Ivus, Olena; Wajda, Joanna

Book

Fluctuations in uncertainty and R&D investment

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Centre for International Governance Innovation

67 Erb Street West
Waterloo, ON, Canada N2L 6C2
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About the Authors

Olena Ivus joined CIGI's Global Economy Program in April 2016, focusing on the innovation and trade research theme. Her research explores the interface between Canada's domestic innovation and international trade.

Olena is associate professor of business economics at Queen's University's Smith School of Business in Kingston, Ontario. Prior to joining Queen's, she was assistant professor at the University of Prince Edward Island and attended as a visiting researcher at the Institute of Economic Research at Hitotsubashi University in Japan.

Olena holds a Ph.D. in economics from the University of Calgary.

Joanna Wajda is a CIGI research associate in the Global Economy Program. She holds a B.A. from the Honours Arts and Business (Economics) Program at the University of Waterloo and an M.A. in economics from the University of Toronto.

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With experts from academia, national agencies, international institutions and the private sector, the Global Economy Program supports research in the following areas: management of severe sovereign debt crises; central banking and international financial regulation; China's role in the global economy; governance and policies of the Bretton Woods institutions; the Group of Twenty; global, plurilateral and regional trade agreements; and financing sustainable development. Each year, the Global Economy Program hosts, co-hosts and participates in many events worldwide, working with trusted international partners, which allows the program to disseminate policy recommendations to an international audience of policy makers.

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Acronyms and Abbreviations

BERD	business enterprise expenditure on R&D
G20	Group of Twenty
GERD	gross domestic expenditures on R&D
IEEE	Institute of Electrical and Electronics Engineers
IMF	International Monetary Fund
IPRs	intellectual property rights
MSTI	Main Science and Technology Indicators
NPEs	non-performing entities
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
SEPs	standard-essential patents

Executive Summary

Efforts at stimulating economic growth are shifting away from factor inputs as governments seek to establish an innovation-friendly environment. This paper investigates the effect of macro uncertainty on research and development (R&D). Against that background, it discusses what the Group of Twenty (G20) and its member states can do in this regard to facilitate increased innovation. Using data on 30 countries covering 1982–2012, the relationship between fluctuations in macro uncertainty and R&D growth is studied. The analysis shows that increased macro uncertainty is associated with lower R&D growth, and that business enterprise expenditure on R&D (BERD) appears to be the leading culprit for lower expenditure during times of higher uncertainty. Regression analysis that accounts for potential endogeneity due to country-specific fixed effects further highlights that R&D may be less susceptible to some measures of uncertainty — such as cross-firm daily stock return spread, which may reflect the potential for higher than normal gains — and more susceptible to others — such as exchange rate daily volatility. In particular, R&D performed by industry does appear to suffer lower growth in the face of greater uncertainty, and there is no evidence that R&D financed by government is growing at a faster rate in such periods to combat the disincentives of investing under uncertainty. Several explanations and mitigating factors are discussed. The analysis underscores the importance for the G20 and its member countries to reduce uncertainty. One way of achieving this is by being clear in their intentions surrounding future policy and establishing effective, consistent and predictable patent regimes. The effect of uncertainty on innovation can be further minimized by pursuing R&D tax credit incentives and streamlining applicable government programs; during times of high uncertainty, a more aggressive innovation agenda should be pursued.

Introduction

The importance of innovation to economic growth and prosperity is now undeniable. In order to foster an economic climate that is conducive to innovation, governments shift economic policy from factor-driven modes (focused on labour and other resources) to more innovation-driven approaches (focused on development of new products and processes). This is no easy task for policy makers. The future is not certain and strategies aimed at promoting innovation largely rely on assumptions. For this reason, sound innovation policy must be sufficiently flexible to allow for rapid and unexpected changes in economic conditions. Further complicating matters is the fact that economic conditions, incentives for innovation, and the nature and extent of uncertainty do not operate in isolation but, rather, interdependently. Understanding the interdependence of these variables is central to crafting and implementing effective innovation policy.

This paper examines two key questions:

→ How does macro uncertainty affect R&D?

→ How can the G20 organization and its members foster an environment for innovation in times of uncertainty?

To answer these questions, the paper first explores possible reasons for a relationship between uncertainty and R&D investment, relying on the theoretical literature and empirical studies of R&D investment under uncertainty. Next, the paper establishes the statistical link between fluctuations in uncertainty and R&D growth across 30 countries over the period 1982–2012. The data used covers five different proxies for uncertainty (stock index daily returns volatility, cross-firm daily stock return spread, sovereign bond yields daily volatility, exchange rate daily volatility and GDP forecast disagreement) and relates each of these measures to three types of R&D expenditure (gross domestic expenditure on R&D [GERD], BERD and government-financed gross domestic expenditures on R&D).[1] An investigation of a

1 The sample covers 15 of the 19 individual G20 member countries, and 19 of the 28 EU member countries, for which the measures of uncertainty and R&D are available. These countries are listed in Table 1.

causal relationship using the within estimator is then performed on the same data, including one uncertainty proxy as an explanatory variable at a time. In conclusion, the paper discusses the role of policy makers in supporting innovation and the impact of macro uncertainty on the effectiveness of governments' innovation policies.

Literature Review

The theoretical literature of investment under uncertainty posits that uncertainty might reduce firm growth in R&D and provides several explanations. The classic argument is provided by the real-options investment theory, in which uncertainty about market revenue reduces firm investment into irreversible capital because it increases the option value of delay (Pindyck 1991; Dixit 1992; Dixit and Pindyck 1994; Bond and Lombardi 2006). In this framework, firms' investment opportunities are treated as "real options." A company with an opportunity to invest chooses whether to "exercise" its option today, or else delay. The option value of delay is high when uncertainty about business conditions is high. The option effects are particularly important for investment in R&D because investment decisions have high irreversibility. In the event R&D projects fail, a large portion of their R&D costs (for example, hiring research personnel, purchasing project equipment and so on) are unrecoverable. Consequently, when market uncertainty is high, companies are cautious about investing in R&D, and business R&D expenditure correspondingly falls.

Andrew B. Abel et al. (1996) also view investment decisions as involving the acquisition or exercise of options but emphasize that options do not always reduce the incentive for current investment. Whether the current incentive to invest rises or falls when future returns are uncertain depends on the relative strength of the two options: the reversibility option and the expandability option. The reversibility option increases current investment. It arises if the firm can disinvest at some point in the future, and the firm acquires this option by purchasing capital that it may later resell. The expandability option, on the other hand, decreases current investment when future returns are uncertain. The expandability option arises if the firm can continue to invest at some point in the future, and the firm acquires this option by delaying investment. Which option dominates will depend on the nature of investment. For R&D investment, the reversibility option is extremely small — because R&D investment is largely irreversible — but the expandability option is high. Consequently, the current incentive to invest in R&D is expected to fall when future returns are uncertain.

Rajeev K. Goel and Rati Ram (2001) have assessed empirically the effects of uncertainty on investment and studied how these effects differ in the degree of investment irreversibility. Using annual data for nine Organisation for Economic Co-operation and Development (OECD) countries from 1981 to 1992 and two inflation-based measures of uncertainty, the authors found that R&D investments are more adversely impacted by uncertainty, when compared to non-R&D investments. These results suggest that a higher degree of irreversibility heightens the negative effect of uncertainty.

The relative strength of the expandability option will also depend on the investors' expectations about the future investment cost. Abel et al. (1996) emphasize that delay is costly if the price of investment is expected to rise in the future. The expected increase in the investment price reduces the value of the expandability option, and so attenuates the negative effect of market uncertainty on the current incentive to invest in R&D.

Another important consideration relevant to the incentive to invest in R&D is the intensity of competition in the post-innovation market. If firms compete aggressively for the discovery of a product or the race for a patent, then delay is costly, which weakens the negative effect of the expandability option on the current incentive to invest in R&D. Dirk Czarnitzki and Andrew A. Toole (2013) provide the firm-level evidence in support of this conclusion. Using data on 870 innovative firms in the German manufacturing sector between 1995 and 2001 and a firm-specific proxy of market uncertainty measured by the coefficient of variation of past sales, the authors find that firms' current investment in R&D falls as uncertainty about market returns rises. Importantly, the negative association between market uncertainty and R&D investment is relatively weak in concentrated markets and markets with a small number of competitors, where strategic rivalry is intense, for example, in the pharmaceutical industry. The negative effect of uncertainty on R&D investment is also relatively weak for large firms, even after controlling for potential financial constraints and access to financing. One possible explanation is that the reversibility option is less costly for large firms, since large firms have greater flexibility in transferring R&D assets to other R&D projects or in redeploying R&D assets to alternative uses within the firm.

It is also important to recognize that R&D investments can take several years to show a return. Such investment lags offset uncertainty and weaken (and, in some cases, reverse) their negative effect on R&D investment (Bar-Ilan and Strange 1996). The reasoning is as follows: When a firm delays investment, it avoids a bad outcome of innovation turning into a disaster. Uncertainty increases the likelihood of "bad news" and so also increases the benefit of delay. But uncertainty also increases the likelihood of "good news" and with that, the opportunity cost of delay, which are the forgone profits in the event the innovation turns into a success. When investment lags are long, the likelihood of extreme outcomes is high but the firm's profit in a bad case is bounded from below (as long as the firm can cancel the project and recover a portion of its R&D cost), while its profit in a good state is not bounded from above. The expected profit from the innovation rises with greater uncertainty as a result, and thus uncertainty can spur R&D investment.

The evidence provided in Gill Segal, Ivan Shaliastovich and Amir Yaron (2015) underscores the importance of decomposing aggregate economic uncertainty into "good" and "bad" volatility components, associated with positive and negative shocks to macroeconomic variables (for example, output, consumption, investment and R&D).[2] Using annual data from 1954 to 2008, the authors find that good uncertainty positively predicts future growth in output, consumption, investment and R&D, while bad uncertainty negatively predicts growth in these macro variables. The response of R&D investment to these shocks is particularly strong. R&D investment increases by about 0.7 percent after one year due to a good uncertainty shock and remains positive until about five years out, while it drops by about 1.1 percent one year after a bad uncertainty shock and becomes positive after the second year. The response of R&D investment to overall uncertainty is less pronounced, which is expected, given that good and bad uncertainty tend to move together but have opposing effects on R&D investment.

If economic agents face uncertainty about future outcomes but do not know how to assign probabilities to each possible outcome, they will respond to uncertainty in accordance with their beliefs: agents with pessimistic beliefs will overestimate the probability of the worst outcome, while agents with optimistic beliefs will overestimate the probability of the best outcome. Consequently, optimism will attenuate the negative impact of uncertainty on current R&D investment. Existing research finds that CEOs are optimistic and overconfident, and that CEO optimism significantly influences R&D project values and plays an important role in the innovation process (see, for example, Giat, Hackman and Subramanian 2010; Campbell et al. 2011; Chen and Lin 2012; Malmendier and Tate 2005; 2008).

Description of Uncertainty Proxy and R&D Investment Data

The analysis in this paper uses data from two sources: the uncertainty measures from Scott R. Baker and Nicholas Bloom (2013), and the R&D measures from the OECD Main Science and Technology Indicators (MSTI) (OECD 2016). These two data sets are merged and the sample is limited to the G20 countries.[3] The merged data set covers 30 countries — 15 (of the 19) individual G20 member countries and 19 (of the 28) EU member countries — over the period 1981–2012. Table 1 provides a breakdown of the countries and years included in the unbalanced (for some countries, the data is not available in every year) data set of 790 observations, from which R&D growth variables are calculated.

2 The authors cite the high-tech revolution of the early to mid-1990s as an example of "good" uncertainty and the recent collapse of Lehman Brothers in the fall of 2008 as an example of "bad" uncertainty.

3 The countries that comprise the G20 are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, the Republic of Korea, Turkey, the United Kingdom, the United States and the European Union.

Table 1: Country Coverage

Country	Earliest Year in Data Set	Latest Year in Data Set	Number of Observed Years
Argentina*	1996	2012	17
Australia*	1981	2011	30
Austria	1981	2012	32
Belgium	1981	2012	31
Canada*	1981	2012	32
China*	1992	2012	21
Czech Republic	1995	2012	18
Denmark	1981	2012	30
Finland	1981	2012	31
France*	1981	2012	32
Germany*	1981	2012	32
Greece	1981	2012	26
Hungary	1991	2012	22
Ireland	1981	2012	32
Italy*	1981	2012	32
Japan*	1981	2012	32
Republic of Korea*	1991	2012	22
Luxembourg	2000	2012	11
Mexico*	1989	2012	24
Netherlands	1981	2012	32
Poland	1995	2012	18
Portugal	1982	2012	31
Romania	1991	2012	22
Russia*	1989	2012	24
South Africa*	1983	2012	18
Spain	1981	2012	32
Sweden	1981	2012	21
Turkey*	1990	2012	23
United Kingdom*	1981	2012	30
United States*	1981	2012	32

Data source: Based on merged data set from Baker and Bloom (2013) and OECD (2016).

* Denotes individual G20 member countries.

Table 2: Uncertainty Proxies

Proxy	Source	Underlying Data	Frequency of Underlying Data
Stock index daily returns volatility	Global Financial Database	General stock market index normalized by country-level consumer price index	Daily where possible, weekly or monthly otherwise
Cross-firm daily stock return spread	Wharton Research Data Services international equity database	Returns of 10 or more listed firms	Daily
Sovereign bond yields daily volatility	N/A	10-year government bond yield rates	Daily
Exchange rate daily volatility	Global Financial Database	Percentage change of exchange rates relative to the US dollar	Daily
GDP forecast disagreement	Consensus forecast database	One year ahead of 10 or more GDP growth forecasts	Quarterly

Data source: Baker and Bloom (2013).

There are several measures of uncertainty in the literature. In the analysis, five different proxies are used for uncertainty: sovereign bond yields daily volatility; exchange rate daily volatility; stock index daily returns volatility; cross-firm daily stock return spread; and GDP forecast disagreement. The first two measures — sovereign bond yields daily volatility and exchange rate daily volatility — are proxies for macro uncertainty. The volatility of sovereign bond yields may increase due to higher dispersion in market expectations of future probability of default, interest rates, inflation or general economic conditions. Uncertainty regarding expectations about the value of the national currency, or the US dollar, will affect exchange rate volatility. The next two measures — stock index daily returns volatility and cross-firm daily stock return spread — reflect both macro and micro stock volatility. Last, the GDP forecast disagreement measure is a proxy for uncertainty about business conditions, as greater volatility implies greater disagreement among experts about future growth.

Availability of each measure by country varies. Stock index daily returns volatility and exchange rate daily volatility have the greatest coverage across the sample of 790 country-year observations, close to 99 percent; and the span of GDP forecasts has the lowest, only 33.5 percent. The proxies are constructed as shown in Table 2.[4]

Each of the uncertainty measures is related to GERD, which is an input measure of innovative activities. An alternative approach is to use an output measure, such as patent counts or patent applications, but a key concern with this approach in this context is that the return from R&D investment might confound the link between uncertainty and innovation. This is because patentable outcomes are not guaranteed, are likely to come to fruition years after initial investments and cannot be traced back to the conditions that existed when decisions were made.

The R&D measures are reported in units of millions of constant US dollars using purchasing power parity conversion. They come from retrospective surveys of the business units responsible for R&D projects (including those in the natural sciences, engineering, and social sciences and humanities fields) carried out on national territory. As such, they will not reveal directly whether firms operating internationally are shifting their R&D operations from one country to another in the

4 The measures are available quarterly and reflect activity over the last four quarters. In order to match the timing of the annual R&D measures, the observations for the last quarter in every year are used; these reflect activity over the entire calendar year.

Table 3: GERD Percentage by Funding Sector and Performance Sector

By Funding Sector	Government	Industry	Other National Sources	Rest of the World
Full sample	41%	49%	3%	7%
1981*	51%	45%	2%	3%
2012*	33%	53%	4%	10%

By Performance Sector	Government	Industry	Higher Education	Private Non-enterprise
Full sample	18%	57%	23%	2%
1981*	25%	53%	21%	2%
2012*	11%	62%	26%	1%

* Limited sample of 16 countries with GERD funding sector and performance sector data available for 1981 and 2012 (Australia, Austria, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, the Netherlands, Spain, Sweden, the United Kingdom and the United States).

sample. The MSTI data set does provide statistics on R&D expenditure financed from abroad, but the country of origin for financing is not available. While the analysis spans G20 countries, it focuses on within-country effects, and does not discuss whether changes in uncertainty in one country may be affecting R&D expenditure elsewhere.

The MSTI data set includes data on the percentage of GERD by funding and performance sectors. Table 3 presents the percentage of GERD funded by government, industry, other national sources and the rest of the world and the percentage of GERD performed by government, industry (BERD), higher education and private non-profit. The first row of each panel contains the average across all countries and years; the bottom two rows contain the average across countries for the first and last year in the sample, limited to the 16 countries with data availability for both years.

The GERD data reveals that while the percentage of expenditures funded by the industry or the government varies across years and countries, government financing forms a significant portion of domestic R&D, 41 percent on average, with industry financing accounting for 49 percent on average.[5] Across the countries in the data set, the average percentage of GERD financed by the government has been falling over time, while the percentage funded by each of the other sources has been increasing.

Moving from funding sector to performance sector, industry is the most significant performer of R&D in the data set, at 57 percent of GERD on average, followed by higher education at 23 percent and government at 18 percent. As both funders and performers, government has become proportionately less involved and industry more involved.

R&D performed by industry, or BERD, includes R&D by both public and private enterprises and institutions that serve them. In large part, this measure will capture the responses of firms to changing uncertainty, but it will also be affected by the availability of government funding. While government financing frequently outpaced that of industry in domestic R&D, the percentage of BERD financed by industry is consistently larger than the percentage financed by government across countries and years (with the exception of Russia). In the sample, industry financed 82 percent of BERD on average, and government financed only 11 percent.

Given these patterns, the graphical analysis focuses mainly on two GERD components: BERD and government-financed GERD. As BERD is determined by sector of performance, and government-financed GERD is determined by source of funds, some overlap exists between the two. In the regression analysis, separate regressions were run for each type of GERD by financing

5 The remainder is funded by "other national sources" and "rest of the world."

and performing sector. Regressions of GERD and BERD on the current and three most recent lagged uncertainty proxies were also performed, but most coefficients on lagged variables are not statistically significant, and the conclusions based on the current period explanatory variables remain qualitatively unchanged.

Empirical Analysis

Figure 1 plots the five proxies for uncertainty against R&D growth quintiles.[6] The three graphs differ in the measure of R&D: it is GERD in Figure 1a, BERD in Figure 1b and government-financed GERD in Figure 1c. For each R&D measure, the growth rates in R&D are calculated as first differences in the logs of R&D, which approximate annual percentage growth rates. Country-year observations of the growth rates are then sorted into quintiles based on each country's own distribution. Annual R&D growth rates are lowest in the first quintile and rise as the quintile number rises. The y-axis shows the average normalized uncertainty measure (average number of deviations from the mean) of the country-year pairs in each quintile bin. The uncertainty measures are normalized so that they have a mean of zero and standard deviation of one and, hence, are expressed in average deviations from the full-sample mean.

The association between quintiles of R&D growth and normalized uncertainty measures is similar for GERD and BERD (Figures 1a and 1b), but not for government-financed GERD (Figure 1c). Greater uncertainty is associated with lower growth in both GERD and BERD, but the association between fluctuations in uncertainty and growth in government-financed GERD is noisy and depends on the measure of uncertainty. As such, the negative association between growth in GERD and fluctuations in uncertainty is largely a result of BERD growth falling when uncertainty is rising. This finding is important as it suggests that in order to understand why fluctuations in uncertainty might matter for R&D growth, the focus should be on growth in BERD.

In addition to BERD, consideration of government-financed R&D expenditure is also important, since government subsidies and credits may play a significant role in determining the level of R&D spending. Two cases in particular stand out: where subsidies and credits increase in recessions, which are contemporaneous with greater uncertainty, and where government financing for R&D expenditures remains at a fixed level but makes up a significant source of R&D funding. In fact, the pattern in Figure 1c suggests that the level of government-financed R&D is not strongly associated with changes in uncertainty, while additional analysis shows that government-financed GERD intensity (as a percentage of GDP) is positively correlated with higher uncertainty, suggesting that the latter case is more likely.

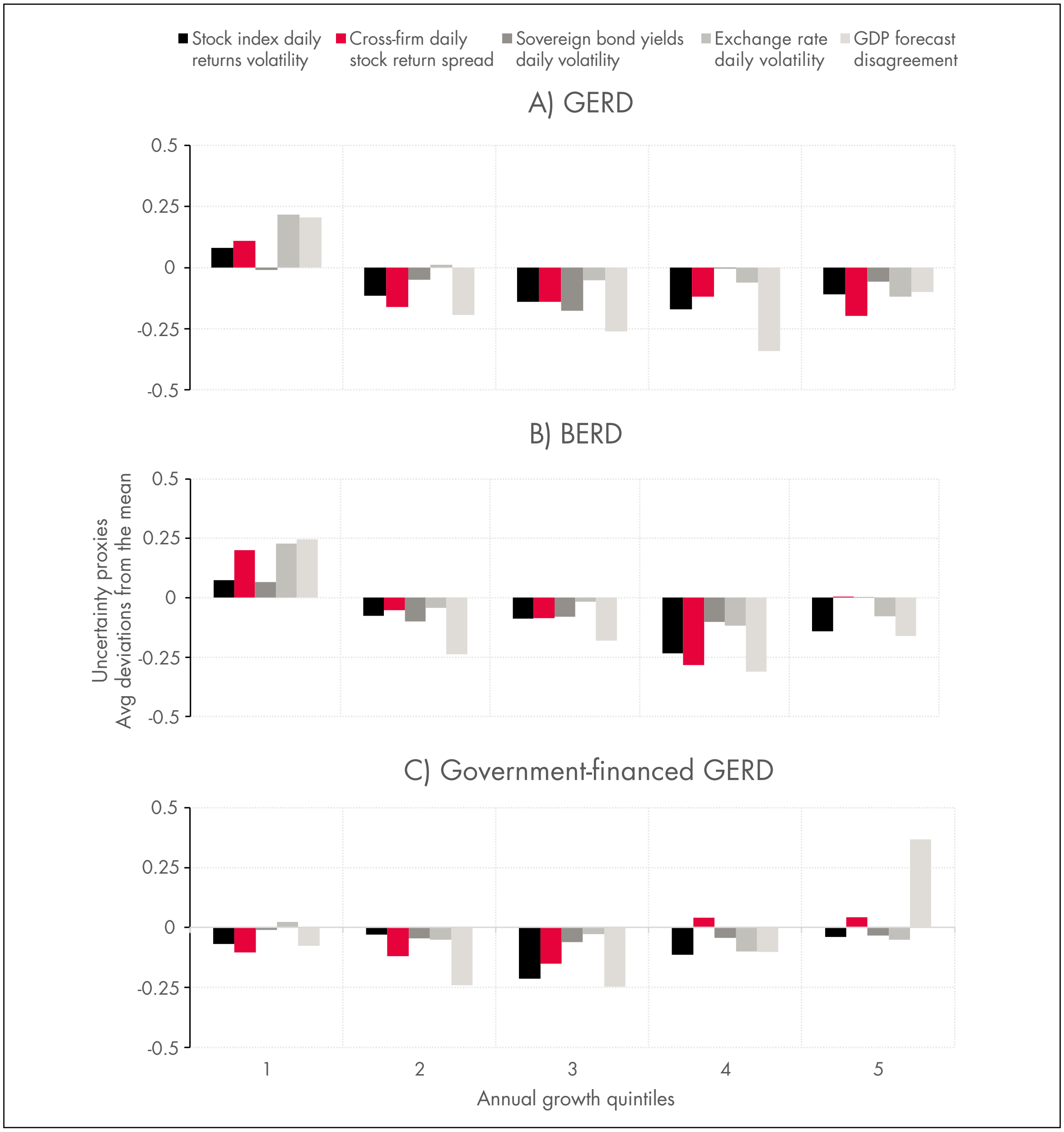
Further analysis along these lines looks at the intensity of GERD, BERD and government-financed GERD (where intensity is R&D as a percentage of GDP). This is done to ensure results are not unduly driven by the positive association between R&D expenditure and the level of economic activity (larger countries spend more on R&D). A weak correlation is found between uncertainty and R&D intensity for GERD and BERD, driven by lower growth in both the R&D measures and GDP when there is higher uncertainty, but a positive correlation is found between uncertainty and government-financed GERD intensity. This additional analysis further highlights the disparity in the extent to which BERD and government-financed GERD are correlated with uncertainty.

Moving from the graphical analysis to regressions, the effect of uncertainty on R&D investment is estimated using the within estimator, which controls for country-fixed effects to mitigate the endogeneity concern.[7] The same unbalanced panel data is used for the regressions as for Figure 1, where the uncertainty proxies are standardized across the whole sample, and R&D growth is calculated using log differences. Thus, the coefficient estimates are the average effect of an increase of one standard deviation in the uncertainty proxy on R&D growth.

6 To construct Figure 1, the methodology behind Figure 1 in Baker and Bloom (2013) was followed. The key difference is that Figure 1 in this paper relates uncertainty to annual R&D growth quintiles, while Figure 1 in Baker and Bloom (2013) relates uncertainty to annual GDP growth deciles.

7 Time-fixed effects and cluster standard errors by country are also included.

Figure 1: Relationship with Uncertainty of GERD, GERD Performed by Industry (BERD) and GERD Financed by Government



Source: Authors' own calculations using data from Baker and Bloom (2013) and OECD (2016).

Notes: Annual growth rates are calculated as first differences in the log of GERD in Figure 1a; first differences in the log of BERD in Figure 1b; and first differences in the log of government-financed GERD in Figure 1c. GERD, BERD and government-financed GERD are in millions constant US dollars. Observations are then sorted into quintile bins based on the location of the growth rate in the own country distribution. The value on the y-axis is the average of the normalized uncertainty measures for observations assigned to each bin (average deviations from the mean in uncertainty).

Table 4 presents the results of 45 different panel regressions, for GERD and each subset of GERD by funding and performance sector, using the five current period explanatory variables separately in each regression. Cross-firm daily stock return spread has the most neutral, if not slightly positive, effect on R&D investment across subtypes, which is consistent with theory if this proxy is more representative of "good" volatility (more "winners" increasing the stock return spread and increasing the upper limit of expected return from successful R&D). Conversely, exchange rate daily volatility, which is more representative of macro uncertainty, appears to more strongly depress R&D growth than the other uncertainty proxies.

Where statistically significant, the regression results indicate that a one standard deviation increase in the uncertainty proxies is associated with a decrease in GERD and BERD growth (columns 1 and 6) of two to three percentage points. These conclusions remain unchanged when including lags of uncertainty proxies for GERD and BERD in the regression. In column 3, an increase of one standard deviation in the sovereign bond yields daily volatility and exchange rate daily volatility is estimated to lead to a decrease in government-financed GERD growth of one and five percentage points, respectively, while all other uncertainty proxy coefficients are statistically insignificant, suggesting that government is not making up a financing shortfall for R&D during times of higher uncertainty. Although positive coefficient estimates are observed for GERD financed by the rest of the world and GERD performed by private non-enterprise (columns 5 and 9), these types of R&D expenditure are a small percentage of GERD as shown in Tables 2 and 3. Remaining subtypes of GERD are negatively affected by an increase of one standard deviation in uncertainty on a scale of approximately one to five percentage points of growth, when statistically significant.

In summary, Figure 1 reveals that uncertainty and growth in R&D spending are negatively correlated, and that the growth of R&D expenditure performed by industry, which is a sizable percentage of total R&D expenditure, is likely the main driver in this relationship. From the regression results in Table 4, which bring us closer to interpreting causation by controlling for the country and year factors that may affect uncertainty and R&D expenditure, we see that exchange rate daily volatility, in particular, suggests negative effects on R&D expenditure growth due to macro uncertainty. At the same time, the association between fluctuations in uncertainty and government-financed GERD growth is weak, suggesting that governments are not increasing funding for R&D during times of high uncertainty.

Policy Recommendations for the G20 and Its Members

How can governments and intergovernmental forums such as the G20 mitigate the negative impact of uncertainty on R&D investment?

One avenue to consider is reducing frictions in financial markets. The literature shows that the negative real-options effect of uncertainty on firm R&D investment is magnified in the presence of financial constraints and distortions in financial markets (Arellano, Bai and Kehoe 2010; Christiano, Motto and Rostagno 2014; Gilchrist, Sim and Zakrajšek 2014). Simon Gilchrist, Jae W. Sim and Egon Zakrajšek (2014), for example, argue that an increase in uncertainty worsens the quality of companies' balance sheets, increases the companies' default risk and, in doing so, increases credit spreads that companies pay for their debt. In an environment where external finance is costly, an increase in uncertainty reduces the supply of credit, and companies' investment spending falls as a result. With the G20's traditional focus on financial stability and market regulation, it is an ideal forum for its members to pursue these goals in a uniform fashion. Members should be advised and encouraged to act swiftly and proactively in the face of financial market turbulence.

Furthermore, effective systems of intellectual property rights (IPRs) can help attenuate the negative impact of uncertainty on business R&D spending. Obtaining a patent reduces the irreversibility of R&D investment because if business conditions become unfavourable, companies can recoup a portion of their original innovation investments by selling their IPRs. In addition, the legal protection afforded to inventions through the patent system reduces uncertainty about future market returns to innovation, which can be a major influence in innovation investment

Table 4: Within Estimator Regression Results of GERD Growth (by Financing and Performance Sectors)

Independent Variable	Dependent Variable								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	GERD	GERD financed by:				GERD performed by:			
		Business enterprise	Government	Other national sources	The rest of the world	BERD	Government	Higher education	Private non-enterprise
a) Stock index daily returns volatility	-0.022*** (0.006)	-0.014. (0.008)	-0.015 (0.009)	-0.032 (0.019)	0.005 (0.034)	-0.022*** (0.006)	-0.043*** (0.011)	-0.012 (0.010)	-0.012 (0.037)
b) Cross-firm daily stock return spread	-0.010 (0.009)	-0.006 (0.009)	0.000 (0.009)	0.029 (0.026)	-0.026 (0.043)	-0.017. (0.009)	-0.013 (0.011)	-0.006 (0.011)	0.083* (0.036)
c) Sovereign bond yields daily volatility	-0.006 (0.003)	-0.010 (0.006)	-0.008* (0.004)	-0.015 (0.023)	0.073* (0.029)	-0.007 (0.006)	-0.014*** (0.003)	-0.006 (0.008)	0.026* (0.012)
d) Exchange rate daily volatility	-0.034*** (0.003)	-0.020 (0.013)	-0.054*** (0.010)	-0.011 (0.028)	-0.047 (0.054)	-0.026** (0.008)	-0.033*** (0.003)	-0.047*** (0.003)	-0.064*** (0.006)
e) GDP forecast disagreement	-0.021*** (0.006)	-0.025** (0.008)	0.002 (0.008)	-0.034** (0.010)	-0.051 (0.036)	-0.023*** (0.006)	0.001 (0.011)	-0.015 (0.009)	0.004 (0.007)

Source: Authors' analysis using data from Baker and Bloom (2013) and OECD (2016).

Notes: Uncertainty proxies are in standard deviations from the sample mean. R&D expenditure is growth calculated as the difference in log values. Standard errors in parentheses are robust to heteroscedasticity and clustered by country. All regressions include time-fixed effects. The number of countries covered ranges from 9 to 12 for regressions using GDP forecast disagreement, and 21 to 29 for regressions using the other uncertainty proxies. The sample begins in 1986 for cross-firm daily stock return spread, 1990 for GDP forecast disagreement and 1982 for the other uncertainty proxies. As a result, the number of observations varies from 175 to 243 for regressions using GDP forecast disagreement, and from 367 to 669 for the other regressions.

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$

decisions. IPRs can limit imitation and increase firms' ability to appropriate the rents accruing from their innovations. This, in turn, makes future market returns to innovation more certain and stimulates R&D investment. The results in Czarnitzki and Toole (2011) support this conclusion, as they show that patent protection reduces the negative influence of uncertainty on firm-level R&D investment. The authors explain this result in the context of the real-options framework, positing that obtaining a patent reduces the firm's perceived level of market uncertainty (for example, because it protects the firm from market competition) and, in so doing, decreases the benefit of delay and increases current R&D investment.

While strong IPRs can help reduce the negative influence of uncertainty on business R&D investment, it is also important to keep in mind that this is a double-edged sword, as overly strong IPRs may also limit access and therefore hamper further innovation. Overly strong IPRs may incentivize firms to patent weak innovations for strategic purposes and lead to the rise of non-performing entities (NPEs), which hold broad patents for the purposes of extracting rents from successful firms. The result of such effects is a high volume of weak and broad patents, and greater cost and uncertainty as it becomes increasingly difficult for firms to disentangle the complicated web of prior art to ensure they are operating with the proper licences and that their innovations are non-infringing.

G20 countries should aim to achieve optimal strength of IPR protection, which would balance the benefit of mitigating the adverse effects of uncertainty with the cost of limited access and adverse rent-seeking behaviour. The beneficial impact of IPRs in this context can be amplified when IPRs are recognized and honoured across geopolitical borders, either through informal efforts at coordination by G20 members or through formal international trade treaties akin to the now defunct Trans-Pacific Partnership. Such coordination would promote exports among patenting firms (Ivus 2010; 2015), which would further increase the potential returns to R&D. However, effective IPR systems must also strike the right balance between the strength of IPR protection and competition in the global economy. One concern with the global harmonization of IPRs is that it creates an incentive for stronger IPRs as countries seek to capture global rents. This can be remedied through a World Trade Organization agreement modelled on the Strategic Arms Limitation Treaty between the United States and the Soviet Union, which would "establish disciplines on the creation of IP, provide for a timely retirement of non-performing IP (modelled on mutual tariff elimination under the General Agreement on Tariffs and Trade (GATT)), and establish an international IP court for the adjudication of cross-border infringement claims" (Ciuriak 2017). Such agreements may also eliminate the incentive for less innovative countries to freeride due to the national treatment of foreign inventors (Blit 2017).

The combination of overburdened patent offices and conflicting studies on the link between patents and innovation leads many to conclude that IPR protection is too high at present levels. Joël Blit (ibid.) argues that this is indeed the case for Canada and recommends avoiding provisions in international agreements that seek to further strengthen IPRs. Uncertainty and holdup risk (the potential for holders of infringed-upon patents to hold up commercialization until they have negotiated for themselves a sizable share of the revenues, after investments have already been made) can be further reduced by making patents narrower, more clearly demarcated, easily searchable and comprehensible (Blit 2015).

A specific category of patents, essential patents or standard-essential patents (SEPs), can create further uncertainty for firms. SEPs cover innovations that are essential for a company to implement a standard. The United States is the leader in SEP markets, but China is beginning to catch up. While many standards organizations require that the licensing of SEPs be fair, reasonable and non-discriminatory, the terms are vague and not always effective in practice (Ernst 2017). This increases uncertainty as firms cannot be sure whether they will be able to obtain the required licences, and start-ups in particular may face discriminatory pricing. Dieter Ernst (ibid.) recommends China adopts *ex ante* disclosure, or structured price commitments, in addition to the Institute of Electrical and Electronics Engineers' (IEEEs') new licensing policy (which ensures that all IEEE members holding patents offer licences to all applicants that request them and outlines what avenues members may pursue in enforcement).

Increasing R&D tax credit incentives and direct (or program-based) subsidies and streamlining government programs that support business innovation are also recommended. In the April

2016 edition of *Fiscal Monitor,* the International Monetary Fund (IMF) calls on advanced economies to reduce firm costs to invest in R&D via tax credits and direct subsidies. In advanced economies, the private returns to R&D investment are already high (between 20 percent and 30 percent), but public returns are estimated to be even higher, by a factor of two to three. Therefore, it is recommended that tax credits and direct subsidies should decrease a firm's R&D costs by 50 percent to optimize returns — this translates into a 40 percent increase in R&D investment and a five percent long-term increase in GDP. Refundable tax credits are particularly effective with start-ups due to their difficulty in obtaining funding and high probability of negative profits; further efficiencies can be gained by targeting incremental R&D investment and gradually increasing the amount of support offered. In times of heightened market uncertainty, increased government support for business R&D investment could mitigate the negative effect of uncertainty on such investment. Czarnitzki and Toole (2007) provide evidence in support of this conclusion. Using data on innovative firms in the German manufacturing sector, the authors find that public R&D subsidies increase the expected return to the firm's R&D investment in markets for new products and in doing so, weaken the negative effects of product market uncertainty on firm-level R&D investment (ibid.). By following the spirit and substance of the "G20 Guiding Principles for Global Investment Policymaking (Annex III),"[8] G20 members could coordinate national and international incentive programs to promote R&D investment in a coherent and mutually reinforcing manner, thereby amplifying the positive effects.

It is important to underscore that the effectiveness of government programs aimed at stimulating R&D activity in the private sector will depend on the sensitivity of economic agents to business conditions. High uncertainty about business conditions increases the option value of waiting and makes economic agents less sensitive to changes in business conditions. This is particularly relevant for R&D investments, which tend to persist over time at higher uncertainty. Investment in the knowledge stock (as opposed to investment in the capital stock) is much less responsive to business conditions, and this can make government policies that support business innovation less effective (Bloom 2007).

As such, in times of heightened uncertainty, it is especially important for the government to invest in an aggressive innovation agenda.

When making changes to government programs or the regulatory landscape, governments should aim to reduce uncertainty associated with their future policy. Huseyin Gulen and Mihai Ion (2016) emphasize that "uncertainty surrounding [policy] decisions can be just as damaging as making the wrong decision." Using a news-based index of policy uncertainty, Gulen and Ion (ibid.) show that policy-related economic uncertainty has strong negative effects on firm-level capital investment, which last for up to eight quarters into the future. Importantly, firms with a higher degree of investment irreversibility (such as R&D-intensive firms) and firms that are more dependent on government spending are most impacted by policy uncertainty.

Other opportunities for the G20 to mitigate uncertainty through predictable and uniform strategies include developing a quick, consistent plan of action for currency fluctuations (both between two members and between members and a non-member), retaining experts to identify and assess potential challenges and risks and then developing plans for coordinated response to such scenarios.

Conclusion

The importance of innovation in overall economic growth is unquestionable. Law makers who recognize this are advancing policies that promote innovation, but they must factor for the ever-looming spectre of uncertainty and its role in the decision making of economic agents. Macro uncertainty has adverse effects on incentives to invest in R&D. However, policy makers can alleviate these effects with targeted and principled changes to business conditions and supportive infrastructures. Options at their disposal include reducing frictions in financial markets, enhancing R&D tax credit schemes and increasing effectiveness of the systems of IPRs.

8 See www.g20.utoronto.ca/2016/160710-trade-annex3.html.

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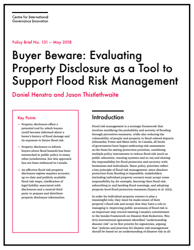
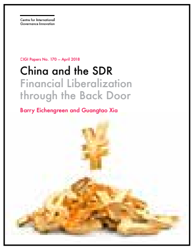


Buyer Beware: Evaluating Property Disclosure as a Tool to Support Flood Risk Management

CIGI Policy Brief No. 131
Daniel Henstra and Jason Thistlethwaite

This policy brief examines property disclosure as a potential tool to improve public understanding of flood risk and support disaster risk reduction. Property disclosure offers a potential tool by which buyers could become informed about a home's history of flood damage and its exposure to future flood risk. An effective flood risk property disclosure regime requires accurate, up-to-date and publicly available flood risk maps, clarification of legal liability associated with disclosures and a neutral third party to prepare and distribute property disclosure information.



China and the SDR: Financial Liberalization through the Back Door

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Barry Eichengreen and Guangtao Xia

This paper analyzes the motives for China's special drawing rights (SDRs) campaign. Shedding light on the motives behind the campaign requires placing the SDR issue in the context of Chinese economic reform. It requires relating the issue to changes in China's international economic relations and analyzing Chinese officials' approaches to managing those changes. And it requires placing the SDR in its historical context — acknowledging that China's views of the SDR have a long history and understanding how those views have evolved over time — as this paper seeks to do.

Issues and Challenges in Mobilizing African Diaspora Investment

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Cyrus Rustomjee

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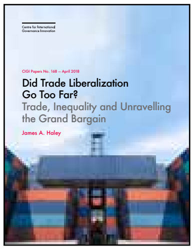

Did Trade Liberalization Go Too Far? Trade, Inequality and Unravelling the Grand Bargain

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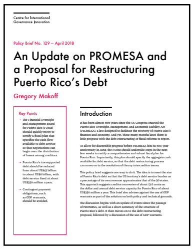
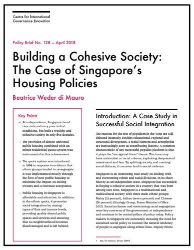
This paper reviews the history of trade liberalization and the effects of freer trade on US labour market outcomes. It is motivated by the rise of economic nationalism, evident in the United States and elsewhere, which threatens the international "architecture" of trade, economic and financial arrangements that has been erected over the past 70 years. The paper argues that these effects do not necessarily imply that trade went "too far." Addressing the challenges posed by political populism and economic nationalism requires a consensus on domestic policies and changes to the international architecture that facilitate this policy framework.



An Update on PROMESA and a Proposal for Restructuring Puerto Rico's Debt

CIGI Policy Brief No. 129
Gregory Makoff

It has been almost two years since the US Congress enacted the Puerto Rico Oversight, Management, and Economic Stability Act (PROMESA), a law designed to facilitate the recovery of Puerto Rico's finances and economy. And yet, these many months later, there is little progress with the debt restructuring or fiscal reforms to report. To allow for discernible progress before PROMESA hits its two-year anniversary in June, the Financial Oversight and Management Board for Puerto Rico should undertake steps in the next few weeks to certify a comprehensive and robust fiscal plan for Puerto Rico.



Building a Cohesive Society: The Case of Singapore's Housing Policies

CIGI Policy Brief No. 128
Beatrice Weder di Mauro

This brief shows how Singapore's social integration policies, in particular the housing policies, have been instrumental in reducing residential segregation among ethnic groups. At independence, Singapore faced race riots and very poor initial conditions, but built a wealthy and cohesive society in only five decades. The provision of almost universal public housing, combined with an ethnic residential quota system, was instrumental in this achievement. Public housing in Singapore is affordable and attractive. In addition to the ethnic quota, it promotes social integration by mixing types of flats and income levels, providing quality shared public spaces and services and ensuring that no neighbourhood becomes disadvantaged and is left behind.

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