回避しようと、企業は投資の意思決定に慎重になる。こうした「慎重効果」により、需要ショックやまたは他の何等かの経済ショックに対する投資の反応は鈍化すると考えられる。たとえ需要の増加という好ましい状況下にあったとしても、研究開発投資をあまり増やそうとはせず、最適な研究開発投資の増加率よりも低い増加にとどまる（逆に需要減の場合は、研究開発投資をあまり減らそうとしない）ことが示唆される。このため、「慎重効果」は研究開発投資の経路依存性をより高めると予想される。

一方、Bloom (2014) は、不確実性が研究開発に成功した場合に得られる利益を増やすのであれば、不確実性はむしろ研究開発を促す可能性があることも指摘している。研究開発投資に伴う不確実を引き受けるからこそ、他企業には真似できない新製品・新技術を実現することが可能となる。研究開発投資を行う企業は、そうでない企業よりも成長機会が大きいと考えられるため、不確実な市場において成功すればそのリターンも大きいと予想される。これを「成長オプション効果」と呼ぶ。

不確実性が企業の研究開発投資に与える影響を定量的に示した先行研究は極めて少ないが、Minton and Schrand (1999), Czarnitzki and Toole (2007, 2011), Grassi and Di Cintio (2016) では、不確実性が高い企業は研究開発投資により慎重になるという結果を導いている。これに対し、不確実性が研究開発投資を促進するという結果はほとんど見当たらず、Kraft et al. (2013) が不確実性は研究開発集約的な企業の株価を押し上げていることを示し、研究開発投資に正の効果を持つ可能性を示唆するにとどまっている。

本研究は、貿易や直接投資など国際的に事業を展開する製造業企業に注目し、為替レートの不確実性が研究開発投資にどのような影響を与えるのかを、経済産業省「企業活動基本調査」の企業個票データを利用して定量的に検証するものである。森川 (2013) によれば、日本の製造業企業の多くは経営の意思決定において為替レートの不確実性に直面している。とりわけ貿易や直接投資など、国際的に事業を展開する企業にとってその影響は重大であると推測される。先行研究の多くは、売上高の標準偏差などの収益に関する指標や各国のインフレ率を不確実性の指標として用いており、為替レートの不確実性を明示的に取り上げたものはない。本研究は、市場や活動を海外に拡げる企業に対し、為替レートの不確実性が研究開発投資にどのような影響を与えるのかという問いに対して実証的な証拠を示す数少ない研究となっている。

2．利用したデータ

本研究では経済産業省の「企業活動基本調査」の企業個票データを用いる。「企業活動基本調査」は、製造業、鉱業、卸売・小売業、飲食店、電気・ガス業、一部のサービス業の事業所を持つ企業のうち従業者数 50 人以上かつ資本金または出資金 3,000 万円以上の会社を調査対象としており、常時従業者数、売上高および費用等、資産・負債および資本、研究開発支出、直接輸入・輸出額（地域別あるいは商品類別の直接輸入額・輸出額を含む）、国内外の子会社・関連会社の数といった企業活動の実態に関する情報を含んでいる。分析対象期間は、1994 年から 2011 年の 18 年間とした。また、本研究では市場や活動を海外に拡げている企業の研究開発活動に焦点を当てていることから、製造業企業のみを対象とした。このため分析に用いる企業数は各年で約 1 万 1 千社となった。

為替レートの不確実性の代理変数には、BIS（国際決済銀行）の実質実効為替レートの各年における標準偏差を用いている。

3．分析方法

本研究では、為替の不確実性が、Bloom (2007, 2014) の示す「遅延効果」や「慎重効果」によって、研究開発に負の影響をもたらすのか、または、「成長オプション効果」より正の影響をもたらすのか、以下の式により固定効果パネル推定とシステム GMM 推定で検証している。

$$RDINT_{it} = \alpha_0 + \beta_1 RDINT_{i,t-1} + \beta_2 \Delta lnY_{it} + \beta_3 EXREERSD_{it}$$
$$+\beta_4 RDINT_{i,t-1} * EXREERSD_{it} + \beta_5 \Delta lnY_{it} * EXREERSD_{it} + X_{it} + \varepsilon_{it}$$

$RDINT_{it}$ は、企業 i の t 年の売上高に対する研究開発支出の割合（研究開発集約度）、ΔlnY_{it} は、 $t\text{-}1$ 年から t 年にかけての企業 i の売上高の成長率を表している。 $EXREERSD_{it}$ は企業 i の t 年の実質実効為替レートの変動に晒されている度合を表す変数であり、本研究で最も注目する変数である。為替レート変動により大きく晒されている企業（輸出から輸入を引いた純輸出が大きい企業）ほど、実質実効為替レートの変動に対してより大きな不確実性に直面していると推測される。このため、具体的には $EXREERSD_{it}$ を BIS の実質実効為替レート (REER) の月次データの標準偏差に、企業 i の t 年における純輸出の大きさ（ネットの通貨エクスポジャー）を掛けたものとして定義している。X_{it} は企業属性を表すコントロール変数である。

第 1 節で述べたように、企業の研究開発活動は、不確実性が高い時期には「慎重効果」によりあまり反応しないと推測される。このため、不確実性が高いと、売上が伸びていても、研究開発支出の伸びは売上ほどには伸びないと考えられる（すなわち推定式の係数 $\beta_5<0$ となる）。 また、不確実性に対する「遅延効果」が働くと、前期に研究開発集約度が最適値よりも低かった（高かった）としても、今期に研究開発集約度を高く（低く）するという行動が抑制される。つまり、「遅延効果」が存在する場合、前期の研究開発集約度と今期の研究開発集約度との相関が正となると推測される（推定式の係数 $\beta_4>0$ となる）。「成長オプション」が働くと、不確実性が研究開発投資を促すと推測される（推定式の係数 $\beta_3>0$ となる）。

4．分析結果

本文の Table 2 に基づき、固定効果モデルの推定結果を概要図表 1 で図示した。概要図表 1 の網掛けをした推定係数の符号により、為替の不確実性が研究開発投資に与える「成長オプション

効果」(β_3)、「慎重効果」(β_5)、「遅延効果」(β_4) を確認する。分析対象の製造業企業には、輸出も輸入もしていない企業や、研究開発支出を計上していない企業も多く含まれていることから、企業をいくつかのパターンに分けた推定も行い、結果の頑健性も確認している。

概要図表1:為替レート変動と研究開発投資額

	全企業		輸出または輸入を行っている企業		研究開発投資を行っている企業	
推定係数	符号	*P* 値	符号	*P* 値	符号	*P* 値
β_1	+	***	+	***	+	***
β_2	—	***	—	***	—	***
β_3	+	**	+		+	
β_4	+		+		+	
β_5	—	***	—	***	—	***

注:***、**、*はそれぞれ、有意水準 1、5、10%レベルを示す.

1 期前の研究開発集約度は全てのパターンで正の有意な係数が認められ(概要図表 I の β_1)、研究開発活動の持続性の高さを確認できる。為替レートの不確実性の係数 (β_3) は正の値となったが、ほとんどのパターンで統計的に有意とならず、不確実性が研究開発投資を促進するという「成長オプション効果」の存在を強く支持することはできない。売上の成長率の係数 (β_2) は負で有意、売上の成長率と為替レートの不確実性との交差項 (β_5) も負で有意な係数が認められた。これは、為替レートの不確実性が高いとき、企業は売上が伸びていてもあまり研究開発を増やさないことを示唆しており、研究開発投資の「慎重効果」の存在を示すものといえる。一方、1 期前の研究開発集約度と為替レートの不確実性との交差項の係数 (β_4) はほとんどのパターンで統計的に有意ではなく、不確実性が高い時に研究開発投資を遅らせるという「遅延効果」の存在を確認することはできなかった。システム GMM の推定結果(本文の Table 3 を参照のこと)においてもほぼ同様の結果となった。

5. 結論と政策的含意

本研究の分析結果から、実質実効為替レートの変動が大きいと、為替変動により大きく晒されている企業は、研究開発投資により慎重になることが示された。研究開発投資は経路依存性が高い投資であるといわれており、企業は需要が増えてもすぐに研究開発投資を増やさず、また需要が減ってもすぐには研究開発投資を減らさないことが先行研究により示されている。本研究からも、為替レート変動に晒されている企業ほど、より慎重で経路依存性が高い投資行動をとるという結果を認めることができた。これはすなわち、市場や事業活動を海外に拡げる国際的な企業において、需要

変化に対する研究開発投資の感応度が低くなることを示唆している。需要の増加に対する研究開発投資の感度を高めるためには、為替レートの不確実性を緩和することが重要となる。

為替レート変動の不確実性緩和のためには、為替の安定に向けた政府および金融当局の一層の努力が重要であることは言うまでもない。しかしその他の方法、例えば、為替レート変動のリスクをヘッジする方法やそれを管理する方法について、公的・民間金融機関が輸出企業に対して積極的にアドバイスすることも有効かもしれない。

また、特許や研究開発補助金は直接的に為替レートの安定をもたらすものではないが、事業環境の不確実性や投資の意思決定への負の効果を緩和することが先行研究から示されている。これゆえ、企業の研究開発投資と事業の国際化とを同時に促すのであれば、輸出促進政策と並行し、特許や研究開発補助金に関する制度の強化を図ることも有効かもしれない。

最後に残された課題と今後の展望について簡潔に述べる。本研究では「成長オプション」効果を示す結果は得られなかった。成長オプション効果についての先行研究は極めて少ないことから、この効果の有無を結論づけるために、今後の研究蓄積が求められる。企業の設立年別、設立形態別、社内外の研究開発投資動向別に基本モデルを推定し、その有無を検証する必要があろう。また、経済活動のグローバル化が進展する中で、円高による輸入への正の影響が輸出への負の影響を上回る企業も増えていることから、不確実性が与える影響やそのメカニズムに関して、通貨エクスポジャーのパターン別にその差異を検証することも求められる。

参考文献

Bloom, Nick. (2007) "Uncertainty and the Dynamics of R&D," *American Economic Review* 97(2): 250-255.

Bloom, Nicolas. (2014) "Fluctuations in Uncertainty," *Journal of Economic Perspectives* 28(2): 153-176.

Czarnitzki, Dirk, and Andrew A. Toole (2007) "Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty," *Review of Industrial Organization* 31(3): 169-181.

Czarnitzki, Dirk, and Andrew A. Toole (2011) "Patent Protection, Market Uncertainty, and R&D investment," *The Review of Economics and Statistics* 93(1): 147-159.

Kraft, Holger, Eduardo S. Schwartz, and Farina Weiss (2013) "Growth Options and Firm Valuation," *NBER Working Paper* 18836, National Bureau of Economic Research.

Grassi, Emanuele, and Marco Di Cintio (2016) "Uncertainty, Flexible Labour Relations and R&D Expenditure," *Metroeconomica*, forthcoming.

Minton, Bernadette A., and Catherine Schrand (1999) "The Impact of Cash Flow Volatility on Discretionary Investment and the Costs of Debt and Equity Financing," *Journal of Financial Economics* 54(3): 423-460.

森川正之 (2013)「政策の不確実性と企業経営」RIETIディスカッションペーパー、13-J-043、独立行政法人経済産業研究所。

本文

［空白のページ］

1. Introduction

Like firms from many other countries, Japanese firms have become increasingly engaged in international trade and investment over the past three decades. In fact, facing sluggish domestic sales against the background of an aging and shrinking population, Japanese firms recently have become more and more reliant on export markets for sales and profits. However, the more heavily reliant on export markets Japanese firms are, the higher is the uncertainty about future productivity and demand conditions they face. Moreover, the Japanese yen is one of the most volatile among developed country currencies. As shown in Figure 1, the real effective exchange rate (REER) index for the Japanese yen fluctuates greatly, often changing by more than 10 percent in a year.[1] Looking at the annual standard deviation of the BIS REER index for major developed countries, the Japanese yen clearly shows the largest standard deviation, suggesting that the yen is a much more volatile currency than the currencies of other developed countries (Figure 2).[2]

Firms engaged in international business typically face considerable uncertainty with regard to currency exchange rates and foreign market conditions when making business decisions. In fact, Morikawa (2013), analyzing data underlying the "Survey on the Outlook of the Japanese Economy and Economic Policy" conducted by the Research Institute of Economy, Trade and Industry (RIETI), reports that a majority of surveyed firms in the manufacturing sector answered that they were highly uncertain about exchange rate developments (55% of responding firms) and that uncertainty over exchange rates had a significant impact on their business (65% of responding firms). The survey results indicate that exchange rate uncertainty is a major concern for many manufacturing firms in Japan.

Against this background, the purpose of this study is to investigate how exchange rate uncertainty affects firms' activities, focusing on research and development (R&D) investment. R&D investment is crucial to the development of new products and processes and firms' growth. In fact, with the intensification of cross-border competition

[1] The base year of the BIS (Bank for International Settlements) REER indices is 2010.
[2] The BIS REER indices are available on a monthly basis and for the comparison we calculated the standard deviation of the monthly index values within a particular calendar year.

firms, particularly those in advanced countries, need to allocate substantial amounts of resources to R&D activities in order to retain their competitiveness vis-à-vis rivals. At the same time, advancing globalization also means that economic crises spread more rapidly from one country or region to another or across the globe, resulting in increased currency volatility and greater exchange rate risks. Furthermore, studies show that there is a positive correlation between trade openness and sales volatility (e.g., Vannoorenberghe 2014). All this implies that coping with higher uncertainty in international markets is becoming more and more important for firms.

There is a sizable literature on investment under uncertainty. Studies such as Bloom et al. (2007) and Bloom (2009) suggest that higher uncertainty reduces the responsiveness of investment to demand shocks. Uncertainty makes firms more cautious and less sensitive to changes in business conditions when investing and disinvesting.[3] This also holds for investment in R&D, with a considerable number of empirical studies providing evidence that higher uncertainty reduces firm-level R&D investment (e.g., Czarnitzki and Toole 2007, 2011, Grassi and Di Cintio 2016).

However, Bloom (2014) points out that it is also possible that uncertainty can stimulate R&D if it increases the upside from innovative new products. While empirical evidence in support of this kind of effect is still very limited, Kraft et al. (2013) do show that higher uncertainty raises the stock value of R&D intensive firms, suggesting that uncertainty potentially has a positive effect on R&D investment.

Thus, although previous studies suggest that uncertainty has a detrimental effect on investment, including R&D investment, the evidence is not conclusive and more empirical research is needed. In addition, most previous studies measure uncertainty in terms of fluctuations in firms' total sales, meaning that these studies do not really address the impact of uncertainty in overseas markets on domestic R&D activities, the key interest of this paper. Investigating how R&D investment is affected by exchange rate uncertainty, what we find is that firms exposed to exchange rate fluctuations tend to be more cautious in their R&D investment. These firms do not increase R&D investment much even if they face favorable demand conditions.

[3] Recent studies such as Bloom et al. (2012) and Bachmann et al. (2013) show that uncertainty leads to significant reductions in production. For a survey of the theoretical and empirical literature on uncertainty and firm behavior, see, for example, Bloom (2014).

Our investigation of how exchange rate uncertainty affects the R&D investment of firms engage in international business also provides important policy implications. While many countries, including Japan, have policies to support firms in their international activities and often actively encourage the internationalization of smaller firms, such policies may expose such firms to uncertainty arising from exchange rate fluctuations. Our results suggest that exchange rate stability can help to boost R&D investment by internationally active firms. R&D activities are essential for a country's sustained economic growth, but R&D investment itself involves high uncertainty with regard to the outcome of the investment. How to encourage investment in knowledge creation and stimulate innovation-based growth by reducing the risks and uncertainties involved in such activities is a key policy issue for many countries.

The remainder of this study is organized as follows. Section 2 briefly reviews the related literature, while Section 3 describes the dataset used in the analysis and provides some descriptive statistics for our sample firms. Section 4 then presents the empirical strategy we employ and Section 5 presents our estimation results. Finally, Section 6 concludes.

INSERT Figures 1 & 2

2. Related Literature

Much of the theoretical literature on investment and uncertainty focuses on the role of the irreversibility of investment in generating "real options" (McDonald and Siegel 1986, Pindyck 1991, Dixit 1992, Dixit and Pindyck 1994, Carruth et al. 2000, etc.). The decision to invest can be treated as the exercising of an option, and firms are assumed to have the option to invest. If a firm becomes uncertain about the future profitability of an investment project, it may prefer to "wait and see" to avoid a costly mistake. In other words, the value of the option to delay an investment is high when uncertainty is high. When an investment is irreversible, the firm incurs an additional opportunity cost by giving up the option to wait for more information. Therefore, uncertainty makes firms cautious about actions such as making investments and will reduce the investment of firms that are risk neutral. Since R&D investment often has low or zero reversibility, uncertainty is likely to negatively impact on R&D investment.

Bloom (2007) uses the terms “delay effect” and “caution effect” to explain such real options effects with regard to R&D investment. At high levels of uncertainty, firms postpone making decisions, so that aggregate investment activity slows down, which is the “delay effect.” The delay effect means that even if firms’ R&D level is below the optimal level, firms will take their time to increase R&D to the optimal level. Conversely, if firms’ R&D is above the optimal level, they will take their time to reduce R&D. Higher uncertainty, moreover, gives rise to the “caution effect,” whereby firms are less responsive to any given shock because higher uncertainty increases the chances of making a costly mistake. Under high uncertainty, firms’ R&D is less responsive to changes in demand conditions, increasing the persistence of R&D.

On the other hand, uncertainty can potentially encourage investment if it increases the size of the potential prize. The market value of a firm is the sum of the present value of cash flows of assets in place plus the value of a firm’s growth options. The value of growth options is simply the value of future growth opportunities. The ultimate value of these growth opportunities is assumed to depend on firms’ discretionary investments. Uncertainty may possibly encourage firms to invest, because the best case scenario for an investment may look ever more profitable as the range of uncertainty increases, while the worst case scenario simply is loss of the sunk costs of an investment. Firms that conduct R&D are generally assumed to have more growth opportunities than firms that do not conduct R&D, so that they are likely to be more affected by uncertainty. Depending on the importance of growth opportunities, uncertainty can potentially have a positive effect on investment.

As mentioned in the introduction, however, evidence on the impact of uncertainty on R&D investment is surprisingly limited. One of the few studies examining the effect of uncertainty on R&D investment is that by Goel and Ram (2001), who measure uncertainty using five-year moving averages of countries’ inflation rate and find that uncertainty reduces the share of R&D expenditure in GDP. At the micro level, Minton and Schrand (1999), using *Compustat* data and measuring uncertainty as cash flow volatility, also find evidence of a negative relationship between uncertainty and R&D

expenditure. Measuring uncertainty as firm revenue volatility, Czarnitzki and Toole (2007, 2011) and Grassi and Di Cintio (2016) come to similar conclusions, using German and Italian firm-level data respectively.[4]

On the other hand, to the best of our knowledge, hardly any studies have examined the relationship between exchange rate changes and R&D investment at the firm level, although there are a limited number of firm-level empirical studies on the relationship between exchange rate changes and firms' exports, production, employment, and productivity.[5]

Thus, there is a lack of empirical evidence on the relationship between R&D investment and uncertainty, particularly for firms exposed to high uncertainty in international markets.

In the following sections, using Japanese firm-level data, we examine whether higher exchange rate uncertainty gives rise to delay and/or caution effects and results in a negative relationship between uncertainty and R&D investment. We also investigate whether uncertainty potentially encourages investment at least for some types of firms, such as firms that conduct R&D, because of the "growth options effect."

3. Description of Data

We use firm-level panel data for the period 1994-2011 collected annually by the Ministry of Economy, Trade and Industry (METI) for the *Basic Survey on Business Structure and Activities* (BSBSA).[6] The survey is compulsory and covers all firms with at least 50 employees and 30 million yen of paid-in capital in the Japanese

[4] While there appear to be no further empirical studies on R&D and uncertainty at the firm level, an increasing number of researchers are investigating the relationship between various measures of uncertainty and firm behavior such as hiring and physical capital investment. See, for example, Bloom (2014).

[5] For example, Berman et al. (2012) examine the relationship between export values and volumes and exchange rate changes, while Ekholm et al. (2012) and Fung (2008) analyze the impact of exchange rate appreciation on firms' production, employment, productivity, and so on.

[6] The statistical analysis of the firm-level data was conducted at the First Theory-Oriented Research Group, National Institute of Science and Technology Policy (NISTEP), Ministry of Education, Culture, Sports, Science and Technology (MEXT) under arrangements that maintain legal confidentiality requirements.

manufacturing, mining, and wholesale and retail sectors as well as several other service sectors. The survey contains detailed information on firm-level business activities such as the 3-digit industry in which the firm operates, its number of employees, sales, purchases, exports, and imports (including a breakdown of the destination of sales and exports and the origin of purchases and imports). It also contains the number of domestic and overseas affiliates or subsidiaries, and various other financial data such as costs, profits, investment, debt, and assets. The survey also contains information on firm-level R&D expenditures.

In order to investigate firms' responses to exchange rate fluctuations, we utilize the BIS real effective exchange rate indices provided by the Bank for International Settlements. The BIS real effective exchange rate indices are available on a monthly basis from 1964 onwards. However, they are available at the macro level only and not at the industry level.[7] In the empirical analysis below, we use the standard deviation of the monthly index values within a particular financial year.

Although the *BSBSA* covers a significant number of non-manufacturing firms, we focus on manufacturing firms only, because we are mainly interested in R&D activities by firms who engage in international trade. Our unbalanced panel data contain approximately 11,000 manufacturing firms per year, almost half of which report non-zero R&D expenditure. Nearly 40 percent of these R&D firms are exporters. On the other hand, approximately a quarter of the manufacturing firms are exporters, and three quarters of them report non-zero R&D expenditure. Therefore, a significant number of R&D firms also conduct exports.

Table 1 shows the number of firms by industry in our dataset for the year 2005 and the shares of firms with non-zero R&D expenditure, exports, imports, and so on. Although the shares of each type of firms vary across industries, almost half of the firms report non-zero R&D expenditure, while nearly 60% of firms neither export nor import. Approximately 20% of firms have at least one manufacturing affiliate abroad.

We also measure the degree of net currency exposure for each firm and show the average currency exposure by industry in Table 1. Following Ekholm et al. (2012), we define the net currency exposure of a firm, which measures the extent to which REER

[7] The BIS real effective exchange rate indices are calculated as geometric weighted averages of bilateral exchange rates adjusted by relative consumer prices. The weighting pattern is time-varying.

fluctuations lead to increased uncertainty, in the following manner. As explained by Ekholm et al. (2012), holding output constant, the elasticity of revenue with respect to the REER is equal to the firm's export share (exports-to-sales ratio), λ_i (where i denotes firm i). A one percent real appreciation decreases total revenue by λ_i percent. They also show that holding inputs constant, the elasticity of costs with respect to the REER is equal to the share of imported inputs in total costs, $\tilde{\lambda}_i$. For given inputs and prices, a one percent real appreciation decreases total costs by $\tilde{\lambda}_i$ percent. If the REER measured by output prices is equal to the REER measured by input prices, the elasticity of profits, i.e., revenues minus costs, with respect to the REER is a function of the difference between the export share and the share of imported inputs, $\lambda_i - \tilde{\lambda}_i$. Therefore, the net currency exposure of a firm is calculated as the difference between the export share and the share of imported inputs.

Let us start by looking at the average R&D intensity (i.e., R&D expenditure divided by sales) of Japanese manufacturing firms in the last decade. We classify firms into several groups in terms of their degree of net currency exposure or their FDI status. We define "exposed firms" as firms whose net currency exposure is positive, while "non-exposed firms" are defined as firms that have zero or negative net currency exposure. We also distinguish firms that do not export and import from those that either export or import.

As for the FDI status, we classify firms into four groups: firms that have both manufacturing affiliates and non-manufacturing affiliates abroad, firms that have only manufacturing affiliates abroad, firms that have only non-manufacturing affiliates abroad, and firms that do not have affiliates abroad.

Looking at Figure 3, the level of R&D intensity is very different across firms with different currency exposure or FDI status. Starting with the left panel, this suggests that the average R&D intensity of firms with positive net currency exposure has been increasing slightly over time, while it has been very stable or even decreasing for non-exposed firms or firms that do not engage in export or import (labeled "No trade" in the figure). On the other hand, the right panel shows that the average R&D intensity fluctuates much more for firms with both manufacturing and non-manufacturing foreign affiliates than for other firms. The panel further shows that the average R&D intensity of firms with manufacturing affiliates only has remained more or less unchanged, while that of firms with non-manufacturing affiliates only has decreased over time. The latter trend may reflect the fact that in recent years firms in less R&D-intensive industries such as food products and beverages have expanded their overseas business and established non-manufacturing affiliates (i.e., sales companies), although for a definitive explanation a closer investigation of this trend is needed.

INSERT Figure 3

4. Empirical Strategy

This section describes the methods used to test our research questions. Bloom et al. (2007) developed a model of firms' investment decisions under uncertainty in which the return from investment is determined by demand conditions, capital stock, and uncertainty.[8] They derive a reduced-form empirical specification that includes the variables representing these factors. Bloom (2007) uses a similar specification in order to examine the relationship between R&D investment and uncertainty. Here, we follow Bloom (2007) and investigate the effect of uncertainty on R&D investment by estimating the following equation:

$$\begin{aligned} RDINT_{it} &= \alpha_0 + \beta_1 RDINT_{i,t-1} + \beta_2 \Delta lnY_{it} + \beta_3 EXREERSD_{it} \\ &\quad + \beta_4 RDINT_{i,t-1} * EXREERSD_{it} + \beta_5 \Delta lnY_{it} * EXREERSD_{it} + X_{it} + \varepsilon_{it} \end{aligned}$$

where $RDINT_{it}$ denotes the R&D intensity (R&D expenditure divided by sales) of firm *i* in year *t*, ΔlnY_{it} is the growth rate of firm *i*'s real sales from year *t-1* to year *t*, and X_{it} is a

[8] They assume that the return from investment is determined by revenue, adjustment costs, and expectations with regard to future returns, and that firms' optimization problem is to maximize the return. Revenue and adjustment costs in the current period are assumed to be functions of demand conditions, the capital stock, and investment flows, while expectations with regard to the future return are assumed to be a function of future demand conditions, the current level of the capital stock and investment, the depreciation rate, the discount rate, and uncertainty with regard to the future.

full set of control variables, including firm fixed effects and year dummies.[9] ε_{it} is the error term. $EXREERSD_{it}$ is the key variable representing the degree of REER uncertainty for firm i in year t, which is the interaction term of firm i's net currency exposure ($NCEX_{it}$) and the standard deviation of the monthly BIS REER index values within a particular financial year. We assume that firms with a high net currency exposure are more exposed to uncertainty with regard to REER fluctuations. As for control variables, we include firm i's TFP level ($lnTFP_{it}$),[10] dummy variables indicating whether the firm is exporting and importing (EXP_{it} and IMP_{it}), and FDI status (FDI_mfg_{it}).[11] FDI_mfg_{it} is a dummy variable which takes one for firms with at least one manufacturing affiliate abroad and zero otherwise. As shown by Aghion et al. (2010) and Aghion et al. (2012), credit constraints affect firms' investment decision over the business cycle. Therefore, we also include the debt-asset ratio ($DARATIO_{it}$) to control for firms' financial constraints.[12]

As explained in Section 2, R&D investment is expected to be less responsive to business conditions in periods of high uncertainty because of the "caution effect" of uncertainty. Therefore, higher uncertainty should reduce the responsiveness of firms to sales growth (β_5<0). The "delay effect" implies that higher uncertainty should increase the responsiveness to lagged R&D intensity (β_4>0).

We estimate the above equation by employing fixed-effect panel and system generalized method of moments (GMM) estimation. In order to control for the potential influence of outliers, we excluded observations in the tails of the distribution for each

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[9] We also tried to include a full set of year-by-industry dummies instead of a full set of year dummies only. Because the fixed-effect panel estimation results in both cases were almost the same, we chose the model with a full set of year dummies only.

[10] In this study, we calculate firms' TFP level using the multilateral TFP index method developed by Good et al. (1997). Specifically, the TFP level of firm i in industry j in year t, $TFP_{i,j,t}$, is defined in comparison with the TFP level of a hypothetical representative firm in the benchmark year t_0 in industry j. The benchmark year t_0 is set to the year 2000 in this study. The representative firm for each industry is a hypothetical firm whose output, inputs, and cost shares of all production factors are identical to the industry average. Then, the firm-level TFP is calculated as an index measuring the deviation from the hypothetical representative firm's TFP for each industry.

[11] The *BSBSA* provides information on the number of overseas affiliates and their industries. However, unfortunately, more detailed information such as sales and employment for these affiliates is not available in the *BSBSA*. In order to obtain such information at the affiliate level, we would have to utilize other databases.

[12] We also used a variable representing firms' cash flow as a proxy for financial constraints instead of the debt-asset ratio. The estimation results were very similar.

variable.[13] In the above specification, the lagged R&D intensity *($RDINT_{it-1}$)* and its interaction term with REER uncertainty *($RDINT_{it-1}$*$EXREERSD_{it}$)* are included as explanatory variables. These variables are endogenously determined and in order to address this endogeneity, we estimate the above equation using system GMM. The instruments used are the second to fourth lags of these variables.[14] The annual REER index is also used as an exogenous instrumental variable.

In addition, in order to investigate the "growth options effect" for a particular type of firms, we add an interaction term of REER uncertainty and the FDI firm dummy (*$EXREERSD_{it}$*FDI_mfg*) as an explanatory variable. If firms with overseas production expect higher future growth opportunities than non-FDI firms, the coefficient of this interaction term will be positive. We also estimate the equation including this interaction term employing fixed-effect panel estimation.

5. Empirical results

Table 2 shows the fixed-effect panel estimation results and Table 3 the system GMM estimation results for the baseline model. As described in Section 3, a substantial number of firms neither export nor import, so that their net currency exposure is zero. Moreover, a substantial number of firms report zero R&D expenditure, so that their R&D intensity is zero. We therefore also estimate the baseline model for various subsamples. Specifically, column (2) in the two tables shows the results for the subsample consisting only of firms that report non-zero exports or imports. Column (3) shows the results for the subsample consisting only of firms that report non-zero R&D expenditure. Finally, column (4) shows the results for the subsample consisting only of firms with at least one manufacturing affiliate abroad.

Starting with the results in Table 2, we find that the lagged R&D intensity

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[13] We drop firms for which the absolute level of the debt-asset ratio variable or the TFP variable falls into the 1st or the 99th percentile. We also drop firms for which the RDINT variable falls into the 99th percentile. Basic statistics (after excluding outliers) for variables used in our analysis are shown in Appendix Table 1.

[14] We also checked whether other explanatory variables such as sales growth and TFP were endogenously determined. The Hansen test of overidentifying restrictions however rejects the specification if we treat other various variables as endogenous.

(L.RDINT) has a positive and statistically significant coefficient, suggesting that R&D is very persistent. The REER uncertainty variable (*EXREERSD*) does not have a statistically significant coefficient in all cases except one. Thus, we do not find evidence of a "growth options effect" where uncertainty encourages R&D investment.

The coefficient on sales growth (*D.lnY*) is negative and significant, which suggests that R&D intensity is negatively associated with sales growth. This result may reflect the fact that R&D expenditure cannot be increased or reduced quickly in response to changes in sales and there is a certain time lag between changes in business conditions and adjustments of R&D expenditure. The interaction term of sales growth and uncertainty (*D.lnY*EXREERSD*) has a significantly negative coefficient. The negative coefficient indicates that under exchange rate uncertainty firms do not increase R&D intensity even when their sales have grown, providing evidence of the existence of a caution effect, meaning that greater uncertainty makes firms more cautious about investing in R&D. However, the coefficient of the interaction term of lagged R&D intensity and uncertainty (*L.RDINT*EXREERSD*) is not statistically significant in most cases, meaning that we find no evidence in favor a delay effect, that is, that greater uncertainty leads firms to delay R&D investment.

Looking at Table 3, we find that while the coefficient on sales growth (*D.lnY*) becomes insignificant, the coefficient on the interaction term of sales growth and uncertainty (*D.lnY*EXREERSD*) remains significantly negative. These results suggest that under high uncertainty R&D investment is less responsive to changes in demand conditions due to the caution effect.

INSERT Tables 2 & 3

Finally, Table 4 shows the estimation results for the specification including the interaction term of REER uncertainty and the FDI firm dummy ($EXREERSD_{it}$*FDI_mfg*) as an additional explanatory variable. The coefficient of this interaction term as well as that of the REER uncertainty variable ($EXREERSD_{it}$) are not statistically significant. We do not find evidence of a "growth options effect" even for firms engaged in overseas production.

INSERT Table 4

6. Conclusion

This study examined how REER uncertainty influences R&D investment. Our results show that firms more exposed to REER uncertainty are less responsive to changes in demand conditions. This pattern with regard to R&D decisions can be explained by real options theory. When uncertainty is high, the value of the option to “wait and see” is high, particularly when investment is irreversible. Under high uncertainty, firms become more cautious in their investment decisions, since high uncertainty increases the chances of making a costly mistake. Due to such a caution effect, firms are less responsive to any given shock.

The contribution of this study to existing literature is at least twofold. First, as mentioned above, the empirical evidence on uncertainty and R&D investment is still scarce and our results add new empirical support to the caution effect of uncertainty. We do not find evidence on a positive relationship between uncertainty and R&D investment suggested by Bloom (2014) and Kraft et al. (2013). In fact, our empirical framework is not directly comparable to the one in Kraft et al. (2013), because they focus on stock value of R&D intensive firms, not focusing on R&D investment itself. Nevertheless, this would be a question which deserves further scrutiny in the future study.

Second, we focus on exchange rate uncertainty, which allows us to obtain an important implication for export promotion policy. The caution effect also increases the persistence of R&D, which implies that R&D investment does not increase much even if firms face favorable demand conditions and their R&D investment growth remains under the optimal rate. This implies that reducing REER uncertainty is important to stimulate R&D investment, especially in the case of firms more exposed to international competition and REER uncertainty.

One way to reduce the degree of uncertainty would be greater efforts by governments and monetary authorities to stabilize currency exchange rates. However, there may be other ways to effectively reduce market uncertainty. First, public and/or private sector banks could actively provide advice to firms on how to hedge risks arising from exchange rate fluctuations. Second, aside from policies which affect exchange rate risks, policies to enhance the patent system and/or R&D subsidies in combination with export promotion maybe required to stimulate both R&D investment and internationalization of firms' activities. While patent system and/or R&D subsidies cannot reduce exchange rate uncertainty itself, they may be able to mitigate the impact of uncertainty. Czarnitzki and Toole (2011), for example, highlight one mechanism through which patents reduce the negative effect of uncertainty on firms' investment decision, while Czarnitzki and Toole (2007) suggest that R&D subsidies mitigate the effect of uncertainty on R&D investment.

Given that the Japanese government pursues policies to promote the internationalization of small and medium-sized firms, policy makers should be aware of the negative effect of REER uncertainty on R&D investment and make every effort to mitigate such uncertainty. At the same time, it is also important to design an incentive system to stimulate R&D investment.

References

Aghion, Philippe, George-Marios Angeletos, Abhijit Banerjee, and Kalina Manova (2010) "Volatility and Growth: Credit Constraints and the Composition of Investment," *Journal of Monetary Economics* 57(3): 246-265.

Aghion, Philippe, Philippe Ashkenazy, Nicolas Berman, Gilbert Cette, and Laurant Eymard (2012) "Credit Constraints and the Cyclicality of R&D Investment: Evidence from France," *Journal of the European Economic Association* 10(5): 1001-1024.

Bachmann, Rüdiger, Steffen Elstner, and Eric R. Sims (2013) "Uncertainty and Economic Activity: Evidence from Business Survey Data," *American Economic Journal: Macroeconomics* 5(2): 217-249.

Berman, Nicolas, Philippe Martin, and Thierry Mayer (2012) "How Do Different Exporters React to Exchange Rate Changes?" *Quarterly Journal of Economics* 127(1): 437-492.

Bloom, Nick. (2007) "Uncertainty and the Dynamics of R&D," *American Economic Review* 97(2): 250-255.

Bloom, Nicolas. (2009) "The Impact of Uncertainty Shocks," *Econometrica* 77(3): 623-685.

Bloom, Nicolas. (2014) "Fluctuations in Uncertainty," *Journal of Economic Perspectives* 28(2): 153-176.

Bloom, Nick, Stephen Bond, and John Van Reenen (2007) "Uncertainty and Investment Dynamics," *Review of Economic Studies* 74(2): 391-415.

Bloom, Nicolas, Max Floetotto, Nir Jaimovich, Itay Saporta-Eksten, and Stephen J. Terry (2012) "Really Uncertain Business Cycles," *NBER Working Paper* 18245, National Bureau of Economic Research.

Carruth, Alan, Andy Dickerson, and Andrew Henley (2000) "What Do We Know about Investment under Uncertainty?" *Journal of Economic Surveys* 14(2): 119-153.

Czarnitzki, Dirk, and Andrew A. Toole (2007) "Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty," *Review of Industrial Organization* 31(3): 169-181.

Czarnitzki, Dirk, and Andrew A. Toole (2011) "Patent Protection, Market Uncertainty, and R&D Investment," *The Review of Economics and Statistics* 93(1): 147-159.

Dixit, Avinash K. (1992) "Investment and Hysteresis," *Journal of Economic Perspectives* 6(1): 107-132.

Dixit, Avinash K., and Robert S. Pindyck (1994) *Investment under Uncertainty*, Princeton, NJ: Princeton University Press.

Ekholm, Karolina, Andreas Moxnes, and Karen Helen Ulltweit-Moe (2012) "Manufacturing Restructuring and the Role of Real Exchange Rate Shocks," *Journal of International Economics* 86(1): 101-107.

Fung, Loretta. (2008) "Large Real Exchange Rate Movements, Firm Dynamics, and Productivity Growth," *Canadian Journal of Economics* 41(2): 392-424.

Goel, Rajeev K. and Rati Ram (2001) "Irreversibility of R&D Investment and the Adverse Effect of Uncertainty: Evidence from the OECD Countries," *Economic Letters* 71(2): 287-291.

Good, David H., M. Ishaq Nadiri, and Robin C. Sickles (1997) "Index Number and Factor Demand Approaches to the Estimation of Productivity," in H. Pesaran and P. Schmidt, eds., *Handbook of Applied Econometrics: Microeconomics*, 14-80, Oxford: Blackwell.

Grassi, Emanuele, and Marco Di Cintio (2016) "Uncertainty, Flexible Labour Relations and R&D Expenditure," *Metroeconomica*, forthcoming.

Kraft, Holger, Eduardo S. Schwartz, and Farina Weiss (2013) "Growth Options and Firm Valuation," *NBER Working Paper* 18836, National Bureau of Economic Research.

McDonald, Robert, and Daniel Siegel (1986) "The Value of Waiting to Invest," *Quarterly Journal of Economics* 101(4): 707-727.

Minton, Bernadette A., and Catherine Schrand (1999) "The Impact of Cash Flow Volatility on Discretionary Investment and the Costs of Debt and Equity Financing," *Journal of Financial Economics* 54(3): 423-460.

Morikawa, Masayuki. (2013) "What Type of Policy Uncertainty Matters for Business," *RIETI Discussion Paper Series* 13-E-076, Research Institute of Economy, Trade and Industry.

Pindyck, Robert S. (1991) "Irreversibility, Uncertainty, and Investment," *Journal of Economic Literature* 29(3): 1110-1148.

Vannoorenberghe, G. (2014) "International Trade, Risk Taking and Welfare," *Journal of International Economics* 92(2): 363-374.

Figure 1. Real effective exchange rate of the Japanese yen

Figure 2. Real effective exchange rate fluctuations for major developed countries

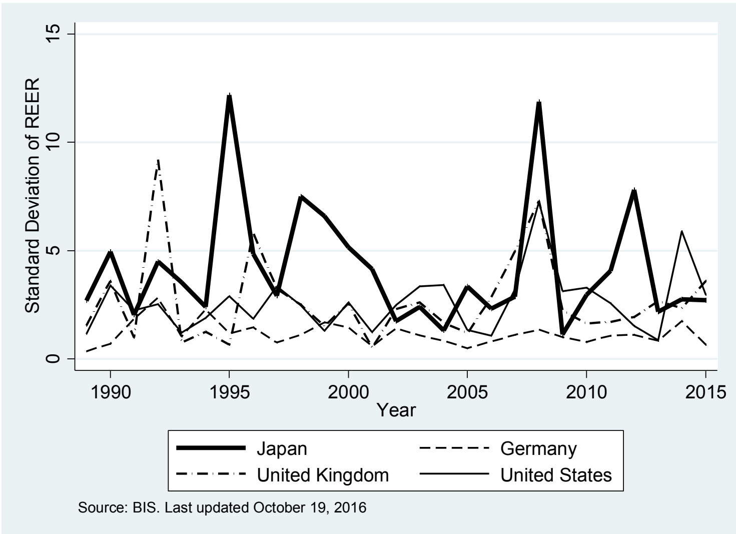

Figure 3. Annual average R&D intensity by firm type

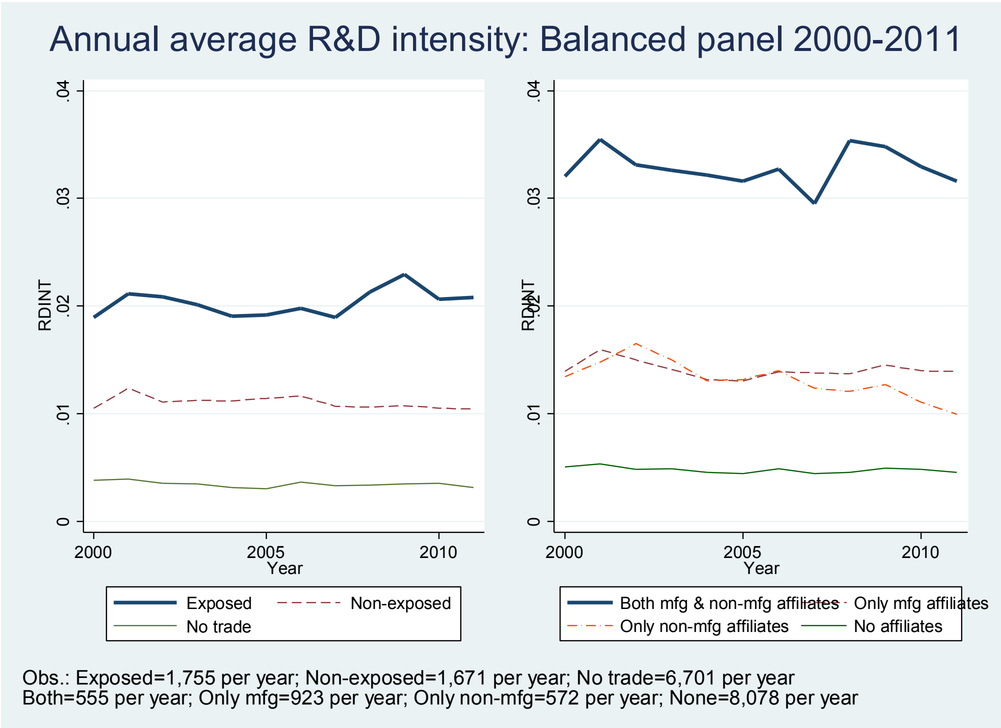

Table 1. Descriptive statistics by industry (Year=2005)

Industry	No. of firms	share (%)	R&D firms as a share of firms (%)	Exporters as a share of firms (%)	Importers as a share of firms (%)	No traders as a share of firms (%)	FDI firms as a share of firms (%)	Gross currency exposure: Exporters' exports-sales ratio (%)	Gross currency exposure: Importers' imports-purchases ratio (%)	Net currency exposure: EXPINT-IMPINT (%)
1 Food products and beverages	1,326	12.1	47.7	9.9	13.2	82.4	9.1	4.0	16.2	-9.9
2 Textiles	450	4.1	36.7	18.7	28.0	68.0	19.3	6.2	19.8	-13.7
3 Lumber and wood products	237	2.2	43.0	11.8	38.8	58.6	13.9	3.5	25.0	-22.5
4 Pulp, paper and paper products	328	3.0	29.9	14.3	15.5	77.4	12.2	5.9	12.4	-4.8
5 Printing	510	4.6	13.1	7.6	6.3	89.8	5.5	3.2	3.6	0.2
6 Chemicals and chemical fibers	239	2.2	77.4	49.8	38.1	45.6	32.6	13.0	15.0	1.4
7 Paint, coating, and grease	121	1.1	82.6	52.1	43.0	43.0	34.7	11.5	9.1	3.7
8 Pharmaceutical products	198	1.8	87.4	48.5	48.5	36.4	15.2	5.8	26.3	-15.7
9 Miscellaneous chemical products	233	2.1	86.7	63.1	45.5	32.6	29.2	10.5	11.8	1.9
10 Petroleum and coal products	46	0.4	73.9	60.9	58.7	28.3	15.2	5.8	44.9	-31.8
11 Plastic products	606	5.5	43.9	30.7	27.7	63.2	27.1	8.9	14.6	-3.5
12 Rubber products	137	1.2	54.7	43.8	42.3	48.9	31.4	11.6	17.3	-4.4
13 Ceramic, stone and clay products	406	3.7	46.8	20.9	19.5	72.2	13.1	10.5	22.4	-7.8
14 Iron and steel	358	3.3	35.2	22.6	14.0	72.1	17.9	7.5	15.1	-1.5
15 Non-ferrous metals	272	2.5	51.1	42.6	30.5	51.8	25.7	9.1	15.5	-1.8
16 Fabricated metal products	833	7.6	45.3	28.1	21.6	66.3	18.8	8.7	15.0	-2.4
17 Metal processing machinery	215	2.0	58.6	59.1	39.5	37.2	24.2	19.0	12.0	10.3
18 Special industry machinery	368	3.3	58.7	50.5	38.0	43.8	21.5	24.4	9.4	15.6
19 Office and service industry machines	118	1.1	65.3	36.4	38.1	50.0	22.9	13.1	13.9	-1.0
20 Miscellaneous machinery	664	6.0	52.1	50.8	39.5	42.6	28.8	12.1	13.3	1.6
21 Electrical machinery and apparatus	358	3.3	51.7	36.6	36.3	55.0	22.3	12.3	11.3	0.9
22 Household electric appliances	113	1.0	54.9	36.3	38.9	53.1	25.7	12.0	23.5	-10.3
23 Communication equipment	206	1.9	63.6	43.2	42.2	49.0	26.2	16.2	20.9	-3.5
24 Computer and electronic equipment	181	1.6	64.1	46.4	47.5	42.5	22.1	20.9	18.5	1.6
25 Electronic parts and devices	593	5.4	49.2	44.5	39.3	50.1	29.5	22.6	23.5	1.6
26 Miscellaneous electrical machinery	216	2.0	65.7	48.6	36.1	44.9	22.7	18.7	13.2	7.8
27 Motor vehicles and parts	814	7.4	45.1	36.9	28.1	59.2	34.2	11.1	8.6	4.1
28 Other transportation equipment	208	1.9	46.2	40.4	35.6	51.9	20.7	29.3	12.7	15.2
29 Precision machinery	329	3.0	66.0	63.2	51.1	30.7	24.6	19.0	20.4	2.3
30 Miscellaneous mfg. industries	310	2.8	56.8	42.3	43.2	45.5	23.2	12.6	21.0	-6.9
Total	10,993	100.0	49.8	33.4	29.7	59.2	21.2	13.4	16.3	-0.9

Notes: R&D firms are firms that report non-zero R&D expenditure. No traders are firms that neither export nor import. FDI firms are firms that have at least one manufacturing affiliate or subsidiary abroad.

Table 2. Exchange rate fluctuations and R&D investment

Dependent variable: RDINT (R&D expenditure / Sales)

	(1)	(2)	(3)	(4)
VARIABLES	All firms	EXP or IMP firms	R&D firms	FDI mfg firms
L.RDINT	0.446***	0.399***	0.415***	0.436***
	(0.00862)	(0.0115)	(0.00892)	(0.0152)
D.lnY	-0.00329***	-0.00559***	-0.00732***	-0.00627***
	(0.000171)	(0.000359)	(0.000333)	(0.000455)
EXREERSD	0.000124**	0.00008	0.000131	0.00004
	(0.00006)	(0.00007)	(0.00010)	(0.000117)
L.RDINT*EXREERSD	0.00540	0.00472	0.00345	0.00918*
	(0.00428)	(0.00481)	(0.00436)	(0.00534)
D.lnY*EXREERSD	-0.00141***	-0.00118***	-0.00180***	-0.00183***
	(0.000250)	(0.000257)	(0.000349)	(0.000424)
DARATIO	-0.00148***	-0.00249***	-0.00278***	-0.00312***
	(0.000342)	(0.000846)	(0.000679)	(0.00104)
lnTFP	-0.00103***	-0.00171***	-0.00196***	-0.000594
	(0.000284)	(0.000609)	(0.000535)	(0.000794)
FDI_mfg	0.00009	0.000294	-0.00002	
	(0.000162)	(0.000251)	(0.000231)	
IMP	0.000255**	-0.00005	0.000001	0.000386
	(0.000123)	(0.000226)	(0.000171)	(0.000251)
EXP	0.000635***	0.000413*	0.000472***	0.000556**
	(0.000119)	(0.000246)	(0.000171)	(0.000244)
Firm fixed effects	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Observations	154,719	52,549	77,409	30,469
R-squared	0.210	0.175	0.215	0.208
Number of firms	18,244	8,152	10,913	4,167

Notes: Values in parentheses are standard errors clustered by firm.

*** p<0.01, ** p<0.05, * p<0.1.

Table 3. Exchange rate fluctuations and R&D investment (System GMM estimation results)

Dependent variable: RDINT (R&D expenditure / Sales)

VARIABLES	(1) All firms	(2) EXP or IMP firms	(3) R&D firms	(4) FDI_mfg firms
L.RDINT	0.236***	0.210***	0.239***	0.190***
	(0.0332)	(0.0440)	(0.0352)	(0.0573)
D.lnY	0.00342	-0.00400	0.000477	0.00796
	(0.00813)	(0.00857)	(0.00893)	(0.0135)
EXREERSD	-0.000640	-0.00118	-0.00315	0.000977
	(0.00251)	(0.00236)	(0.00232)	(0.00268)
L.RDINT*EXREERSD	0.0152	0.0258	0.0675	-0.0323
	(0.0505)	(0.0472)	(0.0456)	(0.0537)
D.lnY*EXREERSD	-0.00545**	-0.00449*	-0.00591**	-0.00859***
	(0.00242)	(0.00236)	(0.00268)	(0.00324)
DARATIO	-0.0298	-0.0280	-0.0254	-0.0127
	(0.0323)	(0.0331)	(0.0320)	(0.0373)
lnTFP	-0.0468**	-0.0444**	-0.0528**	-0.0548**
	(0.0213)	(0.0220)	(0.0233)	(0.0277)
IMP	0.0111	0.00758	0.0105	0.0131
	(0.00752)	(0.00875)	(0.00735)	(0.00965)
EXP	0.0105	-0.00254	0.00838	0.0110
	(0.00995)	(0.0109)	(0.0106)	(0.0139)
FDI_mfg	0.0109	0.0147	0.0154	
	(0.0129)	(0.0139)	(0.0129)	
AR(1) (p-value)	0.000	0.000	0.000	0.000
AR(2) (p-value)	0.319	0.205	0.434	0.874
Overid. (Hansen) (p-value)	0.162	0.092	0.366	0.832
Observations	128,459	47,141	65,233	26,337
Number of firms	16,073	7,435	9,694	3,809

Notes: One-step coefficients and standard errors robust to autocorrelation and heteroscedasticity are reported.

A full set of year dummies is included in all specifications.

*** p<0.01, ** p<0.05, * p<0.1.

Table 4. Exchange rate fluctuations and R&D investment: Growth options effect

Dependent variable: RDINT (R&D expenditure / Sales)

VARIABLES	(1) All firms	(2) EXP or IMP firms	(3) R&D firms
L.RDINT	0.446***	0.399***	0.415***
	(0.00862)	(0.0115)	(0.00892)
D.lnY	-0.00329***	-0.00559***	-0.00732***
	(0.000171)	(0.000359)	(0.000333)
EXREERSD	0.000101	0.0001	0.000103
	(0.00007)	(0.00007)	(0.000105)
EXREERSD*FDI_mfg	0.00006	-0.00003	0.00006
	(0.000121)	(0.000130)	(0.000155)
L.RDINT*EXREERSD	0.00525	0.00479	0.00335
	(0.00437)	(0.00490)	(0.00443)
D.lnY*EXREERSD	-0.00141***	-0.00119***	-0.00179***
	(0.000253)	(0.000260)	(0.000353)
DARATIO	-0.00148***	-0.00249***	-0.00278***
	(0.000342)	(0.000846)	(0.000679)
lnTFP	-0.00103***	-0.00171***	-0.00195***
	(0.000284)	(0.000610)	(0.000535)
IMP	0.000252**	-0.00005	-0.000002
	(0.000123)	(0.000226)	(0.000171)
EXP	0.000637***	0.000411*	0.000474***
	(0.000119)	(0.000247)	(0.000171)
FDI_mfg	0.00009	0.000297	-0.00002
	(0.000162)	(0.000251)	(0.000231)
Firm fixed effects	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes
Observations	154,719	52,549	77,409
R-squared	0.210	0.175	0.215
Number of firms	18,244	8,152	10,913

Notes: Values in parentheses are standard errors clustered by firm.

*** p<0.01, ** p<0.05, * p<0.1.

Appendix Table 1. Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min.	Max.
RDINT	201,636	0.0088	0.0176	0	0.1151
L.RDINT	169,993	0.0091	0.0179	0	0.1151
D.lnY	171,708	0.0003	0.2096	-4.7395	5.9971
EXREERSD	203,672	-0.0044	0.6822	-11.7415	11.7407
L.RDINT*EXREERSD	169,992	0.0011	0.0211	-0.9042	0.8271
D.lnY*EXREERSD	171,707	0.0004	0.1866	-17.0589	9.0777
DARATIO	197,821	0.6664	0.2356	0.1018	1.4051
lnTFP	190,547	0.0589	0.1685	-0.3662	0.7292
FDI_mfg	203,673	0.1844	0.3878	0	1
IMP	203,673	0.2259	0.4182	0	1
EXP	203,673	0.2617	0.4395	0	1

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DISCUSSION PAPER No.140

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2017年2月

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Exchange Rate Uncertainty and R&D Investment: Evidence from Japanese Firms

February 2017

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http://doi.org/10.15108/dp140

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