# Geopolitical Risk and Technological Innovation

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**Abstract**

We investigate the relation between geopolitical risk and firm level technological innovation outcome. We find that firms' innovation output reduces when geopolitical risk rises, and the innovation is impacted more by geopolitical threats than acts. To address endogeneity issues, we adopt an instrument variable approach and still find the consistent results. Moreover, the loss of human capital that matters to corporate innovation and lowered risk tolerance amid increased GPR are plausible channels through which geopolitical risk adversely impacts firm innovation outcomes. Our results suggest that geopolitical risk has significant impact on the real economy.



**Keywords:** *Geopolitical risk; Technological innovation; Risk taking; R&D investment; Human capital*



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# Geopolitical Risk and Technological Innovation


**Abstract**

We investigate the relation between geopolitical risk and firm level technological innovation outcome. We find that firms' innovation output reduces when geopolitical risk rises, and the innovation is impacted more by geopolitical threats than acts. To address endogeneity issues, we adopt an instrument variable approach and still find the consistent results. Moreover, the loss of human capital that matters to corporate innovation and lowered risk tolerance amid increased GPR are plausible channels through which geopolitical risk adversely impacts firm innovation outcomes. Our results suggest that geopolitical risk has significant impact on the real economy.



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## 1. Introduction

Does geopolitical risk influence the real economy? Geopolitical risk is a risk that can arise not only from war or terrorism but also from economic sanctions or cancellation of trade deals. Unlike political risk which is broader and covers intra-country political conflicts such as riots or civil war, geopolitical risk deals with only inter-country conflicts. The recent global pandemic of 2020 has seen the rise of geopolitical risks among economic superpowers, like the U.S. and China[1]; to such extent that top analysts expect it will have repercussions on stock markets globally [2]. Despite its tremendous impact on all forms of financial activities, to the best of our knowledge there are very few studies on how geopolitical risk (henceforth GPR) affects real corporate decisions and outcomes. This paper fills this gap in the literature by studying the impact of GPR on corporate innovation.

While innovation is affected by firm-specific risks which are to some extent idiosyncratic (Biais et al., 2015, Hsu et al., 2015, Jia, 2018), firms should be more concerned about the effect of exogenous risk rather than firm-specific risks. Unlike firm-specific risks that can be reduced through diversified portfolio (Markowitz, 1952), exogenous risks or uncertainties such as GPR cannot be controlled by firms and hence it is important to understand how such risks affect corporate innovation. The exogenous nature of GPR is expected to have profound effect on innovation outputs. Uncertainty in general is known to reduce corporate innovation (e.g., Bhattacharya, Hsu, Tian, & Xu, 2017; Xu, 2020). However, some studies have suggested different views on how risk, or uncertainty, affect corporate innovation. Oi (1961), Hartman (1972) and Abel and Eberly (1994) all claim that there is a convex relation between corporate innovation and uncertainty, from the effect on investment. This means although initially investment may reduce with uncertainty increases, but after a certain period it will start to rise again.

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[1] See https://www.cnbc.com/2020/05/08/coronavirus-us-china-tensions-increase-beijing-seeks-more-influence.html

[2] See https://www.cnbc.com/2019/12/23/markets-cannot-ignore-major-geopolitical-events.html

The reason of the conflicting predictions and empirical findings on the relationship between uncertainties and corporate innovation is that there are many forms of uncertainties or risks faced by firms. A central challenge in examining the effect of GPR, therefore, is to differentiate GPR from other uncertainties. To overcome this challenge, we take advantage of the Geopolitical Risk Index (henceforth, GPR Index) developed by Caldara and Iacoviello (2018). GPR index is a monthly index based on the frequency of news articles that cover key terms related to geopolitical risk and threat from 11 international newspapers, which cover most geopolitical events that US is involved. In addition, this index doesn't systematically spike or plunge, unlike many other types of exogenous uncertainty proxies. Thus, this index can help differentiate the effect of GPR from other types of uncertainties.

Notably, a few recent studies use this index to study the effect of geopolitical risk on financial outcomes, such as Wang et al. (2019), Dissanayake et al. (2019), and Pan, (2019). Their findings suggest firms invest less on their fixed assets as well as on the R&D relevant projects when geopolitical risk rises. In this study, we focus on the effectiveness and outcome of corporate investment activities-corporate innovation. Our findings suggest a negative impact of GPR on corporate innovation outcome, proxied by the number of patents and citations. We conduct further analysis on our baseline findings and show that our results remain consistent. Our findings persist even after we control for macroeconomic uncertainty and stock market volatility. In order to deal with endogeneity concerns we conduct two-stage least square regression using religious tension as an instrumental variable. We find that religious tension has a positive impact on GPR in our first stage results. In the second stage we see that increase in religious tension makes the negative association between GPR and innovation more pronounced.

We then examine the possible mechanisms through which GPR influences innovation outcome. First, we conjecture that GPR would re-shift corporations' risk-taking profile. Innovation is about taking risk (see e.g., Holmstrom, 1989). Hence it is highly likely that firms become less risk-taking amid higher GPR. Thus, risk taking can be a possible mechanism if there is a negative association between the geopolitical risk and firms' risk-taking. Our findings support this hypothesis as we find GPR to have a negative relation with firm risk-taking ability. The input for innovation comes from investment in R&D. Therefore, it can be expected that the relation of GPR and innovation can also be influenced by the amount of corporate investment in R&D by firms. Our paper finds that GPR in fact affects R&D investments negatively.

Another channel through which GPR may affect innovation that is investigated is firms' inventor mobility. Based on innovation literature, the inventor mobility is measured by the change in inventors' inflow and outflow of a firm. Positive value of inventor mobility suggests that the firm has more inventors moving in than moving out and negative value means just the opposite. Chemmanur, Kong, Krishnan, & Yu (2019) finds inventor mobility to be a valid channel for factors that affect firm innovation output. In addition, Kaiser, Kongsted, & Rønde (2015) find a significant positive association between inventor mobility and firm innovation output. These studies imply that inventor mobility can be a possible mechanism that impacts the relation between GPR and innovation outcome. Exogenous risk, such as credit supply shocks, are known to have a negative impact on inventor mobility (Hombert and Matray, 2016). Hence, it is expected that GPR, being exogenous, may also have a negative impact on inventor mobility. The reduction of inventor mobility due to an increase in GPR may be the reason for innovation output of firms to fall. We test this hypothesis in this study and find that GPR induces inventor outflow more than inflow.

The existing innovation literature have found several determinants for firm's technological innovation output including exogenous risks from various sources. However, there are still no studies that investigated the relationship between geopolitical risk as a determinant of innovation output. This makes our study one of the first to investigate this research question and contribute to the extant innovation literature. Our study also contributes to the understanding of the impact of exogenous risk, such as geopolitical risk, on real corporate policy making.

The rest of the paper is organized as follows: We report data, sample, and variables in Section 2. We present empirical results in Section 3. We present identification strategy in Section 4. We conduct robustness tests in Section 5. We present additional test results in Section 6. Section 7 concludes.

## 2. Data, Sample and Variables

### *2.1 Sample Selection*

Our sample includes firms with available observations on both Compustat and Center for Research in Security Prices (CRSP) from 1985 to 2017. We use 1985 the starting year to match the availability of the GPR Index, developed by Caldara and Iacoviello (2018); and use 2017 the ending year to match the innovation data. The initial dataset consisted of 5801 firms for 33 years. If there is missing value for any variable, then the entire observation is not included in our result estimation. Following literature, we exclude financial and utility firms, as defined by Standard Industrial Classification (SIC) codes from 6000 to 6999 and from 4901 to 4999, from the sample. After applying these filters, it leaves us 38,064 firm-year observations. We winsorize all variables at $1^{st}$ and $99^{th}$ percentile.[3]

### *2.2 Variable Construction*

#### *2.2.1 Measuring Geopolitical Risk*

We measure geopolitical risk using the Geopolitical Risk Index (GPR Index) developed by Caldara and Iacoviello (2018). This is a relatively new index that covers the period of 1985 until present time. This time period includes some major geopolitical and financial events such as the

[3] Some exceptions apply. For a few variables, such as leverage, cash flow, KZ-Index and Return on Asset, which are still highly skewed after being winsorized at 1 and 99 percentiles. We winsorized them at 5 and 95 percentiles.

Gulf war, 9/11 attack, the Afghanistan and Iraq war as well as the global financial crisis. Figure 1 shows a trend graph of the GPR Index values and we see that the graph peaks during those significant events. The graph peaks in between January 1990 and April 1991 during which the Gulf war took place. Again, it spikes sometime after April 2001 when the 9/11 attack happened followed by the Afghanistan war. Then there is a major rise in the index value between July 2002 and October 2003 when the Iraq war occurred. In the last few months since January 2020 the graph has risen again capturing the high geopolitical risk caused due to the global pandemic. One thing that is noticeable from the graph is that the GPR Index value did not rise during the 2008 global financial crisis. This shows that the index is quite accurate to distinguish between financial risk and geopolitical risk. This distinguishing factor makes it more reliable compared to other geopolitical measures that are more broadly defined

The GPR index is a news-based index that captures the monthly measure of geopolitical risk for each country. It runs automated text-searches in electronic archives of eleven renowned newspapers and counts the number of times any word associated with geopolitical risk is mentioned. The count is then normalized to an average out of 100. The text-search program looks for specific words that are categorized in to five groups namely: Geopolitical threats, Nuclear threats, War threats, Terrorist threats, War acts, Terrorist acts. Furthermore, the index value is also segregated into threats and acts. Geopolitical threat (GPT) Index is the measure of potential geopolitical events that might occur, while Geopolitical acts (GPA) Index is the measure of actual events happening. These two sub-index measures are also collected along with the main GPR index data for this study. As the indices are monthly datasets, in our study we have taken the twelve-month average of the measures to get our annual values of GPR, GPT and GPA Index. We use the natural log of all three index measures in this study to reduce the skewness in their distribution.

Caldara and Iacoviello (2018) test their GPR Index for endogeneity issues through granger causality test and claim that their measure is quite exogenous. They find that most macroeconomic, financial and other forms of uncertainty measures do not cause GPR. The exogenous nature of the GPR Index has made it a valid measure of geopolitical risk within the academic literature. Berg and Mark (2018) find it to be useful in understanding currency excess returns. While others find it to be an important determinant of oil price (Antonakakis et al., 2017, Mei et al., 2020). The effectiveness and robustness of GPR Index as a proxy for geopolitical risk is unparalleled till now and hence, we have selected this as the measure of our primary independent variable.

#### *2.2.2 Measuring Innovation*

We use patent count and citation-weighted patent data from Kogan, Papanikolaou, Seru and Stoffman (2017) database (henceforth KPSS) to measure innovation output. KPSS data is originally sourced from US Patent Office (USPTO). Past innovation studies have mostly obtained the patent data from NBER (Chemmanur and Tian, 2018, He and Tian, 2013). However, in recent times KPSS database has been preferred over NBER as NBER data is only at patent level but KPSS data is at firm-level; and it connects firm identifiers to the patent numbers (Xu, 2020, Chemmanur et al., 2019). This helps us to merge patent data with firm-level data from Compustat database. Furthermore, the patent data in NBER is updated only till 2006 while the data is updated till 2017 in KPSS. The citation-weighted patent data, however, is yet to be updated and it is available till 2010 only. Nonetheless, we acquire the data for both innovation output measures for our study. Both the innovation variables, the number of patents and citation-weighted patents are skewed to the right so that is why we use the natural logarithm of the variables in our estimation.

One of the challenges we face in this study is that the innovation data are fraught with truncation bias. The first type of truncation bias occurs with patents as they are granted a few years later (2-3 years approximately) from the year of application. This means that GPR Index value in a given year may have a lagged effect on the patent and citation counts of the firm. We adjust this bias by taking the third-year lead variable of patent counts; and by using the filing year of the patent rather than grant year. The second type of truncation bias occurs with citation counts. The data available on citation is till 2010, which means all citation counts are till that year. However, we know that patents can get more citations in the coming years. Furthermore, patents filed in the last few years of the sample do not get enough opportunity to accumulate more citations compared to the patents filed in the beginning of the sample. This bias is adjusted by using the citation-weighted patents measure instead of the citation counts as suggested and computed by Kogan et al. (2017).

#### *2.2.3 Control Variables*

We follow the extant innovation literature to include a vector of control variables in our empirical analysis. Firstly, we control major firm characteristics known to effect innovation outcome, such as firm size (measured by natural logarithm of book value of assets), firm age (natural logarithm of number of years since IPO date), investment in intangible asset (R&D expenditure scaled by one year lagged value of total asset), profitability (ROA), asset tangibility (net PPE scaled by total asset), leverage (percentage of debt over total asset), capital expenditure (scaled by one year lagged value of total asset), growth opportunities (Tobin's Q), financial constraint (KZ-Index), and cashflow (scaled by total asset). To control the effect of equity market and product market competition on innovation outputs, we control for Amihud ratio as a measure of illiquidity and Herfindahl-Hirschman Index (sum of squared market shares of firms' sales at two-digit SIC industry level).

## 3. Baseline Results

### *3.1 Summary Statistics*

Table 1 provides the summary statistics for the dependent, independent and firm-level control variables. Based on the results in the table, the average natural log value of our patents is

1.270. This means in our sample for each firm-year the average number of patents are approximately 3.45 patents. Whereas the average natural log value of citation-weighted patents is 1.593 that constitutes to 4.91 citation-weighted patents approximately for each firm-year. Among the other variables whose natural logarithm are used it can be deduced that the book value of assets on average is $234.63 million dollars, and the number of years since IPO on average is 11.53 years. The primary independent variable GPR Index is country-level data and according to the summary statistic on average its value is 68.37% per year. All the other control variables are stated in their original form but only scaled by total assets. The mean value provided are the mean of the scaled values per firm-year.

### *3.2 Baseline Results*

We estimate the relation between geopolitical risk and technological innovation through OLS regression for the following model:

$$Innovation_{it+j} = \beta_0 + \beta_1 X_{it} + \beta_2 Z_{i,t} + Firm_i + \varepsilon_{i,t+j} \quad (1)$$

where *i* indexes firms, *t* indexes time and *j* indexes the number of years the said variable is ahead of time *t*. The dependent variable, $Innovation_{it+j}$, represents the innovation outcome of *i* firms in the form of log of number of patents (*Patents*) or log of citation-weighted patents (*CitationPat*). The dependent variables are lead variables of either one-year (*t+1*) or three-years ahead (*t+3*) of time *t*[4]. The independent variable, $X_{it}$, represents the geopolitical measures which are log of geopolitical risk (*GPR*), log of geopolitical threat (*GPT*) and log of geopolitical act (*GPA*), all at time *t*. Since the geopolitical measures are at country level and varies over time only, but remains firm-invariant, hence we use firm fixed effect only and not time fixed effect. This is captured by $Firm_i$. If time fixed effect was used, then it would have absorbed all the explanatory power of the geopolitical measures. $Z_{i,t}$ is a vector of firm-specific control variables, that are discussed in Section 2.2.3, as

[4] Two-year lead patent and citation weighted patent variables are also used initially to estimate the regression and they gave similar results

having some form of effect on firm's innovation output. We cluster the standard errors at firm level. $\beta_1$ and $\beta_2$ are the coefficients for the dependent and control variables respectively, while $\beta_0$ and $\varepsilon_{i,t+j}$ are the intercept and error term respectively.

We report the results of the baseline regression in Table 2. The coefficients of *GPR* in all the columns of the table are negative and significant suggesting that higher GPR reduces innovation outcome and quality for firms. However, the effects on both lead variables of *Patents* are stronger, i.e. more negative, than the effects on the two lead variables of *CitationPat*. According to the results, 1% increase in GPR reduces number of patents the following year by 0.112% and after three years by 0.104%. While, a 1% increase in GPR reduces citation-weighted patents in the following year by 0.097% and after three years by 0.066%. Citations start accumulating only once the patent has been granted. Hence, citations of patents that are already granted may not reduce as much as patents when GPR rises, resulting in the lower negative coefficient of citation-weighted patents compared to that of patents. With regards to the estimation results of the control variables newer firms with more investment in fixed asset and R&D, as well as lower leverage and higher Tobin's Q are found to be more innovative. In addition, firms with increasing cashflow and operating in lower market competition increases the patent counts but does not have any significant impact on citation-weighted patents. Profitability of the firms tend to reduce innovation in the first year but by the third year it shows no significant effect. It was also seen that financial constraints and stock illiquidity do not have any significant impact on innovation outcome of firms.

When the GPR Index was replaced by the natural log of the two sub-indices: geopolitical threats (*GPT*) and geopolitical acts (*GPA*), the results in Table 3 shows that effects of GPT are significant on both innovation measures. GPT reduces firm's number of patents as well as citation-weighted patents but the effect on number of patents is more pronounced. 1% increase in GPT reduces firm patents by 0.105% but it reduces citations by 0.064%. While the effects of GPA are not significant on any of the innovation measures. The direction of impact of all the control variables, except ROA, remain the same with the sub-indices as they were with GPR Index. The effect of ROA, which represents profitability, is insignificant for all innovation measures in Table 3.

## 4. Possible Mechanisms

Our results so far have shown that firms' innovation output decrease with the increase of geopolitical risk. In this section we investigate the possible mechanisms through which geopolitical risk influences innovation outcomes.

### *4.1 Firm Risk-Taking and R&D Investment*

Innovation is about taking risk (see e.g., Holmstrom, 1989). Hence it is highly likely that a firm's risk-taking ability is the reason for the relation between innovation outcome and geopolitical risk. There are studies that has empirical evidence that CEOs with high risk tolerance are keen on making risky R&D investments (Sunder et al., 2017, Hirshleifer et al., 2012, Custódio et al., 2017). The risk-tolerance level of CEOs creates a high risk-taking envnironment within the firm. The corporate risk-taking ability can be a possible mechanism in this study if there is signficant negative association between the geopolitical risk and risk-taking ability. With increase in geopolitical risk, the resources firms use to survive in high-risk environment can become vulnerable which may lead to lowering of their risk-taking ability. To prove this hypothesis we follow Faccio, Marchica & Mura (2011) and develop a model. The model is as follows:

$$Risk\ Taking_{it+j} = a_0 + a_1 GPR_{it} + a_2 C_{it} + Firm_i + \mu_{i,t+j} \quad (2)$$

where *i* indexes firms, *t* indexes time and *j* indexes the number of years the said variable is ahead of time *t*. The dependent variable, $Risk\ Taking_{it+j}$, is a measure for corporate risk-taking ability

($\sigma dROA$) as suggested by Faccio et. al. (2011). It is the standard deviation of the difference between firm ROA and 4-digit SIC-based industry-mean ROA with a 5-year rolling window. ROA represents profitability and by taking the difference with industry mean we adjust for any industry-level biases resulting in a cleaner measure of the level of risk resulting from corporate operating decisions (Faccio et. al., 2011). In order to get the risk-taking measure, we make sure that the standard deviation is calculated only when there is a minimum of five consecutive observations. The primary independent variable, $GPR_{it}$, is the Geopolitical Risk Index measure followed by a series of control variables denoted by $C_{it}$. We use the controls commonly used in corporate risk-taking studies which are: firm size, firm age, return on asset, leverage and 1-HH Index. $a_1$ and $a_2$ are the coefficients for the dependent and control variables respectively, while $a_0$ and $\mu_{i,t+j}$ are the intercept and error term respectively. Similar to equation 1, this model also has a firm-fixed effect term, $Firm_i$.

Panel A of Table 4 displays the results of this model's estimation where the dependent variables are the risk-taking ability at time $t$, $t+1$ and $t+3$. The results show that the effect of geopolitical risk on corporate risk-taking ability is negative and significant for all the risk-taking variables. The magnitude of the effect gradually diminishes as we move forward in time. Estimation results suggest that the risk-taking ability of firms tend to lower when exposed to increasing geopolitical risk. This perhaps is the reason why these firms produce lesser number of patents indicating that risk-taking ability is an important channel for the effect of geopolitical risk on innovation outcome.  But risk-taking ability may not be the only mechanism for the negative association between GPR and innovation.

Similar to firm's risk-taking ability, the R&D investment of firm is also a possible channel for the relation between GPR and innovation. R&D investment is the input for patents, and so, any factor that affects R&D investment also affects innovation output. Hence, it is important to check the possibility of R&D investment as another mechanism for the negative association between geopolitical risk and innovation outcome. High risk environment has always been detrimental for investment. With corporate investments such as R&D, which requires huge commitment, it can be presumed that firms will take the wait and see policy during times of high risk. As a result, it can be hypothesized that R&D investment will reduce when geopolitical risk rises. We develop the following model to test this hypothesis:

$$R\&D_{it+j} = \gamma_0 + \gamma_1 GPR_{it} + \gamma_2 N_{it} + Firm_i + v_{it+j} \quad (3)$$

where *i* indexes firms, *t* indexes time and *j* indexes the number of years the said variable is ahead of time *t*. The dependent variable in the model is the research and development investment ($R\&D_{it+j}$) of the firm where index *j* takes on the values 0, 1 and 3. The primary independent variable, $GPR_{it}$, is the geopolitical risk measure and then the models have a series of control variables denoted by $N_{it}$. The control variables are the same ones used in equation 1 excluding R&D which is the dependent variable here. $\gamma_0$ is the intercept and $v_{it+j}$ is the residual, while $\gamma_1$ and $\gamma_2$ are the coefficients for the dependent and control variables respectively. $Firm_i$ is the firm-fixed effect term.

Panel B of Table 4 shows the estimation results of this model with three different time periods *t*, *t+1*, and *t+3* of R&D as dependent variables. The results show significant negative association between GPR and R&D investment. The coefficient of GPR for the model with R&D time period *t* has the highest magnitude of negative coefficient. These results suggest that R&D investment reduces with increasing geopolitical risk and this could be the reason why innovation output in future years decreases.

*4.2 Inventor Mobility*

Inventors are employees of the firm who are primarily responsible for increasing firm's innovation output through their inventions. Keeping inventors motivated to remain in the firm is important for the innovation growth of the firm. Kaiser, Kongsted & Rønde (2015) finds empirical evidence that the more inventors come in to the firm as opposed to leaving it, the higher the firm innovation output. The difference between the inventor inflow and outflow of a firm is commonly known as inventor mobility. Exogenous shocks have been found to affect inventor mobility (Hombert and Matray, 2016). Hence, it may be expected that GPR, being exogenous, may also have a significant impact on inventor mobility. In this section we test inventor mobility of firms as a possible channel for the relation between GPR and innovation by estimating the following model:

$$InvMob_{it+j} = \lambda_0 + \lambda_1 GPR_{it} + \lambda_2 H_{it} + Firm_i + \tau_{it+j} \quad (4)$$

where $i$ indexes firms, $t$ indexes time and $j$ indexes the number of years the said variable is ahead of time $t$. The dependent variable, $InvMob_{it+j}$, is a measure of inventor mobility called Inventor Net Inflow, calculated based on the method suggested in Chemmanur, Kong, Krishnan, & Yu, (2019). The U.S. Patent Inventor Database is collected from the Harvard Business School Dataverse which has the details of inventor name, address, assignee names, application and grant dates of patents. The data is updated till the year 2009. From there the move-in and move-out dates of an inventor is determined. This is done with the assumption that the application year of the inventor's first patent in a firm is the move-in date and the application year of the inventors first patent in a following firm is the move-out date. All the move-ins and move-outs are accumulated for each firm and then the difference between the move-ins and move-outs results in the inventor net inflow of the firm. If the value of the inventor net inflow is positive it means, that more inventors moved-in to the firm than inventors moving out. The opposite is true when the inventor net inflow is negative. The primary independent variable, $GPR_{it}$, is the geopolitical risk index measure. $H_{it}$ is the set of control variables which are the same ones used in equation 1. $\lambda_0$ is the intercept and $\tau_{it+j}$ is the residual, while $\lambda_1$ and $\lambda_2$ are the coefficients for the dependent and control variables respectively. $Firm_i$ is the firm-fixed effect term.

The estimation results for this model in Table 5 shows that geopolitical risk have negative and significant impact on inventor mobility measures of time period $t$, $t+1$ and $t+3$. The coefficient of GPR in the model with mobility measure for *t+3* shows the largest impact. The results indicate that more inventors move out of firms at times of increasing geopolitical risk causing the firms to generate lower innovation outcome. Inventor mobility can be an important mechanism through which geopolitical risk can affect the innovation outcome of firms.

## 5. Robustness

### *5.1 Endogeneity Issues*

While Caldara and Iacoviello (2018) claim the GPR Index is considerably exogenous there might still be some endogeneity concerns. The endogeneity issue might arise from any omitted variable which is associated with GPR and affects innovation only through this association. The most common approach to deal with endogeneity is to choose an instrumental variable for the endogenous independent variable. We use an instrumental variable for the GPR Index that is the religious tension index of The International Country Risk Guide (hereafter, ICRG) which is collected from Harvard Dataverse.

Religious tension is one of the twelve weighted variables used by ICRG for their Political Risk Rating[5]. According to ICRG, their religious tension measure stems from domination of society or governance by a single religious group. It can also arise when countries replace their civil law with religious law. It is a country-level measure on a scale of six points, with six being the points given to the country with the least religious tension. This form of scoring is counter intuitive because a higher value of religious tension index may be perceived as the country with the most tension due to religion. In order to align the score with this perception we multiplied negative one with the given values of religious tension index by ICRG. In addition, we scale the religious tension

[5] We regressed GPR on all twelve variables used by ICRG Political Risk Rating and found religious tension to be the most significant one that affects GPR.

index values by six to get a percentage value. This transformed variable is used in our two-stage least square estimation to analyse the effect of the instrument.

Table 6 reports the two-stage least square (TSLS) estimation results with religious tension as the instrumental variable and GPR as endogenous. The first and third columns report the first stage regression results. We find that religious tension is positively and significant related to GPR suggesting that it was indeed a valid instrument. We have further conducted few identification tests and those test results also suggest the validity of our instrument. The second stage regression results are not significantly different from our OLS outputs. GPR still affects the innovation output of firms negatively. Although the magnitude of the coefficient from TSLS of GPR on patent count remains very close to that of our OLS regression, but the magnitude of the coefficient of GPR on citation-weighted patents from TSLS decreased from our OLS results. Since the sign and significance of the coefficients remain the same, we can say that the relation between innovation and GPR is not affected by any endogeneity issues.

*5.2 Controlling Macro Environment*

We test for the robustness of our findings in our baseline regression by controlling for other exogenous variables that represent the macro environment of firms and might affect innovation outcome of firms but do not affect GPR. We focus on the macroeconomic and financial market uncertainties. In order to capture the macroeconomic uncertainty, we use the index developed by Jurado, Ludvigson and Ng (2015). This index data is provided monthly, calculated in three versions: one-month ahead, three-months ahead and twelve-months ahead. We use the annual average of twelve-months ahead values of Macroeconomic Uncertainty Index (henceforth MU Index). We also use the stock market volatility data (VXO) that we collected from Chicago Board Options Exchange (CBOE) online database to proxy the financial market uncertainties. As we have seen in Figure 1, GPR Index does not reflect shocks in financial markets like the global financial crisis in 2008. Hence to control for such financial shocks the inclusion of the volatility of VXO is vital.

With the inclusion of the two exogenous control variables we attempt to capture both economic and financial market uncertainties and we tabulate our OLS results in Table 7. The results show that the negative relation between GPR and technological innovation of firms still remains and is more pronounced when the macroeconomic and financial market uncertainties are controlled. However, with citation-weighted patents as dependent variable the negative association is not as pronounced as it is without the exogenous controls. We find that the macroeconomic uncertainty (MU) is not significantly related with patent counts but is negatively and significantly related with citation-weighted patents. This means that if MU Index increases by 1% then firm patent counts may not be affected but citation-weighted patents may reduce by 1.53% approximately. On the other hand, stock market volatility has a positive and significant effect on both innovation output. However, the effect is much smaller than the effect of GPR. We have addressed the issue whether macro level omitted variables change the relation of GPR and innovation. These results confirm that the negative impact of GPR on innovation output is significant and robust.

*5.3 Alternative GPR Measures*

Our baseline result uses the mean value of monthly GPR index value to represent the annual measure for geopolitical risk. By taking the log transformed value of the mean GPR the effect of some of the significant geopolitical events may have been reduced. Hence, we use another measure of central tendency, the median, to annualize the monthly GPR measures. The estimation results when using median value of monthly GPR is provided in Panel A of Table 8. These results show that the relation between GPR and innovation outcomes are still negative and significant. The magnitude of the coefficient of median GPR on both patents and citation-weighted patents are more negative than the coefficient of the mean GPR that are shown in Table 2. The persistent negative association of all median geopolitical measures on the innovation outcome suggests that our baseline results in Table 2 are robust.

Engle and Martins (2020) develop a new measure for geopolitical risk, called Geovol, that is based on volatility of the capital market. They have found co-movement between a portion of the idiosyncratic volatility of several financial markets across the world, which is assumed to have been caused by geopolitical risk. The paper extracted this common movement of the idiosyncratic volatility, calling it Geovol[6], and proposed that it can be used as a proxy measure for geopolitical risk. The data of Geovol is updated from 2000 onwards with daily estimates. In this paper we take the annual mean of the daily estimates of Geovol, from 2000 till 2017, as an alternative measure of geopolitical risk.

Panel B of Table 8 presents the results of the OLS regression of patents and citation-weighted patents on Geovol. These results show that the negative association between geopolitical risk and patents is still significant when using the alternative measure, Geovol. The magnitude of the coefficients for the Geovol variable in Panel B of Table 8 is higher than the coefficient of GPR Index we saw in Table 2. In addition, the results in Panel B of Table 8 shows that Geovol have no significant impact on the citation-weighted patents of firms. Both news-based measure, GPR Index, and market-based measure, Geovol, show a strong negative association with the number of patents of firms. However, in case of the citation-weighted patents the news-based measure, GPR Index, has a significant and negative association unlike the market-based measure.

*5.4 Exclusion of Significant Geopolitical Events*

In figure 1 the distribution of the monthly GPR values shows very steep rise during significant geopolitical events. We test to see whether the negative association between GPR and innovation is only due to those significant events or does it occur during at any level of GPR. We identify the years of the major geopolitical events based on figure 1. Next, we remove observations during each of those events one by one and have estimated the relation between GPR and the

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[6] We collected the estimates of Geovol measure from the V-Lab website of Stern Business School, NYU. Website: https://vlab.stern.nyu.edu/analysis/GEORISK.COUNTRY-GD.GEOVOL

innovation outputs. Finally, we remove all the significant events together and estimate the results again. The results presented in Table 9 show that in all our estimation the strong negative association between GPR and patents and citation-weighted patents persists. Particularly, when all the significant events were removed from the sample the coefficient of the GPR variable was more negative than most of the other results that have excluded a single event. This shows that even without the influence of the significant geopolitical events GPR has significant negative association with firm's innovation output. Hence, our primary results can be considered robust.

## 6. Is the Effect of GPR Short-lived?

From the results in Table 2 it is evident that the effect of GPR on number of patents of firms is adverse and lasts for at least three years. In this section we investigate the trend of this adverse effect, i.e. how many years the effect remains significant. We re-estimate the same model, whose results are displayed in the first column of Table2, but with different dependent variables starting with number of firm-patents in year t+1 till year t+8. The coefficients of GPR in each of the eight models are then plotted in a graph, as shown in figure 2, along with the upper and lower confidence interval at 95% confidence level. The origin of the axes is considered the starting point of the plot and should not be interpreted as the coefficient of GPR in year t+0.

The plot in figure 2 shows that the negative effect of GPR on firms' number of patents continues for four years, after which the effect becomes insignificant. Within these first four years, the second-year number of patents takes the most severe hit from any increase of geopolitical risk, as the negative coefficient have the highest magnitude. The plot of coefficients implies that the effect of GPR on innovation does not last very long but within that short period of time the effect can be quite severe.

## 7. Conclusion

We explore the effect of geopolitical risk on firm level technological innovation. Using the GPR Index developed by Caldara and Iacoviello (2018), we document a negative association between GPR and innovation. This finding suggests that increased geopolitical risk may reduce corporate innovation outputs. The findings are further confirmed with two alternative measures of geopolitical risks, the annual median of the GPR Index and Engle & Martin's (2020) capital market-based Geovol. The negative association remains significant after controlling for macro level exogenous variables like macroeconomic uncertainty and stock market volatility. Further test shows that the negative association persists even after removing effect of major geopolitical events, suggesting strong robust findings. In addition, we use religious tension measure from International Country Risk Guide (ICRG) as an instrument to address any endogeneity concerns that might arise. The two-stage least square regression results show that the association between religious tension fitted value of GPR and innovation remains significant and negative. When GPR is categorized into geopolitical threats and geopolitical acts it was found that the threats have more significant and negative effect on innovation than acts.

Our study also establishes three channels through which geopolitical risk can affect firm innovation. Geopolitical risk has significant negative impact on risk-taking ability, R&D investments and inventor mobility of firms. All of these can be important mechanism for GPR to affect the innovation outcome of firms. Policy makers should be aware of the level of GPR in the country as it can affect technological innovation which is crucial for financial market development (Tadesse, 2006, Hsu et al., 2014). Our paper makes significant contribution to not only the extant innovation literature but also towards policy making and the understanding of geopolitical risk.

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**APPENDIX**

**Appendix 1: Variable Definitions**

| Variable | Definition |
|---|---|
| $Patents_t$ | Natural logarithm of one plus each firm's total number of patents filed (and eventually granted) in year *t*, which is the filing year. The time period is between 1985 till 2017. |
| $CitationPat_t$ | Natural logarithm of one plus each firm's total number of patents weighted by non-self-citations received on the firm's patents in year *t*, which is the patent filing year. |
| $GPR_t$ | Natural logarithm of annual monthly average of Geopolitical Risk Index in year *t*. |
| $GPT_t$ | Natural logarithm of annual monthly average of Geopolitical Threat Index in year *t*. |
| $GPA_t$ | Natural logarithm of annual monthly average of Geopolitical Act Index in year *t*. |
| $GPR\text{-}median_t$ | Natural logarithm of the median of monthly Geopolitical Risk Index for year *t*. |
| $Size_t$ | Natural logarithm of one plus the total book value of assets for each firm in year *t*. |
| $Age_t$ | Natural logarithm of one plus the number of years for each firm from IPO date of the firm till year *t*. |
| $R\&D_t$ | Research and development investment for each firm in year *t*, scaled by lagged book value of asset. |
| $ROA_t$ | Return on asset for each firm calculated by operating income before depreciation in year *t* divided by lagged book value of asset in year *t*. |
| $PPE_t$ | Net property, plant and equipment total of year *t* scaled by lagged book value of asset in year *t* for each firm. |
| $Cash\ Flow_t$ | The sum of total funds from operation and total funds from outside source in year *t*, scaled by lagged book value of assets. |
| $Leverage_t$ | The sum of total current liabilities and total long-term liabilities in year *t* scaled over lagged book value. |
| $CAPEX_t$ | Capital expenditure of year *t* scaled over lagged book value of assets. |
| $Tobin's\ Q_t$ | Tobin's Q for each firm calculated by (Total market value of outstanding stocks + Total book value of assets – Total stockholder's equity – Balance sheet deferred tax)/Total book value of assets. |
| $KZ\text{-}Index_t$ | The Kaplan and Zingales (1997) five-variable KZ-Index, as (-1.002*Cashflow+0.283*TobinsQ+3.139*Leverage-39.368*Dividend-1.315*Cash holding). |

| | |
|---|---|
| $HHI_t$ | Herfindahl–Hirschman Index, as calculated by sum of all the firms' squared market share within the industry. Each firm's market share is expressed as sales divided by total sales of the SIC classified industry. |
| $Illiquidity_t$ | The annual average of daily Amihud (2002) ratio for each firm in year *t* multiplied by 1000 for scaling purpose. The daily Amihud ratio is calculated by the absolute value of dollar return for a firm's stock in one day divided by absolute value of dollar volume of stocks traded in that day. |
| $MU_t$ | 12-months ahead value of Macroeconomic Uncertainty Index of Jurado et al. (2015) in year t matched by fiscal year and month. |
| $VXO_t$ | The annual mean of stock market volatility index from Chicago Boards Options Exchange (CBOE) based on S&P 100 (OEX) options in year t. |
| $RelgTens_t$ | Religious Tension measure of year t, from International Country Risk Grading (ICRG) political risk index. |
| $\sigma dROA_t$ | Firm-level risk taking measure, measured as the standard deviation of the difference between firm ROA and industry mean (based on SIC number) ROA at time periods *t* in a 5-year rolling-window. |
| $Inventor\ Net\ Inflow_t$, | Inventor mobility measure, proxied by the difference between the number of inventors moving into a firm and the number of inventors moving out in years *t*. |
| $Geovol_t$ | Natural logarithm of the annual mean of daily Geovol Index from Engle & Martin (2020). The available time period is between 2000 and 2017. |

**TABLES**

**Table 1: Descriptive Statistics**

This table reports the descriptive statistics of one plus natural log of patent number (*Patents*), one plus natural log of citation-weighted patents (*CitationPat*), natural log of one plus geopolitical risk index (*GPR*), natural log of one plus geopolitical threat index (*GPT*), natural log of one plus geopolitical acts index (*GPA*), natural log of size of firm (*Size*) as measured by total asset, natural log of age of firm (*Age*) as measured by number of years since IPO, R&D investment (*R&D*), Return on Asset (*ROA*), Property Plant and Equipment (*PPE*), Net cash flow (*Cash Flow*), financial leverage (*Leverage*), Capital Expenditure (*CAPEX*), Tobin's Q (*Tobin's Q*), Kaplan-Zingales Index (*KZ-Index*), Herfindahl-Hirschman Index (*HHI*), stock illiquidity (*illiquidity*) as measure by Amihud ratio. All the variables are defined in Appendix 1.

| | N | Mean | Median | Std. Dev. | P25 | P75 |
|---|---|---|---|---|---|---|
| Patents | 38,064 | 1.270 | 0.693 | 1.480 | 0.000 | 2.079 |
| CitationPat | 32,085 | 1.593 | 1.167 | 1.779 | 0.000 | 2.668 |
| GPR | 38,064 | 4.225 | 4.209 | 0.458 | 3.847 | 4.496 |
| GPT | 38,064 | 4.208 | 4.219 | 0.494 | 3.762 | 4.483 |
| GPA | 38,064 | 4.248 | 4.192 | 0.427 | 3.962 | 4.504 |
| Size | 38,064 | 5.458 | 5.192 | 2.302 | 3.745 | 7.034 |
| Age | 38,064 | 2.445 | 2.485 | 0.671 | 1.946 | 2.944 |
| R&D | 38,064 | 12.15 | 5.626 | 20.37 | 1.937 | 13.74 |
| ROA | 38,064 | 0.038 | 0.109 | 0.225 | 0.007 | 0.169 |
| PPE | 38,064 | 21.98 | 18.62 | 16.01 | 9.579 | 30.69 |
| Cash Flow | 38,064 | 0.367 | 8.253 | 24.79 | -2.343 | 14.08 |
| Leverage | 38,064 | 17.96 | 14.38 | 17.31 | 1.390 | 29.00 |
| CAPEX | 38,064 | 6.261 | 4.246 | 6.947 | 2.170 | 7.701 |
| Tobin's Q | 38,064 | 2.396 | 1.644 | 2.339 | 1.179 | 2.646 |
| KZ-Index | 38,064 | -24.47 | -18.09 | 107.9 | -79.47 | 46.44 |
| HHI | 38,064 | 0.262 | 0.210 | 0.193 | 0.125 | 0.344 |
| Illiquidity | 38,064 | 0.008 | 0.000 | 0.022 | 0.000 | 0.004 |

**Table 2: Geopolitical Risk and Corporate Innovation: Baseline OLS Results**

This table reports regression results of the innovation outcome variables (one-year and three-year ahead number of patents and citation-weighted patents) on geopolitical risk and other control variables. Definitions of the variables are provided in appendix. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | (1)<br>$Patents_{(t+1)}$ | (2)<br>$Patents_{(t+3)}$ | (3)<br>$CitationPat_{(t+1)}$ | (4)<br>$CitationPat_{(t+3)}$ |
|---|---|---|---|---|
| GPR | -0.112*** | -0.104*** | -0.097*** | -0.062*** |
| | (0.014) | (0.016) | (0.016) | (0.018) |
| Size | 0.294*** | 0.186*** | 0.388*** | 0.327*** |
| | (0.020) | (0.020) | (0.024) | (0.026) |
| Age | -0.433*** | -0.518*** | -0.126*** | -0.391*** |
| | (0.023) | (0.025) | (0.029) | (0.031) |
| R&D | 0.003*** | 0.002*** | 0.001** | 0.002*** |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| ROA | -0.170*** | -0.053 | -0.452*** | -0.004 |
| | (0.062) | (0.060) | (0.093) | (0.091) |
| PPE | 0.007*** | 0.008*** | 0.007*** | 0.007*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Cash Flow | 0.001** | 0.001** | 0.001 | -0.001 |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| Leverage | -0.006*** | -0.005*** | -0.003*** | -0.005*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| CAPEX | -0.005*** | -0.005*** | -0.007*** | -0.004*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Tobin's Q | 0.018*** | 0.019*** | 0.007* | 0.022*** |
| | (0.004) | (0.004) | (0.004) | (0.005) |
| KZ-Index | 0.000*** | 0.000 | 0.000** | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.239** | -0.190* | 0.100 | 0.110 |
| | (0.108) | (0.111) | (0.120) | (0.123) |
| Illiquidity | 0.329 | 0.397 | 0.298 | -0.293 |
| | (0.332) | (0.374) | (0.372) | (0.422) |
| N | 37,376 | 35,893 | 30,608 | 28,801 |
| Adjusted $R^2$ | 0.72 | 0.72 | 0.75 | 0.70 |

**Table 3: Geopolitical Threat Versus Geopolitical Act**

This table reports regression results of the innovation outcome variables (three-year ahead number of patents and citation-weighted patents) on geopolitical threat (1 & 2) or geopolitical act (3 & 4) along with other control variables. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | (1) $Patents_{(t+3)}$ | (2) $CitationPat_{(t+3)}$ | (3) $Patents_{(t+3)}$ | (4) $CitationPat_{(t+3)}$ |
|---|---|---|---|---|
| GPT | -0.105*** | -0.064*** | | |
| | (0.015) | (0.017) | | |
| GPA | | | -0.003 | -0.019 |
| | | | (0.015) | (0.016) |
| Size | 0.186*** | 0.327*** | 0.183*** | 0.326*** |
| | (0.020) | (0.026) | (0.020) | (0.026) |
| Age | -0.515*** | -0.390*** | -0.524*** | -0.396*** |
| | (0.025) | (0.031) | (0.025) | (0.031) |
| R&D | 0.002*** | 0.002*** | 0.002*** | 0.002*** |
| | (0.000) | (0.001) | (0.000) | (0.001) |
| ROA | -0.054 | -0.004 | -0.028 | 0.007 |
| | (0.060) | (0.091) | (0.061) | (0.091) |
| PPE | 0.008*** | 0.007*** | 0.008*** | 0.007*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Cash Flow | 0.001** | -0.001 | 0.001** | -0.001 |
| | (0.000) | (0.001) | (0.000) | (0.001) |
| Leverage | -0.004*** | -0.005*** | -0.005*** | -0.005*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| CAPEX | -0.005*** | -0.004*** | -0.004*** | -0.004*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Tobin's Q | 0.018*** | 0.022*** | 0.019*** | 0.023*** |
| | (0.004) | (0.005) | (0.004) | (0.005) |
| KZ-Index | 0.000 | 0.000 | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.184* | 0.113 | -0.216* | 0.088 |
| | (0.111) | (0.123) | (0.111) | (0.123) |
| Illiquidity | 0.400 | -0.294 | 0.502 | -0.252 |
| | (0.373) | (0.422) | (0.376) | (0.424) |
| N | 35,893 | 28,801 | 35,893 | 28,801 |
| Adjusted $R^2$ | 0.72 | 0.70 | 0.71 | 0.70 |

**Table 4: Geopolitical Risk and Risk Taking**

This table reports panel regression results of risk taking measures on geopolitical risk along with other control variables. Panel A reports the OLS regression results for risk-taking measures (contemporaneous, one-year and three-year ahead standard deviation of the difference between firm and industry ROA with a 5-years rolling window). Panel B reports the OLS regression results of R&D investment (contemporaneous, one-year ahead and three-year ahead values). Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

**Panel A: Firm-level Risk Taking**

| | $\sigma dROA_{(t)}$ | $\sigma dROA_{(t+1)}$ | $\sigma dROA_{(t+3)}$ |
|---|---|---|---|
| GPR | -0.011*** | -0.005*** | -0.002** |
| | (0.001) | (0.001) | (0.001) |
| Size | -0.007*** | -0.007*** | -0.005*** |
| | (0.001) | (0.001) | (0.001) |
| Age | 0.005*** | 0.003** | 0.001 |
| | (0.002) | (0.002) | (0.001) |
| ROA | -0.046*** | -0.042*** | -0.066*** |
| | (0.005) | (0.005) | (0.006) |
| Leverage | -0.000*** | -0.000*** | -0.000*** |
| | (0.000) | (0.000) | (0.000) |
| 1-HHI | 0.019*** | 0.019*** | 0.022*** |
| | (0.005) | (0.005) | (0.005) |
| N | 54,124 | 54,142 | 54,157 |
| Adjusted $R^2$ | 0.61 | 0.60 | 0.61 |

**Table 4, cont'd**

**Panel B: R&D Investment**

| | R&D$_{(t)}$ | R&D$_{(t+1)}$ | R&D$_{(t+3)}$ |
|---|---|---|---|
| GPR | -1.503*** | -0.650*** | -0.982*** |
| | (0.189) | (0.160) | (0.224) |
| Size | -0.946*** | -3.440*** | -2.002*** |
| | (0.214) | (0.251) | (0.261) |
| Age | -1.848*** | 2.803*** | 0.603* |
| | (0.313) | (0.314) | (0.351) |
| ROA | 24.054*** | -19.769*** | -8.222*** |
| | (2.066) | (1.578) | (1.853) |
| Leverage | 0.100*** | -0.045*** | -0.020 |
| | (0.013) | (0.011) | (0.013) |
| HHI | 0.712 | 0.581 | 0.498 |
| | (1.146) | (1.064) | (0.924) |
| PPE | -0.030* | 0.094*** | -0.009 |
| | (0.016) | (0.016) | (0.015) |
| Cash Flow | -0.490*** | 0.031*** | -0.026* |
| | (0.019) | (0.011) | (0.013) |
| Tobin's Q | 1.260*** | 1.770*** | -0.155* |
| | (0.118) | (0.130) | (0.085) |
| KZ-Index | -0.049*** | 0.009*** | -0.005** |
| | (0.003) | (0.002) | (0.002) |
| Illiquidity | -0.816 | -8.235** | 0.303 |
| | (4.925) | (4.156) | (5.260) |
| N | 38,465 | 35,853 | 30,908 |
| Adjusted $R^2$ | 0.68 | 0.70 | 0.65 |

**Table 5: Geopolitical Risk and Inventor Mobility**

This table reports the OLS regression results of the firm's Inventor Mobility (contemporaneous, one-year and three-year ahead Inventor Net Inflow) on geopolitical risk along with other control variables. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | (1)<br>Inventor Net Inflow$_{(t)}$ | (2)<br>Inventor Net Inflow$_{(t+1)}$ | (3)<br>Inventor Net Inflow$_{(t+3)}$ |
|---|---|---|---|
| GPR | -0.107*** | -0.086*** | -0.119*** |
| | (0.018) | (0.020) | (0.024) |
| Size | 0.217*** | 0.196*** | 0.123*** |
| | (0.023) | (0.024) | (0.028) |
| Age | -0.258*** | -0.258*** | -0.218*** |
| | (0.031) | (0.033) | (0.041) |
| R&D | 0.001** | 0.001 | -0.001 |
| | (0.001) | (0.001) | (0.001) |
| ROA | -0.145 | -0.126 | 0.120 |
| | (0.110) | (0.114) | (0.127) |
| PPE | 0.002 | 0.004** | 0.004* |
| | (0.002) | (0.002) | (0.002) |
| Cash Flow | -0.000 | 0.001 | -0.001 |
| | (0.001) | (0.001) | (0.001) |
| Leverage | -0.004*** | -0.002* | -0.001 |
| | (0.001) | (0.001) | (0.001) |
| CAPEX | -0.001 | -0.001 | 0.001 |
| | (0.002) | (0.002) | (0.002) |
| Tobin's Q | 0.031*** | 0.034*** | 0.021*** |
| | (0.006) | (0.006) | (0.006) |
| KZ-Index | 0.001*** | 0.000* | 0.000** |
| | (0.000) | (0.000) | (0.000) |
| HHI | -0.157 | -0.163 | -0.016 |
| | (0.156) | (0.162) | (0.161) |
| Illiquidity | 2.059*** | 2.326*** | 1.755** |
| | (0.645) | (0.801) | (0.739) |
| N | 9,102 | 8,168 | 6,574 |
| Adjusted $R^2$ | 0.45 | 0.46 | 0.47 |

**Table 6: Two Stage Least Square (2SLS) Regression Results**

This table reports the two-stage least square regression results of the innovation outcome variables (three-year ahead number of patents and citation-weighted patents) on geopolitical risk as endogenous variable and religious tension (*RelgTens*) as instrumental variable along with other control variables. Column 1 and 3 are the first stage results and columns 2 and 4 are the second stage results. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | $GPR_{(t)}$ | $Patents_{(t+3)}$ | $GPR_{(t)}$ | $CitationPat_{(t+3)}$ |
| RelgTens | 0.828*** | | 0.833*** | |
| | (0.003) | | (0.003) | |
| GPR | | -0.101*** | | -0.051*** |
| | | (0.014) | | (0.017) |
| Size | 0.044*** | 0.186*** | 0.043*** | 0.327*** |
| | (0.004) | (0.008) | (0.004) | (0.012) |
| Age | 0.266*** | -0.518*** | 0.273*** | -0.392*** |
| | (0.006) | (0.012) | (0.006) | (0.017) |
| R&D | -0.000 | 0.002*** | -0.000 | 0.002*** |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| ROA | -0.219*** | -0.052 | -0.221*** | -0.001 |
| | (0.023) | (0.056) | (0.024) | (0.073) |
| PPE | -0.001** | 0.008*** | -0.001*** | 0.007*** |
| | (0.000) | (0.001) | (0.000) | (0.001) |
| Cash Flow | 0.000 | 0.001** | 0.000* | -0.001 |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| Leverage | 0.001** | -0.005*** | -0.000 | -0.005*** |
| | (0.000) | (0.000) | (0.000) | (0.001) |
| CAPEX | -0.000 | -0.005*** | -0.000 | -0.004*** |
| | (0.000) | (0.001) | (0.000) | (0.001) |
| Tobin's Q | 0.009*** | 0.019*** | 0.005*** | 0.023*** |
| | (0.001) | (0.003) | (0.001) | (0.003) |
| KZ-Index | -0.000 | 0.000*** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.061** | -0.190*** | -0.098*** | 0.105 |
| | (0.025) | (0.052) | (0.028) | (0.070) |
| Illiquidity | -1.031*** | 0.399 | -1.130*** | -0.281 |
| | (0.116) | (0.296) | (0.129) | (0.394) |
| N | 38,064 | 35,755 | 31,925 | 28,684 |
| Adjusted $R^2$ | 0.60 | -0.01 | 0.62 | -0.06 |
| Weak IV test | 52.77*** | | 8.80*** | |
| Sargan | 0.00*** | | 0.00*** | |
| Endog | 0.062 | | 1.037 | |

**Table 7: Controlling Macroeconomic Uncertainty and Market Volatility**

This table reports the OLS regression results of the innovation outcome variables (three-year ahead number of patents and citation-weighted patents) on geopolitical risk while controlling for macroeconomic uncertainty (*MU*) and stock market volatility (*VXO*) along with other control variables. Column 1 reports the results with patents as the dependent variable and column 2 for the results with citation-weighted patents as the dependent variable. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | (1)<br>$Patents_{(t+3)}$ | (2)<br>$CitationPat_{(t+3)}$ |
|---|---|---|
| GPR | -0.135*** | -0.042** |
| | (0.016) | (0.019) |
| MU | 0.175 | -1.534*** |
| | (0.169) | (0.292) |
| VXO | 0.011*** | 0.004** |
| | (0.001) | (0.002) |
| Size | 0.175*** | 0.329*** |
| | (0.020) | (0.027) |
| Age | -0.531*** | -0.395*** |
| | (0.026) | (0.033) |
| R&D | 0.002*** | 0.002*** |
| | (0.000) | (0.001) |
| ROA | -0.055 | -0.027 |
| | (0.062) | (0.093) |
| PPE | 0.008*** | 0.007*** |
| | (0.001) | (0.001) |
| Cash Flow | 0.001** | -0.001 |
| | (0.000) | (0.001) |
| Leverage | -0.005*** | -0.004*** |
| | (0.001) | (0.001) |
| CAPEX | -0.004*** | -0.004*** |
| | (0.001) | (0.002) |
| Tobin's Q | 0.020*** | 0.022*** |
| | (0.004) | (0.005) |
| KZ-Index | 0.000 | 0.000 |
| | (0.000) | (0.000) |
| HHI | -0.156 | 0.153 |
| | (0.114) | (0.129) |
| Illiquidity | 0.390 | -0.301 |
| | (0.389) | (0.431) |
| N | 34,827 | 27,747 |
| Adjusted $R^2$ | 0.72 | 0.70 |

**Table 8: Alternative Measures of Geopolitical Risk**

This table reports the OLS regression results of the innovation outcome variables (one-year and three-year ahead number of patents and citation-weighted patents) on alternative measures of geopolitical risk. Panel A reports the results while using the median of monthly GPR Index as the measure of geopolitical risk, and Panel B reports the results while using Engle & Martin (2020) Geovol measure along with other control variables. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

**Panel A: Using Median of GPR Index**

| | $Patents_{(t+1)}$ | $Patents_{(t+3)}$ | $CitationPat_{(t+1)}$ | $CitaitonPat_{(t+3)}$ |
|---|---|---|---|---|
| GPR-median | -0.218*** | -0.179*** | -0.127*** | -0.087*** |
| | (0.017) | (0.019) | (0.020) | (0.022) |
| Size | 0.297*** | 0.188*** | 0.389*** | 0.327*** |
| | (0.020) | (0.020) | (0.024) | (0.026) |
| Age | -0.422*** | -0.512*** | -0.125*** | -0.392*** |
| | (0.023) | (0.025) | (0.029) | (0.031) |
| R&D | 0.003*** | 0.002*** | 0.001** | 0.002*** |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| ROA | -0.193*** | -0.068 | -0.457*** | -0.009 |
| | (0.062) | (0.060) | (0.093) | (0.091) |
| PPE | 0.006*** | 0.007*** | 0.007*** | 0.007*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Cash Flow | 0.001** | 0.001** | 0.001 | -0.001 |
| | (0.000) | (0.000) | (0.001) | (0.001) |
| Leverage | -0.006*** | -0.004*** | -0.003*** | -0.005*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| CAPEX | -0.005*** | -0.005*** | -0.007*** | -0.004*** |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Tobin's Q | 0.017*** | 0.018*** | 0.007 | 0.022*** |
| | (0.004) | (0.004) | (0.004) | (0.005) |
| KZ-Index | 0.000** | 0.000 | 0.000** | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.216** | -0.177 | 0.101 | 0.110 |
| | (0.108) | (0.111) | (0.120) | (0.123) |
| Illiquidity | 0.188 | 0.277 | 0.223 | -0.368 |
| | (0.330) | (0.372) | (0.372) | (0.422) |
| N | 37,376 | 35,893 | 30,608 | 28,801 |
| Adjusted $R^2$ | 0.72 | 0.72 | 0.75 | 0.70 |

**Panel B: Engle & Martin (2020) Geovol Measure**

| | (1) $Patents_{(t+1)}$ | (2) $Patents_{(t+3)}$ | (3) $CitationPat_{(t+1)}$ | (4) $CitatinPat_{(t+3)}$ |
|---|---|---|---|---|
| Geovol | -0.702*** | -0.254** | -0.043 | -0.435** |
| | (0.106) | (0.106) | (0.120) | (0.188) |
| Size | 0.054* | -0.072*** | 0.247*** | 0.191*** |
| | (0.027) | (0.027) | (0.034) | (0.042) |
| Age | -1.187*** | -1.194*** | -0.233*** | -0.640*** |
| | (0.062) | (0.065) | (0.080) | (0.117) |
| R&D | 0.001 | -0.000 | 0.001 | 0.001 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| ROA | 0.248** | 0.211** | -0.277* | 0.095 |
| | (0.101) | (0.095) | (0.143) | (0.152) |
| PPE | 0.002 | 0.002 | 0.008*** | 0.007*** |
| | (0.002) | (0.002) | (0.002) | (0.002) |
| Cash Flow | 0.002** | 0.002*** | 0.001 | 0.000 |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| Leverage | -0.007*** | -0.004*** | -0.001 | -0.002* |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| CAPEX | 0.003 | -0.001 | -0.005 | -0.001 |
| | (0.003) | (0.003) | (0.003) | (0.003) |
| Tobin's Q | 0.000 | -0.004 | -0.006 | 0.009 |
| | (0.006) | (0.006) | (0.007) | (0.008) |
| KZ-Index | 0.001*** | 0.000** | 0.000 | 0.000 |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| HHI | -0.325 | -0.257 | 0.353 | 0.136 |
| | (0.210) | (0.208) | (0.263) | (0.277) |
| Illiquidity | 1.500*** | 0.968* | -0.367 | 0.552 |
| | (0.556) | (0.502) | (0.716) | (0.872) |
| N | 16,025 | 14,542 | 9,845 | 8,163 |
| Adjusted $R^2$ | 0.73 | 0.73 | 0.80 | 0.79 |

**Table 9: Geopolitical Risk and Corporate Innovation: Excluding Significant Events**
This table reports the OLS regression results of the innovation outcome variables (three-year ahead number of patents and citation-weighted patents) on geopolitical risk (GPR) excluding the significant geopolitical events along with control variables. Standard errors along with the number of observations are displayed in separate columns beside the coefficient of *GPR*. Standard errors adjust for heteroskedasticity and are clustered by firm. Firm fixed effects are included in each regression. ***, **, and * indicate significance at the 1%, 5%, and 10% levels respectively. All variables are defined in Appendix 1.

| | *Dependent Variable: $Patents_{(t+3)}$* | | | *Dependent Variable: $CitationPat_{(t+3)}$* | | |
|---|---|---|---|---|---|---|
| | *Coefficient of GPR* | *Standard Error* | *No. of Observations* | *Coefficient of GPR* | *Standard Error* | *No. of Observations* |
| *Excluding US Bombing Libya* | -0.093*** | 0.016 | 34,739 | -0.064*** | 0.018 | 27,660 |
| *Excluding Kuwait Invasion* | -0.113*** | 0.016 | 34,688 | -0.060*** | 0.019 | 27,620 |
| *Excluding Gulf War* | -0.111*** | 0.016 | 34,630 | -0.065*** | 0.018 | 27,559 |
| *Excluding 9/11 Attack* | -0.121*** | 0.016 | 34,549 | -0.066*** | 0.019 | 27,508 |
| *Excluding Iraq War* | -0.246*** | 0.020 | 33,345 | -0.101*** | 0.022 | 26,753 |
| *Excluding ISIS Escalation* | -0.040** | 0.016 | 35,136 | -0.062*** | 0.018 | 28,801 |
| *Excluding Paris Attacks* | -0.104*** | 0.016 | 35,893 | -0.062*** | 0.018 | 28,801 |
| ***Excluding All Events*** | **-0.216*** ** | **0.028** | **27,622** | **-0.146*** ** | **0.031** | **21,896** |

## Figures

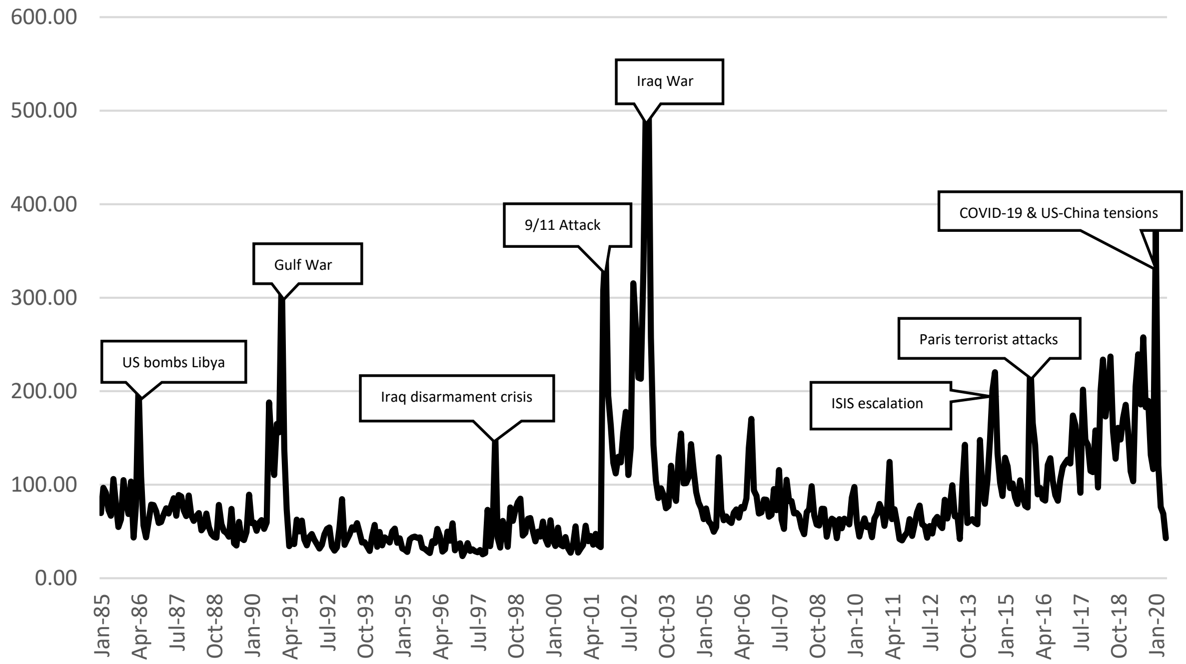


**Figure 1: Geopolitical Risk Index**

This figure illustrates the trend of monthly Geopolitical Risk Index measure as developed by Caldara and Iacoviello (2018) from January 1985 till January 2020. Significant geopolitical events are labelled at the corresponding time points.

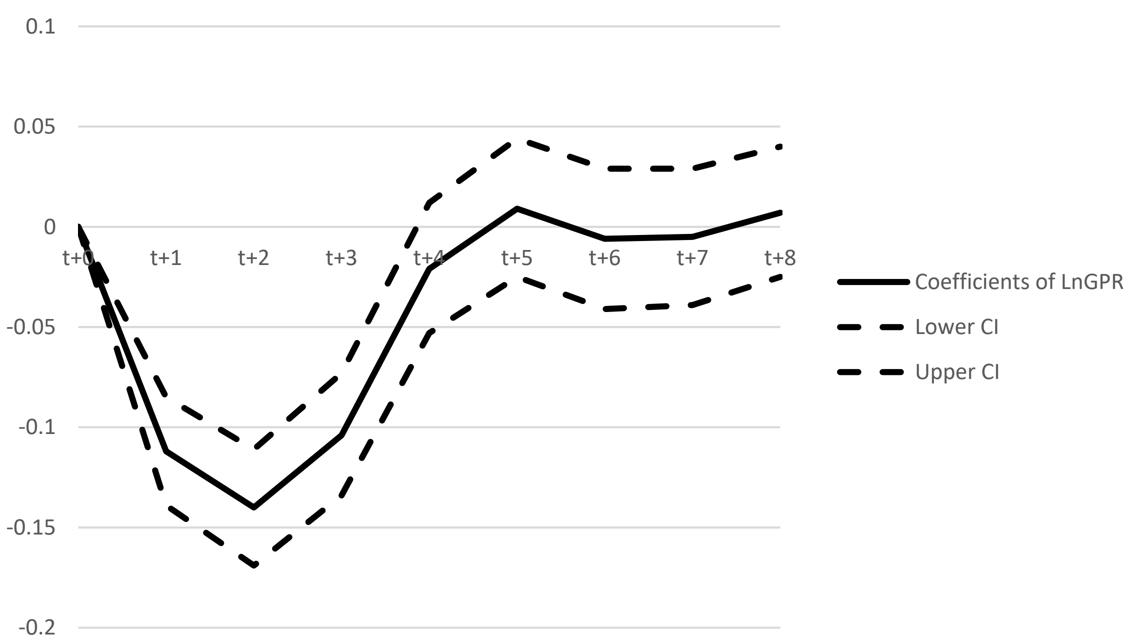


**Figure 2: The Evolution of the Geopolitical Risk Effect**

This figure illustrates the effect of Geopolitical Risk on future levels of corporate innovation (up to eight years). All the plots are retrieved by estimating the full baseline regression with the number of patents as outcome variables. The dashed lines correspond to the 95% confidence intervals of the coefficient estimates. Confidence intervals are calculated from standard errors clustered by firm.