sustainability

MDPI

Article

The Negative Impact of Uncertainty on R&D Investment: International Evidence

Yuchen Lin [1], Daxin Dong [2,*] and Jiaxin Wang [2]

[1] School of Law, Southwestern University of Finance and Economics, Chengdu 611130, China; lyc1124452151@smail.swufe.edu.cn
[2] School of Business Administration, Southwestern University of Finance and Economics, Chengdu 611130, China; 41912431@smail.swufe.edu.cn
* Correspondence: dongdaxin@swufe.edu.cn

Abstract: Previous studies have not provided consistent conclusions regarding the impact of uncertainty on research and development (R&D) investment. While most of the previous literature has focused only on one or a small group of countries, this study examines the effect of uncertainty on R&D on the basis of a sample covering 109 countries from 1996 to 2018. The country-level uncertainty is measured using the "World Uncertainty Index", which has recently been developed by Ahir et al. (2018). By estimating a panel data fixed-effects regression model, it is found that uncertainty has a significantly negative impact on R&D investment at the country-level aggregate scale. We also find that uncertainty depresses the number of R&D personnel and patent applications, although the effect on R&D personnel is not statistically significant. These findings imply that high uncertainty poses a considerable threat to global innovation and technological progress. Heterogeneity analyses across different country groups demonstrate that, although the impact of uncertainty on R&D is not statistically significant in some country groups, its effect is always negative and no positive effect is observed.

Keywords: uncertainty; world uncertainty index; R&D investment; patent application

check for updates

Citation: Lin, Y.; Dong, D.; Wang, J. The Negative Impact of Uncertainty on R&D Investment: International Evidence. *Sustainability* **2021**, *13*, 2746. https://doi.org/10.3390/su13052746

Academic Editor: Pompeo Della Posta

Received: 8 January 2021
Accepted: 28 February 2021
Published: 3 March 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

The world is full of uncertainties. For example, the current coronavirus (COVID-19) pandemic has generated a very high degree of uncertainty regarding the future of the global economy and society. Previous studies have reported that numerous economic activities, such as industrial production, consumption, corporate investment, and credit provision, are depressed during periods of high uncertainty. As an important kind of economic activity for sustainable development, research and development (R&D) is expected to also be affected by uncertainty. Interestingly, previous studies have not provided consistent conclusions about the impact of uncertainty on R&D investment. While some studies have reported negative effects, others have reported that the influence was positive. Our study revisits this research topic by utilizing a new dataset covering a wider sample.

This study aims to empirically investigate the overall responses of R&D investment to variations in uncertainty around the world, based on the country-level aggregate data collected for over 100 countries. The quantitative analyses were conducted by using an econometric regression model for panel data structure. The effect of uncertainty was measured by the coefficient estimated from regressions. The main finding is that country-level macro-uncertainty negatively affects R&D investment, and the negative effect is observed in the full sample as well as in various country groups.

This study contributes to the literature in three aspects. First, it is notable that most of the previous literature has focused on only one country, particularly China or the US. As the experience from one country may not be applicable to other areas, a study covering more countries is valuable. Our study examines the effect of uncertainty on R&D on

the basis of a cross-country sample. A total of 109 countries are included in the study and, thus, the general circumstances in the world are analyzed. We also explore whether there are heterogeneities across different kinds of countries. Second, as prior studies have majorly focused on the influence of uncertainty on firm-level R&D investment, it is unclear whether R&D activities aggregated at the macroeconomic level are affected in the same way. Given the fact that, in many countries, nearly half of all R&D activities are financed by non-firm organizations [1], it is necessary to investigate the overall variations of total R&D investment at the country level, as we do in this study. Third, this study is an attempt to utilize a newly developed measure of county-level uncertainty, the World Uncertainty Index (WUI), constructed by Ahir et al. [2], in order to examine the influence of uncertainty on the real economy. As the WUI is available for over 100 countries, we are able to track uncertainty across the globe and make cross-country comparisons more comprehensively by including many countries and regions, for which an alternative measure of macro-uncertainty is lacking. Our study demonstrates the usefulness of this index.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature and develops the research hypotheses. Section 3 gives the details about the econometric model and data used in this study. Section 4 provides our empirical results. Finally, Section 5 concludes the article and discusses the policy implications of our findings.

2. Literature Review and Hypothesis Development

2.1. Literature Review

Several previous studies have estimated the impact of uncertainty on R&D investment. Table 1 provides a non-exhaustive list of relevant studies. Table 1 lists the author names and published year, the sample and period covered, the measurement of uncertainty, and the sign of the estimated effect in each study. Among the 18 studies listed in the table, 9 of them reported a negative impact of uncertainty while 9 studies reported a positive effect. Thus, the extant literature does not provide a consistent conclusion and, so, this research topic deserves more exploration.

Several kinds of indicators are available to measure the degree of uncertainty. Generally speaking, three types of indicators have been used in prior studies: political election or turnover (e.g., [3,4]), the economic policy uncertainty (EPU) index (e.g., [5–7], and observed market or firm-specific volatility (e.g., [1,8,9]). At the country level, the EPU index developed by Baker et al. [10] and other researchers is the most frequently used indicator. The EPU index was constructed based on the information provided by newspaper articles containing textual terms related to uncertainties in economic policies. Roughly speaking, the researchers collected the corresponding countries' major newspapers and, then, counted the proportion of articles mentioning economic policy uncertainties in all newspaper articles. A higher proportion indicated a higher degree of EPU. More details on the methodology of constructing EPU index are available at its website http://www.policyuncertainty.com (accessed on 30 September 2020). Among the 18 studies listed in Table 1, 7 studies analyzed the effect of EPU. However, it is notable that, so far, the EPU index is only available for 26 countries and regions, which are majorly developed countries plus several large emerging economies. This property limits its usefulness in cross-country comparisons or empirical studies designed for a large set of countries. Particularly, EPU data are not available for most developing countries, in which the uncertainty is often high and R&D plays a crucial role in their long-term growth potential.

Table 1. A non-exhaustive list of previous studies on the impact of uncertainty on R&D investment.

Literature	Sample	Period Covered	Measurement of Uncertainty	Estimated Effect
Arif Khan et al. [5]	2542 listed firms in China	2000–2017	(1) firm-specific uncertainty (residuals' moving standard deviation obtained from the AR(1) model of sales), (2) market-based uncertainty (conditional variance obtained from the GARCH model using daily data on stock market returns), (3) economic policy uncertainty (EPU) index	negative
Atanassov et al. [3]	90,637 firm-year observations in the US	1976–2013	US gubernatorial elections	positive
Cho and Lee [11]	6987 manufacturing firms in South Korea	2008–2014	firm-specific uncertainty (variation in a firm's sales revenues)	negative
Czarnitzki and Toole [8]	702 manufacturing firms in Germany	1998, 2000	firm-specific product market uncertainty (variance of the share of sales achieved with new products per year in the pre-sample period at the firm level)	negative
Goel and Ram [12]	9 OECD countries	1981–1992	(1) 5-year moving standard deviation of inflation, (2) 5-year moving average of inflation	negative
Gu et al. [13]	10,641 firm-year observations in China	2007–2015	EPU index	positive
Han et al. [14]	872 listed firms in China	2009–2017	EPU index	positive
Ivus and Wajda [1]	30 countries	1982–2012	(1) stock index daily returns volatility, (2) cross-firm daily return spread, (3) sovereign bond yields daily volatility, (4) exchange rate daily volatility, (5) GDP forecast disagreement	negative
Jiang and Liu [6]	1163 listed firms in China	2008–2016	EPU index	positive
Jung and Kwak [15]	6084 firms in South Korea	2010–2014	firm-specific uncertainty (squared value of the residual obtained from the AR(1) model of a firm's profit margins)	negative
Meng and Shi [16]	10,514 firm-year observations in China	2008–2015	EPU index	positive
Nan and Han [17]	351 listed firms in China	2009–2016	firm-specific uncertainty (residuals obtained from the AR(1) model of stock return volatility)	negative
Ross et al. [9]	551 business divisions of manufacturing firms in Germany	1995–2008	industry-level uncertainty (square root of the conditional variance obtained from the GARCH model using monthly data on industry sales)	positive
Stein and Stone [18]	3965 listed firms in the US	2001–2011	firm-specific uncertainty (volatility consistent with the market price of an exchange-traded option using an inversion of the Black-Scholes formula)	positive

Table 1. *Cont.*

Literature	Sample	Period Covered	Measurement of Uncertainty	Estimated Effect
Tajaddini and Gholipour [7]	19 countries	1996–2015	EPU index	positive
Vo and Le [19]	90,650 firm-year observations in the US	1985–2013	firm-specific uncertainty (standard deviation of the residuals from the regression model of a firm's stock returns on market returns over a year)	positive
Wang et al. [4]	1868 listed firms in China	2002–2012	(1) policy uncertainty (turnover of local government officials), (2) market uncertainty (moving standard deviation of current sales revenues)	negative
Xu [20]	12,408 listed firms in the US	1985–2007	EPU index	negative

Previous research has mostly utilized firm-level microeconomic data to explore the influence of uncertainty on R&D investment. In other words, the existing research has essentially focused on the investment of firms (which were majorly listed firms). Only three studies—those of Goel and Ram [12], Ivus and Wajda [1], and Tajaddini and Gholipour [7]—have analyzed R&D investment at the country level. Definitely, R&D investments in business enterprises are extremely important, as numerous innovations and inventions are created in the industry. However, it is non-negligible that non-firm organizations are also crucial platforms for R&D. According to the statistics reported by Ivus and Wajda [1], during the period 1981–2012, in major developed countries, 51% of gross domestic expenditure on R&D was not industry-funded. In many developing countries with weak market economies and fragile protection of intellectual property rights, the roles of public sectors may even be larger. Therefore, it is necessary to explore whether, and to what extent, R&D investment responds to uncertainty at the country level. This serves to provide a more integrated picture about the dynamics of R&D investment within an economy.

Most of the extant studies have concentrated on one single country, particularly China or the US; however, it is unclear whether the experience from the single country studied still applies to other regions. Only three studies used panel data econometric models to investigate a set of countries: Goel and Ram [12], Ivus and Wajda [1], and Tajaddini and Gholipour [7] studied 9, 30, and 19 countries, respectively. Interestingly, analogous to those single-country studies, these three studies obtained opposite conclusions. While Goel and Ram [12] and Ivus and Wajda [1] reported a negative effect of uncertainty, Tajaddini and Gholipour [7] reported a positive impact. Our study intends to expand the sample to cover as many countries as possible, by utilizing a recently developed country-level uncertainty index. This will help us check the general circumstance in the world. Furthermore, considering the possibility that one size does not fit all, we will divide the countries into different groups based on several classification criteria. Then, we examine the heterogeneities across different country groups.

2.2. Hypothesis Development

Theoretically, the influence of uncertainty on R&D investment is unclear. On the one hand, several theories have suggested that R&D investment will decline when uncertainty is high. On the other hand, arguments about a positive correlation between R&D investment and uncertainty also have logical foundations. Next, we briefly introduce the major arguments regarding the impact of uncertainty on R&D investment.

2.2.1. Uncertainty May Reduce R&D Investment

The total scale of available funding for R&D investment shrinks during high uncertainty periods. Solid empirical evidence has been given that aggregate economic activities are depressed when macro-uncertainty rises. In an environment with high uncertainty, consumption decreases largely [21–23], as consumers intend to save more for precautionary purposes and industrial production declines as demand decreases [10,22,24]. In consequence, on average, there are generally substantial reductions in the revenues of R&D-conducting organizations, including those in both private and public sectors. It is natural to see that the potential funding for R&D investment becomes less available and smaller in size.

Uncertainty critically raises the financing cost of firms and tightens their financial constraints. This largely increases the opportunity cost of R&D investment. When uncertainty is high, firms are expected to have higher default risks. Hence, banks are less willing to provide loans [25,26] and firms' cost of capital becomes higher [20,27]. Moreover, the informal financing channels such as trade credits are also reduced [28,29]. Facing tighter financial constraints, it is highly possible that firms will cut down on R&D investment, as many R&D activities are not urgent and a relatively long time is needed to recover investment into R&D.

The "theory of real options" provides another argument about why firms may reduce R&D investment when uncertainty is high. In this theory, firms' investment opportunities are considered "real options". A corporation can choose whether to exercise its option today or delay its investment until tomorrow. The option value of such a delay is high if uncertainty about future market conditions is high, because the company may be able to avoid costly mistakes if the future business environment really worsens. This option is especially valuable when the investment is highly irreversible [30,31]. Clearly, R&D investment is a typical kind of irreversible investment [12,32]. Thus, during periods of high uncertainty, firms are willing to "wait and see" and delay their R&D investment.

Based on the arguments discussed in Section 2.2.1, uncertainty may reduce R&D investment because the available funding shrinks, firms' financial constraints become tighter, and firms would like to delay irreversible investment when uncertainty is high. Accordingly, the following hypothesis can be built:

Hypothesis 1. *Uncertainty has a negative impact on the scale of R&D investment.*

2.2.2. Uncertainty May Increase R &D Investment

The "theory of strategic growth options" suggests that firms have an incentive to invest more in R&D when uncertainty is high [33]. In some industries, being the first to offer a new product or patent a new technology will build a substantial competitive advantage in the market. In contrast, delay in R&D investment generates opportunities for competitors and, thus, is not desirable. Uncertainty implies that the future business environment may become either good or bad. The worst outcome for a firm investing in R&D is losing the costs; however, the best outcome is extremely profitable, as the firm may occupy a great market share within a new business environment, especially when the industry is growing rapidly. According to the "theory of strategic growth options", because uncertainty actually increases the best possible benefits of R&D investment, firms should strategically invest more in R&D, in order to secure their market shares, when uncertainty increases [7,19,34].

Another argument for a positive effect of uncertainty on R&D investment emphasizes the increased value of information and knowledge provided by R&D activities when uncertainty is high [9]. During periods of high uncertainty, there exist a lot of chaos and noises in the environment, and firms have insufficient information to effectively forecast the future business conditions. The initial investments in R&D are low-cost probes prior to full-scale commercial production. The early-stage R&D investment can help firms make more informed judgment about the technical bottleneck, failure risk, cost structure, and production capacity required to launch new products in the future [35–37]. All these items of information are useful, especially when the competitors lack relevant knowledge in an uncertain business environment. In addition, engagement in R&D activities is essentially an approach of "learning-before-doing" to generate useful knowledge [38]. In normal times, firms "learn by doing" from cumulative commercial production, which means that the productivity increases and unit production cost declines as firms produce more and more. Under high uncertainty, the stable environment required to realize the learning-by-doing effect is disturbed [39–41]. As learning-before-doing through R&D activities can advance the subsequent progress of learning-by-doing of producing new products [9,42,43], firms have the incentive to expand R&D investment if uncertainty increases.

Another possible reason to justify a positive impact of uncertainty on R&D investment stems from the policies of governments. Typically, governments implement counter-cyclical policies to stabilize the macroeconomy and to ease public concerns about the uncertainty [44–46]. When uncertainty is high, after observing a decline in aggregate economic activities, governments tend to expand public expenditures, including public R&D budgets [47]. Moreover, governments will take actions, through such efforts as offering tax rebates, subsidies, and more credits, in order to reinforce their support for

private investment [48]. If these policies are effective, R&D investment in private sectors will be stimulated.

Based on the arguments discussed in Section 2.2.2, uncertainty may raise R&D investment because firms want to strategically utilize R&D investment to build competitive advantage and get beneficial information, and government may implement policies to encourage investment during high uncertainty periods. Accordingly, the following hypothesis can be established:

Hypothesis 2. *Uncertainty has a positive impact on the scale of R&D investment.*

As discussed above, either of Hypothesis 1 or 2 is theoretically possible. We will rely on the results of empirical analyses to see how uncertainty changes R&D investment in our study sample. Then, we can check which hypothesis will be verified.

3. Model, Variable, Furthermore, Data

3.1. Model

Our study sample has a standard panel data structure, which contains two dimensions: the cross-country and the time dimension. Therefore, the empirical analysis is based on a classical linear regression model with two-way fixed-effects, which is suitable for panel data analysis. This kind of model has been used in previous studies, such as Atanassov et al. [3], Goel and Ram [12], Jiang and Liu [6], and Tajaddini and Gholipour [7], to investigate the impact of uncertainty on R&D investment. The model is expressed by the following equation:

$$y_{it} = \alpha Uncertainty_{it} + X_{it}^{'}\beta + s_i + v_t + \varepsilon_{it}, \quad (1)$$

where the dependent variable, y_{it}, is the scale of R&D investment in country i during year t; $Uncertainty_{it}$ is the degree of uncertainty, which is the core explanatory variable of interest in this study; X_{it} is a set of control variables; s_i and v_t refer to the country-fixed and time-fixed effects, respectively; ε_{it} is the error term; and α and β are the parameters to be estimated. These coefficients capture the effects of independent variables on R&D. We are particularly interested in the coefficient α, which measures the impact of uncertainty.

3.2. Variable

3.2.1. Dependent Variable

We are interested in the effects of uncertainty on R&D investment. The dependent variable is $ln(R\&DInvestment)$, the logarithmic value of the scale of R&D investment (in constant 2010 US$). This variable has been widely used in the literature to measure the size of R&D input. We took the logarithmic value to mitigate the potential heteroscedasticity issue in econometric regressions, as some countries have very large scales of R&D investment, while the scales in some countries are quite small. Accordingly, the variations in R&D investment are expressed as percentage changes.

3.2.2. Core Explanatory Variable of Interest

In this study, the core explanatory variable of interest is *Uncertainty*, which measures the degree of uncertainty in economic and political developments of a country. In the literature, several kinds of indicators have been used to measure the degree of country-level uncertainty. We chose the "World Uncertainty Index" constructed by Ahir et al. [2], who utilized information from the Economist Intelligence Unit (EIU) country reports. As discussed in their study, this index reflects "the frequencies of the word 'uncertainty' (and its variants) in the EIU country reports". This index is the first panel index of uncertainty for a large set of countries and, thus, can be used in our study. As shown in Ahir et al. [2], globally, this index spiked near great events such as the 9/11 attack, Euro debt crisis, and Brexit. This index has a high correlation coefficient (>0.7) with the economic policy uncertainty index, which has been used in many previous studies (e.g., [5,14,20]). This property ensures that

we can compare our study results with those reported in the literature while having the advantage that we can examine many more countries.

3.2.3. Control Variable

The vector of control variables, X, contains 11 variables: $ln(Population)$, $ln(GDPPerCapita)$, $GDPGrowthRate$, $UnemploymentRate$, $FinancialDevelopment$, $FinancialOpenness$, $TradeOpenness$, $HumanCapital$, $GovernmentSize$, $ControlofCorruption$, and $RuleofLaw$.

$ln(GDPPerCapita)$ is the logarithmic value of GDP per capita (in constant 2010 US$). This variable measures the degree of economic development of the country. $ln(Population)$ is the logarithmic value of the population. This variable controls the effect of population size. $GDPGrowthRate$ and $UnemploymentRate$ are the annual growth rate of the real GDP and the unemployment rate. These two variables are indicators of business cycles. $FinancialDevelopment$ refers to the degree of financial development, which affects the financing of R&D and associated business activities. Previous studies, such as those of Tee et al. [49] and Hsu et al. [50], have reported significant impacts of financial development on R&D. $FinancialOpenness$ and $TradeOpenness$ are the degrees of international financial and trade openness. In a globalized world, numerous R&D activities are not financed within one single country. Thus, we take into account the potential impacts of financial and trade openness. $HumanCapital$ is an index of human capital. It is expected that the stock of human capitals is an important determinant of innovative ability. $GovernmentSize$ is the government size, measured by the share of government spending in GDP. Given that R&D are strongly supported by governments in most countries, government size likely has a positive effect on R&D. $ControlofCorruption$ and $RuleofLaw$ are the indices for control of corruption and rule of law, respectively. These two variables are used to indicate the institutional quality of a country. It is expected that good institutional quality helps build a beneficial environment for R&D.

Table 2 provides a brief summary about the names and definitions of the variables used in this study.

Table 2. Summary statistics.

Variable	Definition	Mean	SD	Min	Max
$ln(R\&DInvestment)$	Logarithmic value of R&D investment (in constant 2010 US$)	25.341	2.776	17.053	31.510
$Uncertainty$	Uncertainty index, obtained from the updated dataset of Ahir et al. [2]	0.172	0.137	0	1.263
$ln(Population)$	Logarithmic value of population	16.695	1.450	14.203	21.050
$ln(GDPPerCapita)$	Logarithmic value of GDP per capita (in constant 2010 US$)	9.146	1.380	5.420	11.425
$GDPGrowthRate$	Annual growth rate of real GDP (%)	3.609	3.639	−14.814	25.163
$UnemploymentRate$	Unemployment rate (%)	7.821	4.879	0.170	32.456
$FinancialDevelopment$	Financial development index, obtained from the updated dataset of Svirydzenka [51]	0.442	0.245	0.040	0.985
$FinancialOpenness$	Financial openness index, obtained from the updated dataset of Chinn and Ito [52]	0.676	0.348	0	1
$TradeOpenness$	Trade openness, measured by international trade volume as a share of GDP (%)	86.769	59.542	18.349	442.620
$HumanCapital$	Human capital index, obtained from the Penn World Table (PWT) 9.1	2.803	0.596	1.053	3.809
$GovernmentSize$	Government size, measured by government spending as a share of GDP (%)	16.507	4.750	5.398	40.444
$ControlofCorruption$	Control of corruption index, obtained from the Worldwide Governance Indicators (WGI) database	0.352	1.060	−1.525	2.470
$RuleofLaw$	Rule of law index, obtained from the WGI database	0.376	0.984	−1.916	2.100

Abbreviations: SD, standard deviation; Min, minimum; Max, maximum.

3.3. Data

We collected the original data of different variables from various sources. Then, we dropped the samples with missing data. Ultimately, based on the availability of data, the final sample contained 109 countries in the world, covering the period from 1996 to 2018. The name list of sample countries was provided by Table S1 in the Supplementary Materials.

The data of the uncertainty index (*Uncertainty*) were constructed by Ahir et al. [2]. The data were readily downloadable from http://www.worlduncertaintyindex.com (accessed on 30 September 2020). The original index was measured at a quarterly frequency. We transformed it into a yearly index by calculating the annual mean value. The data of R&D investment (*R&DInvestment*), population (*Population*), GDP per capita (*GDPPerCapita*), GDP growth rate (*GDPGrowthRate*), unemployment rate (*UnemploymentRate*), trade openness (*TradeOpenness*), and government size (*GovernmentSize*) were provided by the World Bank's World Development Indicators (WDI) database. The financial development index (*FinancialDevelopment*) was obtained from the updated dataset of Svirydzenka [51], available at http://data.imf.org/fdindex (accessed on 30 September 2020). The measurement of financial openness (*FinancialOpenness*) was the capital account openness index of Chinn and Ito [52]. This index was available at http://web.pdx.edu/~ito/Chinn-Ito_website.htm (accessed on 30 September 2020). The human capital index (*HumanCapital*) was obtained from the Penn World Table (PWT) 9.1. The data in the PWT 9.1 ended in 2017 and the data for 2018 have not been reported so far. Hence, we estimated the value for 2018 by assuming that the annual growth rate of human capital from 2016 to 2017 was maintained in the subsequent year. The data of control of corruption (*ControlofCorruption*) and rule of law (*RuleofLaw*) were obtained from World Bank's Worldwide Governance Indicators (WGI) database.

The summary statistics of variables are reported in Table 2. From the table, we can see that the sample countries included in our study were highly heterogeneous. Some countries had very large scales of R&D investment, while the scales in some regions were relatively small. The degree of uncertainty was sometimes very high, while it was low during some periods.

4. Results

In this section, the estimation results of Equation (1) are reported and analyzed. In Section 4.1, we demonstrate the results regarding R&D investment. In Section 4.2, we extend our analysis to show the effect of uncertainty on R&D personnel and patent applications. In Section 4.3, we examine whether the negative impact of uncertainty held in different groups of countries.

4.1. R&D Investment

4.1.1. Baseline Result

We examined the effect of uncertainty on R&D investment. The regression result was reported in column (i) of Table 3. The coefficient of *Uncertainty* was −0.156, which is statistically significant at the 5% level. This indicates that uncertainty had a significant negative impact on R&D investment at the country level. Hence, Hypothesis 1 in this study is verified, while Hypothesis 2 is not supported. According to the estimated coefficient, numerically, a one unit increase in the uncertainty index will cause R&D investment to decline by 15.6%. As the event of a one unit increase in uncertainty rarely occurs in reality, we can think about the consequences of a realistic scenario—when the degree of uncertainty increases by one standard deviation (0.137).

A one standard deviation increase of uncertainty was not rare in history. For example, in 2003, the uncertainty index of Hong Kong suddenly rose by 0.186—from 0.063 in 2002 to 0.249 in 2003—due to the Severe Acute Respiratory Syndrome (SARS) outbreak. In 2007, the uncertainty index of the US rose by 0.214—from 0.060 in 2006 to 0.274 in 2007—caused by the appearance of a financial crisis. In 2016, the announcement of Brexit increased the uncertainty in the UK by 0.509—from 0.477 in 2015 to 0.986 in 2016. The estimated

coefficient (−0.156) of *Uncertainty* indicates that, if the degree of uncertainty increases by one standard deviation (0.137), then R&D investment will decline by 2.1372% (=−0.156 × 0.137). This magnitude is economically significant. In our sample, the average annual growth rate of R&D investment was around 5.218%. Thus, a one standard deviation increase in uncertainty probably pulls down more than 40% (≈2.1372/5.218) of average annual R&D investment growth.

Table 3. Estimated effect of uncertainty on R&D investment.

Independent Variable	Baseline Result	Robustness Check				
		Winsorize Top and Bottom 1% Sample	y = Logarithmic Value of R&D Investment per million Population	y = Logarithmic Value of R&D Investment per million US$ GDP	*Uncertainty* = Dummy Variable for Legislative Election	*Uncertainty* = Economic Policy Uncertainty (EPU) Index
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Uncertainty	−0.156 **	−0.156 *	−0.157 **	−0.159 **	−0.0173 *	−0.100 ***
	[0.0770]	*[0.0817]*	*[0.0768]*	*[0.0767]*	*[0.0092]*	*[0.0324]*
ln(Population)	1.000 **	0.986 **	-	-	0.588	0.697
	[0.4487]	*[0.4458]*	-	-	*[0.6568]*	*[0.5612]*
ln(GDPPerCapita)	1.160 ***	1.176 ***	1.158 ***	-	0.936 ***	1.477 ***
	[0.2052]	*[0.2039]*	*[0.2004]*	-	*[0.1763]*	*[0.2220]*
GDPGrowthRate	−0.00299	−0.000776	−0.00305	−0.00251	−0.00168	−0.00438
	[0.0044]	*[0.0037]*	*[0.0047]*	*[0.0046]*	*[0.0036]*	*[0.0026]*
UnemploymentRate	0.0127	0.0132 *	0.0128	0.0114	0.0056	0.0126
	[0.0080]	*[0.0080]*	*[0.0081]*	*[0.0075]*	*[0.0070]*	*[0.0077]*
FinancialDevelopment	0.209	0.233	0.211	0.275	0.221	0.358
	[0.3661]	*[0.3658]*	*[0.3697]*	*[0.3781]*	*[0.3601]*	*[0.3184]*
FinancialOpenness	0.0327	0.0305	0.0311	0.0423	0.219 *	−0.0176
	[0.1337]	*[0.1341]*	*[0.1348]*	*[0.1326]*	*[0.1314]*	*[0.1753]*
TradeOpenness	0.00227 *	0.00230 *	0.00227 **	0.00213 *	0.00363 ***	0.00185 **
	[0.0012]	*[0.0012]*	*[0.0011]*	*[0.0011]*	*[0.0013]*	*[0.0008]*
HumanCapital	0.513 *	0.563 *	0.511 *	0.520 *	0.485	0.175
	[0.2893]	*[0.2897]*	*[0.2834]*	*[0.2839]*	*[0.3941]*	*[0.1562]*
GovernmentSize	0.0249 *	0.0262 *	0.0248 *	0.0224	0.0332 **	0.0144
	[0.0141]	*[0.0141]*	*[0.0144]*	*[0.0148]*	*[0.0161]*	*[0.0127]*
ControlofCorruption	0.258 *	0.261 *	0.259 *	0.277 *	0.201	−0.0738
	[0.1458]	*[0.1453]*	*[0.1477]*	*[0.1490]*	*[0.1664]*	*[0.1029]*
RuleofLaw	−0.161	−0.166	−0.161	−0.143	−0.0942	−0.0209
	[0.1590]	*[0.1585]*	*[0.1618]*	*[0.1603]*	*[0.1817]*	*[0.1627]*
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1497	1497	1497	1497	1179	496
Countries	109	109	109	109	76	26
R^2	0.555	0.559	0.490	0.154	0.592	0.892

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively. Robust standard errors are reported in parentheses.

Some control variables included in our empirical model can also help explain the variations in R&D investment. Population size (*ln(Population)*) and GDP per capita (*ln(GDPPerCapita)*) both had significantly positive coefficients, consistent with the fact that, on average, economies with larger population and higher levels of economic development tend to invest more in innovation and technological progress. Trade openness (*TradeOpenness*) had a significantly positive coefficient, indicating that international trade promotes R&D investment. As expected, the coefficient of human capital (*HumanCapital*) was significantly positive, as human capital is one of the most crucial foundations for R&D. Government size (*GovernmentSize*) had a significantly positive impact, reflecting the importance of governmental support on R&D activities. Control of corruption (*ControlofCorruption*) had a significantly positive effect, showing that corruption damages R&D investment and, thus, should be controlled. Some control variables, including GDP growth rate (*GDPGrowthRate*), unemployment rate (*UnemploymentRate*), financial

development (*FinancialDevelopment*), financial openness (*FinancialOpenness*), and rule of law (*RuleofLaw*), did not show any statistically significant effects on R&D investment.

4.1.2. Robustness Check

We conducted several additional regressions, in order to check the robustness of our estimation result reported in column (i) of Table 3. We checked whether the result was sensitive to the existence of possible outliers in the sample, selection of indicator for R&D investment used as the dependent variable, selection of index to measure uncertainty, dealing with the endogeneity issue, taking into account the business cycle effects, and testing the existence of structural change.

[Existence of Outliers] To exclude the disturbances of possible outliers, we winsorized the dependent variable ($ln(R\&DInvestment)$) and core explanatory variable of interest (*Uncertainty*) at their top and bottom 1% values. Then, we estimated Equation (1) based on the winsorized sample and reported the estimated coefficients in column (ii). This time, the estimated coefficient of *Uncertainty* was still significantly negative. The coefficient value of -0.156 was equal to that reported in column (i).

[Selection of R&D Investment Indicator] Previously, we used the logarithmic value of R&D investment as the dependent variable in regression. This variable measures the country-level aggregate scale of investment. To enhance the cross-country comparability, we can alternatively rescale this variable, according to the population and GDP size of the corresponding country. In columns (iii) and (iv), we examined the effect of uncertainty on R&D investment per million population ($R\&DInvestment/Population$) and per million US$ GDP ($R\&DInvestment/GDP$), respectively. We took the natural logarithm of these two variables and used the logarithmic values, $ln(R\&DInvestment/Population)$ and $ln(R\&DInvestment/GDP)$, as dependent variables. As $ln(Population)$ was already incorporated into $ln(R\&DInvestment/\ Population)$, the control variable $ln(Population)$ is not included in column (iii). As $ln(GDP)$ (= $ln(Population)$+$ln(GDPPerCapita)$) was already incorporated into $ln(R\&D\text{-}Investment/GDP)$, the control variables $ln(Population)$ and $ln(GDPPerCapita)$ are excluded in column (iv). The estimated coefficients of *Uncertainty* were -0.157 in column (iii) and -0.159 in column (iv), close to that reported in column (i).

[Selection of Uncertainty Indicator] In this study, we chose the "World Uncertainty Index" constructed by Ahir et al. [2] as our principal measurement of uncertainty, because this index is reliable and available for a large set of countries. However, given that this index was newly developed, it has not been widely used in the literature and, so, we would like to examine whether our finding still holds if we use alternative uncertainty indices. As summarized in the literature review section, generally speaking, there are three types of indicators which have been used in previous studies: political election or turnover, the EPU index, and observed market or firm-specific volatility. We examined the effects of uncertainty measured by political election, EPU, and stock market volatility.

We used a dummy variable for legislative election to replace the variable *Uncertainty* in our regression. This dummy variable equals 1 if a national-level legislative election occurred in the country in the corresponding year and 0, otherwise. The data were obtained from the Democratic Electoral Systems (DES) dataset Version 3.0 (http://mattgolder.com/elections (accessed on 30 September 2020)). The estimated coefficient of the election dummy was -0.0173 and statistically significant at the 10% level, as reported in column (v). This means that, on average, R&D investment declined by 1.73% when there was an election event in the country.

We used the logarithmic value of the EPU index to replace the variable *Uncertainty* in our regression. The data of EPU index were downloaded from its website (http://www.policyuncertainty.com (accessed on 30 September 2020)). Previous studies [7] using the EPU index covered 19 different regions, at most. This time, we were able to extend the analyses to cover 26 regions, as the index has recently been developed for seven more regions. The estimated coefficient for the logarithmic EPU index was -0.100, which was

significant at the 1% level, as reported in column (vi). This means that, if the EPU increases by 1%, R&D investment will decrease by 0.1%.

We used an index of stock market volatility instead of the variable *Uncertainty* in the regression. The index is constructed as follows. First, we obtained the data of annual stock price volatility, defined as the "360-day standard deviation of the return on the national stock market index". Then, we calculated the absolute value of the annual stock market return rate and its average value over the sample period for each country. Lastly, we got the index of stock market volatility, computed as the annual stock price volatility divided by the average of the absolute value of annual stock return rate. The original data used to construct the index were provided by World Bank's Global Financial Development Database (https://databank.worldbank.org/source/global-financial-development (accessed on 30 September 2020)). The estimated regression coefficient for the stock market volatility index was −0.0977 and significant at the 10% level, as reported in column (ii) of Table S2 in the Supplementary Materials. It indicates that R&D investment tends to decline if financial market becomes more volatile. This supports our baseline result. In short, columns (v) and (vi) of Table 3 and column (ii) of Table S2 show that our core finding regarding the negative impact of uncertainty is unchanged, even if we use other indicators of country-level uncertainty.

[Causal Analysis] The estimation result reported in column (i) showed a significant negative correlation between uncertainty and R&D investment. However, it was a concern that the detected correlation might not be a causality. In our study, at least two problems should be discussed. First, the correlation between uncertainty and R&D might be driven by other covariates that affected uncertainty and R&D simultaneously. Second, there possibly existed a reverse causality from R&D to uncertainty, which means that the R&D investment in a country changed the degree of uncertainty in the economy. These two problems both caused the "endogeneity" of uncertainty in the regression model. In order to mitigate the endogeneity issue, the first thing we can do is to include important covariates in the regression equation. This has been done already, as we have controlled a set of important control variables capturing the economic, financial, and institutional aspects plus country-fixed and time-fixed effects in Equation (1).

Next, we utilized three approaches to further mitigate the endogeneity issue. (a) We followed several previous studies, including Stein and Stone [18], Vo and Le [19], and Xu [20], to use the uncertainty in the last period, instead of the value in current period, as explanatory variable. Using the 1-year-lagged uncertainty has the advantage to weaken the reverse causality problem, because as today's R&D investment occurs at a later date, it cannot affect the degree of uncertainty in the past. The regression result was reported in column (ii) of Table S3 in the Supplementary Materials. The estimated coefficient of 1-year-lagged uncertainty was −0.188 and statistically significant, supporting our baseline result. (b) Another way to deal with the endogeneity is the instrumental variable (IV) estimation. As we failed to find other feasible IVs, we used the value of uncertainty in the last period as the IV for the current period. The IV-2SLS (Two-Stage Least Squares) estimates were reported in column (iii) of Table S3. Uncertainty has a coefficient of −0.616, which is still significantly negative. It is admitted that the 1-year-lagged variable was probably not a good IV, because it might not satisfy the "exclusion restriction" for IV, which requires that the IV affects dependent variable only through the endogenous explanatory variable. Thus, now we move to another way of mitigating the endogeneity problem. (c) Some previous studies, such as Arif Khan et al. [5], Atanassov et al. [3], Cho and Lee [11], and Ross et al. [9], used the GMM (Generalized Method of Moments) to tackle the endogeneity. The advantage of GMM is that it relies on the "internal" instruments generated from the data and, thus, does not require to seek for additional "external" instruments. We used both the Difference GMM and System GMM estimations, whose results were reported in columns (iv) and (v) of Table S3, respectively. The coefficients of uncertainty were −0.112 and −0.153, and were both significant. After we mitigated the endogeneity using alternative methods, we still found a negative impact of uncertainty.

[Business Cycle Effects] There was a concern that our estimation may be biased because of the existence of business cycle fluctuations. The investment in R&D is probably pro-cyclical, which means that investment is expanded when economic growth rate is high and reduced when growth rate is low. Differently, uncertainty is possibly counter-cyclical, as uncertainty tends to decrease during macroeconomic booms and increase during recessions. In this case, it is natural to observe a negative correlation between uncertainty and R&D investment along the business cycles. If we did not rule out the disturbances caused by business cycle effects, we might overestimate the negative impact of uncertainty. In order to mitigate this concern, we have already controlled the business cycle indicators of GDP growth rate and unemployment rate in the regression equation. However, some unobserved business cycle factors might still exist and cause an omitted variable bias in our estimation. To further deal with this cyclical problem, we conducted additional robustness checks by using the multi-year-average values of the variables to re-estimate Equation (1). The idea behind these exercises is that after we computed the average values of variables over several years, the unobserved positive and negative business cycle effects may probably cancel each other out. First, we calculated the non-overlapping 2-year-average variable values (for periods 1996–1997, 1998–1999, ..., 2016–2017) and re-estimated the model based on the averaged data. The estimated coefficient of *Uncertainty* was reported in column (ii) of Table S4 in the Supplementary Materials, which was -0.200 and significant at the 10% level. Similarly, we calculated the 3-year-average (for periods 1996–1998, 1999–2001, ..., 2014–2016), 4-year-average, and 5-year-average variable values. The estimated coefficients of *Uncertainty* based on the 3, 4, 5-year-average values were reported in columns (iii)–(v) of Table S4. The coefficients were -0.258, -0.128, and -0.255, respectively. In brief, after we considered the cyclical aspects in the time frame, we still detected a negative effect of uncertainty on R&D investment.

[Existence of Structural Change] In addition, we tested the existence of possible structural change along the time dimension. As commonly accepted in the literature, the year 2008 brought a substantial financial crisis globally and caused transformations in many aspects of the economic system. It is conjectured that the relationship between uncertainty and R&D investment might also be altered by that crisis. In order to test this, we added an interactive term between uncertainty and a dummy for the after-2008-period in the regression equation and, then, we inspected the statistical significance of the coefficient of this interactive term. If the coefficient is significant, a structural change around 2008 is implied. To be precise, we used this regression equation: $y_{it} = \alpha Uncertainty_{it} + \gamma Uncertainty_{it} \times D_t^{after2008} + X_{it}'\beta + s_i + v_t + \varepsilon_{it}$, where $D_t^{after2008}$ is a binary dummy variable which equals 1 if $t \geq 2008$ and 0 if $t < 2008$. The regression result was reported in column (i) of Table S5 in the Supplementary Materials. The coefficient of *Uncertainty* was -0.265 and significant, while the coefficient of $Uncertainty \times D^{after2008}$ was not significant. The result did not support the conjecture that the uncertainty–R&D nexus was altered by the 2008 crisis. In columns (ii)–(vi) of Table S5, we have also conducted additional robustness checks analogous to those in columns (ii)–(vi) of Table 3. Those estimation results consistently suggested that the uncertainty–R&D relationship was stable over time.

Clearly, the robust checks reported above provided support to the baseline result in column (i). It was confirmed that uncertainty negatively influenced the R&D investment of countries.

4.2. R&D Personnel and Patent Applications

Having shown that uncertainty reduces R&D investment, we now consider the effects of uncertainty on another type of R&D input—personnel, and the output of R&D activities—patents. Investigating how R&D personnel and patents respond to uncertainty is also useful.

Although R&D investment declines during periods of high uncertainty, the number of R&D personnel may not necessarily vary in the same direction. If the number of R&D researchers even increases in response to higher uncertainty, R&D activities are probably

not depressed when uncertainty rises. The previous literature has not examined the influence of uncertainty on R&D personnel. We supplement the literature by reporting our empirical results on this issue. We found that uncertainty did not show any significant impact on R&D personnel, although we generally obtained negative regression coefficients.

Moreover, we investigated whether uncertainty also had an adverse effect on the outputs of R&D activities, which are new scientifical knowledge and technologies. Following the tradition in the literature, we used the number of new patents to proxy the size of R&D outputs. Some prior studies have reported that uncertainty significantly affected the number of patents. However, while some of them [20,53–56] reported a negative effect, others [7,13,57] have reported a positive influence. We revisited this research topic, based on our country-level sample. Our regression results indicate that uncertainty significantly reduced the number of patent applications.

4.2.1. R&D Personnel

We first estimated the effect of uncertainty on the number of R&D researchers. We still used regression Equation (1), but the dependent variable was $ln(R\&DPersonnel)$—the logarithmic value of the number of R&D researchers—instead of $ln(R\&DInvestment)$. The data were from the WDI dataset. The regression result was reported in column (i) of Table 4. The estimated coefficient of $Uncertainty$ was -0.0109, which was not statistically significant. To check the robustness of this result, we replaced the dependent variable with $ln(R\&DPersonnel/Population)$ and $ln(R\&DPersonnel/GDP)$, and reported the estimation coefficients in columns (ii) and (iii), respectively. Once again, the coefficients of $Uncertainty$ were not statistically significant, though they were still negative. Therefore, we did not find any evident impact of uncertainty on the number of R&D researchers.

4.2.2. Patent Applications

Next, we examined the effect of uncertainty on patent applications. Once more, we utilized regression Equation (1) to estimate uncertainty's effect. The dependent variable was $ln(Patent)$, the logarithmic value of the number of annual new patent applications. We obtained the data from the WDI database. The vector of control variables, X, contains 13 variables, including the 11 above-mentioned control variables for $R\&D$ investment and two additional control variables: $ln(R\&DInvestment)_{t-1}$ and $ln(R\&DPersonnel)_{t-1}$. $ln(R\&DInvestment)_{t-1}$ is the logarithmic value of R&D investment in the last year. $ln(R\&DPersonnel)_{t-1}$ is the logarithmic value of the number of R&D personnel in the last year. The R&D investment and personnel in the last period were included as additional control variables, because the scale of R&D output substantially depends on the volume of previous inputs.

Column (iv) of Table 4 reports the regression result. The coefficient of $Uncertainty$ was -0.227, which was statistically significant at the 5% level. This indicates that uncertainty had a significantly negative impact on R&D output at the country level. According to the estimated coefficient, if the degree of uncertainty increases by one standard deviation (0.137), then the number of patent applications will decline by 3.1099% ($= -0.227 \times 0.137$). This magnitude is economically significant. In our sample, the average annual growth rate of patent applications was 3.530%. This implies that a one standard deviation increase in uncertainty will likely pulls down more than 88% ($\approx 3.1099/3.530$) of average annual patent applications growth.

In order to check the robustness of the finding, we replaced the dependent variable with $ln(Patent/Population)$ and $ln(Patent/GDP)$, and reported the estimation results in columns (v) and (vi), respectively. When the dependent variable was the logarithmic value of patent applications per million population ($ln(Patent/Population)$), the coefficient of $Uncertainty$ was -0.225, which was statistically significant at the 5% level. When the dependent variable became the logarithmic value of patent applications per million US$ GDP, $Uncertainty$ had a significantly negative coefficient of -0.233. Thus, the finding reported in column (iv) is supported.

In short, columns (iv)–(vi) of Table 4 provide consistent evidence that uncertainty reduces the number of patent applications at the country level.

Table 4. Estimated effect of uncertainty on R&D personnel and patent applications.

Independent Variable	Dependent Variable: R&D Personnel			Dependent Variable: Patent Applications		
		Robustness Check			Robustness Check	
	Baseline Result	y = Logarithmic Value of R&D Personnel per million Population	y = Logarithmic Value of R&D Personnel per million US$ GDP	Baseline Result	y = Logarithmic Value of Patent Applications per million Population	y = Logarithmic Value of Patent Applications per million US$ GDP
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
Uncertainty	−0.0109	−0.0377	−0.0228	−0.227 **	−0.225 **	−0.233 **
	[0.0725]	*[0.0761]*	*[0.0775]*	*[0.0939]*	*[0.1042]*	*[0.1024]*
ln(Population)	1.682 ***	-	-	2.610 ***	-	-
	[0.3488]	-	-	*[0.8119]*	-	-
ln(GDPPerCapita)	0.419 **	0.341 *	-	1.887 ***	1.866 ***	-
	[0.1812]	*[0.1751]*	-	*[0.4871]*	*[0.5169]*	-
GDPGrowthRate	0.00325	0.00453	0.00298	0.000596	0.00352	0.00658
	[0.0044]	*[0.0044]*	*[0.0048]*	*[0.0059]*	*[0.0061]*	*[0.0060]*
UnemploymentRate	0.0127 *	0.0124 *	0.0209 ***	0.0660 ***	0.0652 ***	0.0558 ***
	[0.0066]	*[0.0065]*	*[0.0070]*	*[0.0165]*	*[0.0167]*	*[0.0153]*
FinancialDevelopment	0.868 **	0.828 **	0.670 *	0.859 *	0.745	1.053
	[0.3579]	*[0.3668]*	*[0.3838]*	*[0.4368]*	*[0.4850]*	*[0.6707]*
FinancialOpenness	−0.288 **	−0.338 **	−0.415 ***	−0.305	−0.386 *	−0.316
	[0.1298]	*[0.1320]*	*[0.1409]*	*[0.1958]*	*[0.2021]*	*[0.1934]*
TradeOpenness	0.00331 **	0.00276	0.00301 *	0.00286 *	0.00151	0.00105
	[0.0017]	*[0.0018]*	*[0.0018]*	*[0.0017]*	*[0.0016]*	*[0.0017]*
HumanCapital	0.529 *	0.564 *	0.378	−0.466	−0.339	−0.225
	[0.2800]	*[0.2856]*	*[0.2825]*	*[0.3426]*	*[0.3970]*	*[0.3844]*
GovernmentSize	0.0402 ***	0.0421 ***	0.0530 ***	0.00917	0.0231	0.00841
	[0.0110]	*[0.0099]*	*[0.0095]*	*[0.0211]*	*[0.0250]*	*[0.0209]*
ControlofCorruption	0.0576	0.0339	−0.0323	−0.054	−0.0618	−0.0588
	[0.1356]	*[0.1460]*	*[0.1488]*	*[0.2152]*	*[0.2215]*	*[0.2344]*
RuleofLaw	−0.219 *	−0.243 *	−0.327 **	0.070	0.0498	0.158
	[0.1292]	*[0.1299]*	*[0.1315]*	*[0.1952]*	*[0.1942]*	*[0.2202]*
$ln(R\&DInvestment)_{t-1}$	-	-	-	0.249 *	0.195	0.373 *
	-	-	-	*[0.1448]*	*[0.1484]*	*[0.1962]*
$ln(R\&DPersonnel)_{t-1}$	-	-	-	0.187	0.328 **	0.246
	-	-	-	*[0.1482]*	*[0.1353]*	*[0.1516]*
Country-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Time-fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1196	1196	1196	1021	1021	1021
Countries	101	101	101	83	83	83
R^2	0.619	0.514	0.309	0.522	0.463	0.298

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively. Robust standard errors are reported in parentheses.

4.3. Heterogeneities across Different Country Groups

As summarized in the literature review section, the extant studies have not provided consistent conclusions about the influence of uncertainty on R&D. One possible explanation is that the different studies were based on the data of different sample countries and periods, such that the effect of uncertainty may have varied in different circumstances. To investigate this possibility, in this subsection, we analyzed the heterogeneities across different country groups. We classified the countries into different groups, according to certain criteria. To be precise, we analyzed the country groups with different levels of income per capita, ratios of R&D investment to GDP, degrees of uncertainty, corruption control, and financial openness. (The detailed name list of various country groups was given in Table S1 in the Supplementary Materials.) Then, we compared the estimated coefficients of *Uncertainty* for different groups. Our finding was that there were, indeed, some inter-country heterogeneities regarding the size and statistical significance of the estimated

negative impact of uncertainty. However, the observed effect was always negative and never turned positive.

4.3.1. R&D Investment

We investigated the heterogeneities across different country groups, regarding the impact of uncertainty on R&D investment. First, we classified countries according to the levels of income per capita. As developed and developing countries have numerous socioeconomic distinctions, their responses of R&D investment to uncertainty may not be the same. The WDI database provided the information of income group to which each country belongs to. A country was clustered in the "High-Income Group" if it was labelled as a "high income country" in the WDI database, and gathered in the "Low-Income Group", otherwise. We estimated Equation (1) for two groups of sample countries separately. As reported in row (a)-column (i) of Table 5, the estimated coefficient of *Uncertainty* for "High-Income Group" was −0.150, which was significant at the 5% level. As reported in row (a)-column (ii), the coefficient for "Low-Income Group" is −0.151, similar to that for the "High-Income Group", although this coefficient was not statistically significant. Either way, we found a negative impact of uncertainty on R&D investment in both high- and low-income country-groups.

Second, we inspected the differences among the countries with different innovative abilities. We classified the countries according to their ratios of R&D investment to GDP. We calculated the average annual R&D investment-to-GDP ratio over the sample period for each country. If its ratio was above the sample median, the country was classified into the "High-R&D Group". Otherwise, the country was classified into the "Low-R&D Group". As shown in row (b)-column (i), the coefficient for "High-R&D Group" was −0.116 and significant at the 10% level. For "Low-R&D Group", the coefficient was −0.171 but not significant, as shown in row (b)-column (ii). Thus, in our sample, the effect of uncertainty on R&D investment maintained negative, no matter whether we focused on the high- or low-R&D countries. In addition, we have tried the classification of countries according to other three indicators of national innovative abilities: the number of annual new patent per capita, the "Global Innovation Index 2019" provided by the World Intellectual Property Organization (WIPO), and the "International Innovation Scorecard 2019" from the Consumer Technology Association (CTA) of the US. Our finding was unchanged, when we used alternative indicators to classify the countries. The detailed empirical results and data sources were reported in Table S6 in the Supplementary Materials. The name list of countries in different groups was given in columns (vi)–(viii) of Table S1.

Third, we grouped the countries according to degree of uncertainty. We computed the average annual level of uncertainty over the sample period for each country. If its value was above the sample median, the country was grouped into the "High-Uncertainty Group", and was grouped into the "Low-Uncertainty Group", otherwise. As demonstrated in row (c)-column (i), the coefficient for "High-Uncertainty Group" was −0.153 and statistically significant. As reported in row (c)-column (ii), the coefficient for "Low-Uncertainty Group" was −0.119, although not significant. Hence, the influence of uncertainty was always negative, even if we divided our sample based on different uncertainty levels.

Next, we investigated whether there was any substantial distinction between countries having different institutional qualities. We grouped the countries based on the degree of corruption control. We used the control of corruption index from the WGI database to quantify the degree of corruption control. If a country had an annual average index above the sample median, this country was grouped into the "High-Corruption-Control Group". Otherwise, it was put into the "Low-Corruption-Control Group". The estimated coefficient of *Uncertainty* for "High-Corruption-Control Group" was −0.097 and not significant, as demonstrated in row (d)-column (i). For the "Low-Corruption-Control Group", the coefficient of *Uncertainty* was −0.299 and statistically significant, as demonstrated in row (d)-column (ii). Hence, the degree of corruption control did not alter the negative

correlation between uncertainty and R&D investment, although statistical significance was not always maintained.

Table 5. Estimated effect of uncertainty in different country groups.

Classification Criterion	Dependent Variable: $ln(R\&DInvestment)$		Dependent Variable: $ln(Patent)$	
	High-Group	Low-Group	High-Group	Low-Group
	(i)	(ii)	(iii)	(iv)
(a) Level of income per capita	−0.150 ** *[0.0612]*	−0.151 *[0.1255]*	−0.205 * *[0.1099]*	−0.251 ** *[0.1239]*
(b) Ratio of R&D Investment to GDP	−0.116 * *[0.0608]*	−0.171 *[0.1668]*	−0.0918 *[0.0857]*	−0.564 *** *[0.1954]*
(c) Degree of uncertainty	−0.153 * *[0.0821]*	−0.119 *[0.2250]*	−0.223 ** *[0.0985]*	−0.362 *[0.2854]*
(d) Degree of corruption control	−0.097 *[0.0717]*	−0.299* *[0.1666]*	−0.133 *[0.0917]*	−0.466 *** *[0.1635]*
(e) Degree of financial openness	−0.159 * *[0.0879]*	−0.218 * *[0.1128]*	−0.381 *** *[0.1315]*	−0.194 *[0.1341]*

Note: ***, **, and * represent the significance levels of 1%, 5%, and 10%, respectively. Robust standard errors are reported in parentheses. In order to save space, only the coefficient of *Uncertainty* is reported in the table. The estimated coefficients of control variables are available from the authors upon request.

Finally, we checked whether financial openness changed the relationship between uncertainty and R&D expenditures. This analysis may make sense, given that many R&D activities in some countries are partially or fully funded by foreign investors. The degree of financial openness was measured by the Chinn–Ito capital account openness index. The country with an annual average Chinn–Ito index above the sample median was classified into the "High-Financial-Openness Group" and the country with an index below the sample median was classified into the "Low-Financial-Openness Group". The estimated coefficients of *Uncertainty* for "High-Financial-Openness Group" and "Low-Financial-Openness Group" were reported in row (e)-column (i) and column (ii), respectively. The coefficients for the two groups were both negative and significant at the 10% level. This indicates that uncertainty, indeed, depressed R&D investment, despite the degree of financial openness in the specific country.

In short, our analyses on different country groups confirmed that uncertainty had an adverse influence on R&D investment, although the estimated negative coefficient of uncertainty lost statistical significance in several subsamples. Consistent with the main conclusion obtained from our full sample analyses reported in Table 3 and discussed in Section 4.1, the heterogeneity analyses based on different country subsamples also provide explicit support to Hypothesis 1. In contrast, Hypothesis 2 is rejected.

4.3.2. Patent Applications

In our full sample, we did not detect a significant impact of uncertainty on R&D personnel, as previously reported in Table 4 and discussed in Section 4.2.1. We also examined the effect on R&D personnel in different country groups, with country groups classified as we have just done in Section 4.3.1. Generally, we failed to find any obvious relationship between uncertainty and the number of R&D researchers. Hence, to save space, we do not report the detailed heterogeneity analysis results for R&D personnel here.

Next, we examined the heterogeneities across different country groups, regarding patent applications. We also divided our full sample into several groups of countries, according to five criteria: (a) level of income per capita, (b) ratio of R&D Investment to GDP, (c) degree of uncertainty, (d) degree of corruption control, and (e) degree of financial openness. The regression results for different groups are reported in columns (iii) and (iv) of Table 5. The core finding was analogous to the heterogeneity analysis for R&D investment, which can be sum-

marized as follows: uncertainty had a negative effect on patent applications, although the estimated negative coefficient of uncertainty was not always statistically significant.

5. Conclusions and Discussion

In summary, in this study, we reported a significantly negative impact of uncertainty on R&D investment at the country level. The analyses were based on a sample covering 109 countries from 1996 to 2018. It was also found that uncertainty reduced the number of annual new patent applications. The adverse impact of uncertainty on R&D was not only significant statistically, but also economically. According to the estimation results, if the uncertainty index rises by one unit (one standard deviation), the scale of R&D investment and the number of patent applications will decline by 15.6% (2.1372%) and 22.7% (3.1099%), respectively. Further analyses demonstrated that the effect of uncertainty was not uniform across all countries. In some country groups, the effect was strong and statistically significant. However, in several country groups, the effect was moderate and insignificant. However, we always observed a negative effect. Overall, Hypothesis 1 in our study is verified, and Hypothesis 2 is contradicted.

The study results provided strong support to some previous studies which reported a negative impact of uncertainty on R&D investment, including Arif Khan et al. [5], Cho and Lee [11], Czarnitzki and Toole [8], Goel and Ram [12], Ivus and Wajda [1], Jung and Kwak [15], Nan and Han [17], Wang et al. [4], and Xu [20]. The results did not support several studies that reported a positive effect of uncertainty, such as Atanassov et al. [3], Gu et al. [13], Han et al. [14], Jiang and Liu [6], Meng and Shi [16], Ross et al. [9], Stein and Stone [18], Tajaddini and Gholipour [7], and Vo and Le [19]. Our study utilized a wide sample of more than 100 countries and examined the country-level aggregate R&D investment. This feature enabled our study to better depict the overall situation in the world, compared to most of the extant studies, which have only focused on the R&D of business corporations within one country.

The findings in this study have important policy implications. First, in order to keep abreast of the R&D investment dynamics, governments and economic agents should pay attention to the degree of uncertainty in the economy. The negative impact of uncertainty on R&D is a phenomenon that widely exists in different countries over the world, as shown by our analyses on the full sample, as well as various subsamples. If governments can effectively monitor the variations in uncertainty and evaluate the relevant market responses, they will be able to understand the current situation and forecast future tendency of aggregate R&D investment in a better way. Being more informed will facilitate governments to make proper public policies if necessary. After understanding the link between uncertainty and R&D, firms can reasonably expect that other enterprises in the industry will adjust investment accordingly when uncertainty changes. During the procedure of making their own R&D investment plans, firms should not neglect the potential responses of the competitors and partners to varying uncertainty.

Second, given the importance of innovation and technological advancement for sustainable economic and social development, it is necessary to reduce the degree of macro-uncertainty. Governments should avoid frequent variations of economic policies and the abrupt implementation of substantial reforms. The communication and information sharing among governments and private sectors should be reinforced to reduce noises, mitigate misunderstanding, and enhance trust and confidence. Countries should also improve their institutional and economic infrastructure—for example, by reducing frictions in financial markets and strengthening governmental effectiveness—in order to increase the resistibility of economic system to unexpected shocks. In the case that the major origins of the uncertainty can be identified—such as the coronavirus pandemic in the current period—urgent actions should be carried out to deal with the problems.

Our study results also provide helpful insights to relevant academic research on R&D investment. For instance, when empirically exploring the determinants of R&D investment using regression models, researchers should not ignore the possible influence of uncertainty.

As our study has demonstrated the important impacts of uncertainty, failing to include this variable in the regression model may cause omitted variable bias and generate questionable results. Besides the empirical studies, the relationship between uncertainty and R&D can also be incorporated in theoretical economic models. An example is the endogenous growth model, which pays attention to the dynamics of innovative investment and accumulation of technologies in different stages of economic development. Taking into account the role of uncertainty may enrich the model structure and provide novel perspectives.

This study has several limitations that provide opportunities for future research. First, due to the lack of the data, we did not distinguish different categories of R&D investment. For instance, the R&D investment financed by business enterprises, private non-enterprises, government, universities, and research institutes may respond to uncertainty unequally. Uncertainty may not have a uniform influence on the R&D activities in different industries. In the future, researchers can investigate whether different types of R&D investment react to uncertainty in the same way. Second, we failed to differentiate different sources of uncertainties. For instance, the uncertainties arising from financial markets, industrial policies, international trade, and political reforms may cause various reactions of R&D investment within a country. Future studies can help us understand the uncertainty–R&D nexus more comprehensively, if researchers are able to collect data to distinguish different categories of uncertainties. Third, it is notable that there are boundaries between country-level and firm-level determinants of R&D investment. As the variables used in our empirical analyses were all measured at the country level, we neglected the heterogeneities among different enterprises. For example, the influences of uncertainty on firms may be moderated and mediated by many factors, such as the type of industry, market structure, managerial behavior, and financial condition. Our study result does not rule out the possibility that firms with some specific characteristics will expand R&D investment in response to increased uncertainty. Therefore, in the future, firm-level analysis about the relationship between R&D investment and uncertainty can still provide beneficial insights. Especially, an important research question is whether and why different firms react diversely to uncertainty.

Supplementary Materials: The following are available online at https://www.mdpi.com/2071-1050/13/5/2746/s1, Table S1: List of 109 sample countries and classification of country groups, Table S2: Estimated effect of uncertainty (measured by the index of stock market volatility) on R&D investment, Table S3: Estimated effect of uncertainty on R&D investment after mitigating the endogeneity issue, Table S4: Estimated effect of uncertainty on R&D investment based on the multi-year-average data, Table S5: Estimated effect of uncertainty on R&D investment based on a model investigating the possible structural change around 2008, Table S6: Estimated effect of uncertainty in different country groups with different innovative abilities.

Author Contributions: Data curation, formal analysis, and writing—original draft, Y.L.; Conceptualization, methodology, and writing—original draft, D.D.; validation, writing—original draft, and writing—review and editing, J.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets used and analyzed during the current study are available from the corresponding author on request.

Acknowledgments: The authors are grateful to the editors and four anonymous referees for their comments and suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Ivus, O.; Wajda, J. Fluctuations in Uncertainty and R&D Investment. *Centre for International Governance Innovation (CIGI) Papers No. 175*. **2018**, Available online: https://www.cigionline.org/publications/fluctuations-uncertainty-and-rd-investment (accessed on 30 September 2020).
2. Ahir, H.; Bloom, N.; Furceri, D. The World Uncertainty Index. *Work. Pap.* **2018**. [CrossRef]
3. Atanassov, J.; Julio, B.; Leng, T. The Bright Side of Political Uncertainty: The Case of R&D. *Work. Pap.* **2015**. [CrossRef]
4. Wang, Y.; Wei, Y.; Song, F.M. Uncertainty and corporate R&D investment: Evidence from Chinese listed firms. *Int. Rev. Econ. Financ.* **2017**, *47*, 176–200. [CrossRef]
5. Arif Khan, M.; Qin, X.; Jebran, K.; Ullah, I. Uncertainty and R&D investment: Does product market competition matter? *Res. Int. Bus. Financ.* **2020**, *52*, 101167. [CrossRef]
6. Jiang, H.; Liu, C. Economic policy uncertainty, CEO characteristics and firm R&D expenditure: A Bayesian analysis. *Appl. Econ.* **2020**, *52*, 3709–3731. [CrossRef]
7. Tajaddini, R.; Gholipour, H.F. Economic policy uncertainty, R&D expenditures and innovation outputs. *J. Econ. Stud.* **2020**. [CrossRef]
8. Czarnitzki, D.; Toole, A.A. Business R&D and the Interplay of R&D Subsidies and Product Market Uncertainty. *Rev. Ind. Organ.* **2007**, *31*, 169–181. [CrossRef]
9. Ross, J.M.; Fisch, J.H.; Varga, E. Unlocking the value of real options: How firm-specific learning conditions affect R&D investments under uncertainty. *Strateg. Entrep. J.* **2018**, *12*, 335–353. [CrossRef]
10. Baker, S.R.; Bloom, N.; Davis, S.J. Measuring Economic Policy Uncertainty. *Q. J. Econ.* **2016**, *131*, 1593–1636. [CrossRef]
11. Cho, S.H.; Lee, J. Estimating the uncertainty–R&D investment relationship and its interactions with firm size. *Small Bus. Econ.* **2020**. [CrossRef]
12. Goel, R.K.; Ram, R. Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries. *Econ. Lett.* **2001**, *71*, 287–291. [CrossRef]
13. Gu, X.; Chen, Y.; Pan, S. Economic Policy Uncertainty and Innovation: Evidence from Listed Companies in China. *Econ. Res. J.* **2018**, *2*, 109–123. (In Chinese)
14. Han, S.; Zhang, X.; Guo, J. Economic Policy Uncertainty, Political Background of Senior Managers, and R&D investment. *Friends Account.* **2020**, *13*, 79–87. (In Chinese)
15. Jung, S.; Kwak, G. Firm Characteristics, Uncertainty and Research and Development (R&D) Investment: The Role of Size and Innovation Capacity. *Sustainability* **2018**, *10*, 1668. [CrossRef]
16. Meng, Q.; Shi, Q. The Impact of Macroeconomic Policy Uncertainty on Enterprises' R&D: Theoretical Analysis and Empirical Study. *World Econ.* **2017**, *9*, 75–98. (In Chinese)
17. Nan, X.; Han, Q. The impact of strategic emerging industrial policy uncertainty on R&D investment. *Stud. Sci. Sci.* **2019**, *37*, 254–266. (In Chinese)
18. Stein, L.C.; Stone, E. The Effect of Uncertainty on Investment, Hiring, and R&D: Causal Evidence from Equity Options. *Work. Pap.* **2013**. [CrossRef]
19. Vo, L.V.; Le, H.T.T. Strategic growth option, uncertainty, and R&D investment. *Int. Rev. Financ. Anal.* **2017**, *51*, 16–24. [CrossRef]
20. Xu, Z. Economic policy uncertainty, cost of capital, and corporate innovation. *J. Bank. Financ.* **2020**, *111*, 105698. [CrossRef]
21. Ghirelli, C.; Pérez, J.J.; Urtasun, A. A new economic policy uncertainty index for Spain. *Econ. Lett.* **2019**, *182*, 64–67. [CrossRef]
22. Mumtaz, H.; Surico, P. Policy uncertainty and aggregate fluctuations. *J. Appl. Econom.* **2018**, *33*, 319–331. [CrossRef]
23. Sahinoz, S.; Erdogan Cosar, E. Economic policy uncertainty and economic activity in Turkey. *Appl. Econ. Lett.* **2018**, *25*, 1517–1520. [CrossRef]
24. Istiak, K.; Serletis, A. Economic policy uncertainty and real output: Evidence from the G7 countries. *Appl. Econ.* **2018**, *50*, 4222–4233. [CrossRef]
25. Bordo, M.D.; Duca, J.V.; Koch, C. Economic policy uncertainty and the credit channel: Aggregate and bank level U.S. evidence over several decades. *J. Financ. Stab.* **2016**, *26*, 90–106. [CrossRef]
26. Hu, S.; Gong, D. Economic policy uncertainty, prudential regulation and bank lending. *Financ. Res. Lett.* **2019**, *29*, 373–378. [CrossRef]
27. Li, X.; Luo, J.; Chan, K.C. Political uncertainty and the cost of equity capital. *Financ. Res. Lett.* **2018**, *26*, 215–222. [CrossRef]
28. Jory, S.R.; Khieu, H.D.; Ngo, T.N.; Phan, H.V. The influence of economic policy uncertainty on corporate trade credit and firm value. *J. Corp. Financ.* **2020**, *64*, 101671. [CrossRef]
29. Liu, P.; Dong, D. Impact of Economic Policy Uncertainty on Trade Credit Provision: The Role of Social Trust. *Sustainability* **2020**, *12*, 1601. [CrossRef]
30. Gulen, H.; Ion, M. Policy Uncertainty and Corporate Investment. *Rev. Financ. Stud.* **2016**, *29*, 523–564. [CrossRef]
31. Schauer, C. How asset irreversibility influences the investment-uncertainty relationship. *Bull. Econ. Res.* **2019**, *71*, 283–306. [CrossRef]
32. Czarnitzki, D.; Toole, A.A. Patent Protection, Market Uncertainty, and R&D Investment. *Rev. Econ. Stat.* **2011**, *93*, 147–159. [CrossRef]
33. Kulatilaka, N.; Perotti, E.C. Strategic Growth Options. *Manag. Sci.* **1998**, *44*, 1021–1031. [CrossRef]

34. Roper, S.; Tapinos, E. Taking risks in the face of uncertainty: An exploratory analysis of green innovation. *Technol. Forecast. Soc. Chang.* **2016**, *112*, 357–363. [CrossRef]
35. Chappin, M.M.H.; Faber, J.; Meeus, M.T.H. Learning patterns in early stage R&D projects: Empirical evidence from the fibre raw material technology project in the Netherlands. *R&D Manag.* **2019**, *49*, 684–695. [CrossRef]
36. Khanna, R.; Guler, I.; Nerkar, A. Fail Often, Fail Big, and Fail Fast? Learning from Small Failures and R&D Performance in the Pharmaceutical Industry. *Acad. Manag. J.* **2015**, *59*, 436–459. [CrossRef]
37. Rhaiem, K.; Amara, N. Learning from innovation failures: A systematic review of the literature and research agenda. *Rev. Manag. Sci.* **2019**. [CrossRef]
38. Pisano, G.P. Learning-before-doing in the development of new process technology. *Res. Policy* **1996**, *25*, 1097–1119. [CrossRef]
39. Leiblein, M.J.; Chen, J.S. Whether and How Does Learning Curve Uncertainty Affect Early Mover Advantage? *Acad. Manag. Proc.* **2020**, *2020*, 12042. [CrossRef]
40. Majd, S.; Pindyck, R.S. The Learning Curve and Optimal Production under Uncertainty. *RAND J. Econ.* **1989**, *20*, 331–343. [CrossRef]
41. Mazzola, J.B.; McCardle, K.F. The Stochastic Learning Curve: Optimal Production in the Presence of Learning-Curve Uncertainty. *Oper. Res.* **1997**, *45*, 440–450. [CrossRef]
42. Lieberman, M.B. The Learning Curve and Pricing in the Chemical Processing Industries. *RAND J. Econ.* **1984**, *15*, 213–228. [CrossRef]
43. Ek, K.; Söderholm, P. Economics of Technology Learning in Wind Power. In *Encyclopedia of Energy, Natural Resource, and Environmental Economics*; Shogren, J.F., Ed.; Elsevier: Waltham, MA, USA, 2013; pp. 188–194. [CrossRef]
44. Diallo, O. Tortuous road toward countercyclical fiscal policy: Lessons from democratized sub-Saharan Africa. *J. Policy Model.* **2009**, *31*, 36–50. [CrossRef]
45. Jalles, J.T. Fiscal rules and fiscal counter-cyclicality. *Econ. Lett.* **2018**, *170*, 159–162. [CrossRef]
46. Jha, S.; Mallick, S.K.; Park, D.; Quising, P.F. Effectiveness of countercyclical fiscal policy: Evidence from developing Asia. *J. Macroecon.* **2014**, *40*, 82–98. [CrossRef]
47. Pellens, M.; Peters, B.; Hud, M.; Rammer, C.; Licht, G. Public Investment in R&D in Reaction to Economic Crises—A Longitudinal Study for OECD Countries. *ZEW Discussion Paper No. 18-005*. **2018**, Available online: http://ftp.zew.de/pub/zew-docs/dp/dp18005.pdf (accessed on 30 September 2020).
48. Sarkar, S. Attracting private investment: Tax reduction, investment subsidy, or both? *Econ. Model.* **2012**, *29*, 1780–1785. [CrossRef]
49. Tee, L.T.; Low, S.W.; Kew, S.R.; Ghazali, A.N. Financial Development and Innovation Activity: Evidence from Selected East Asian Countries. *Prague Econ. Pap.* **2014**, *23*, 162–180. [CrossRef]
50. Hsu, P.H.; Tian, X.; Xu, Y. Financial development and innovation: Cross-country evidence. *J. Financ. Econ.* **2014**, *112*, 116–135. [CrossRef]
51. Svirydzenka, K. Introducing a New Broad-based Index of Financial Development. *IMF Working Paper 16/5*. **2016**, Available online: https://www.imf.org/external/pubs/ft/wp/2016/wp1605.pdf (accessed on 30 September 2020).
52. Chinn, M.D.; Ito, H. What matters for financial development? Capital controls, institutions, and interactions. *J. Dev. Econ.* **2006**, *81*, 163–192. [CrossRef]
53. Bhattacharya, U.; Hsu, P.H.; Tian, X.; Xu, Y. What Affects Innovation More: Policy or Policy Uncertainty? *J. Financ. Quant. Anal.* **2017**, *52*, 1869–1901. [CrossRef]
54. Gholipour, H.F. The effects of economic policy and political uncertainties on economic activities. *Res. Int. Bus. Financ.* **2019**, *48*, 210–218. [CrossRef]
55. Kalamova, M.; Johnstone, N.; Haščič, I. Implications of Policy Uncertainty for Innovation in Environmental Technologies: The Case of Public R&D Budgets. In *The Dynamics of Environmental and Economic Systems: Innovation, Environmental Policy and Competitiveness*; Costantini, V., Mazzanti, M., Eds.; Springer: Dordrecht, The Netherlands, 2013; pp. 99–116. [CrossRef]
56. Saleem, H.; Wen, J.; Khan, M.B. The impact of economic policy uncertainty on the innovation in China: Empirical evidence from autoregressive distributed lag bounds tests. *Cogent Econ. Financ.* **2018**, *6*, 1514929. [CrossRef]
57. He, F.; Ma, Y.; Zhang, X. How does economic policy uncertainty affect corporate Innovation?–Evidence from China listed companies. *Int. Rev. Econ. Financ.* **2020**, *67*, 225–239. [CrossRef]