The pricing of geopolitical risk in cross-sectional commodity returns

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Abstract

In this study, we investigate whether geopolitical risk is a pricing factor in cross-sectional commodity futures returns. By estimating the exposure of commodity futures returns on a historical geopolitical risk index, we find that commodities with high-risk betas generate 7.92% higher annual returns than those with low-risk betas. The results indicate that high geopolitical risk-related commodity futures contracts require extra compensation. A moving average procedure shows that the geopolitical risk beta has a regular changing pattern that cycles every 10 years, and the relative risk premium tends to be higher than average before economic recessions and to further increase during the recession periods. Finally, we find that geopolitical threats better explain the variation of commodity futures return than do geopolitical actions.

JEL classification*: G12; G15; Q02*

Keywords: Geopolitical risk, Commodity futures, Cross-section return

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1. Introduction

In a multi-period economy framework of Merton (1973), Bali et al. (2017) indicate that the covariance with investment and consumption related state variables determines expected return of an asset, thus the level of exposure to economic fundamentals influences returns from risky asset investment. This implies that a cross-sectional model with multiple risk factors could help explain the return of risk assets, for example, commodity futures contracts. While few existing studies managed to explain the cross-section returns for a broad set of commodity futures market (Daskalaki et al., 2014; Koijen et al., 2018), Bakshi et al. (2019) explore basic risk factors and develop a three-factor model following Fama and French (1993). Beyond their work, in this study, we examine a new pricing factor, geopolitical risk, to see whether it is a pricing factor in cross-sectional commodity futures returns.

The existing research has shown that exogenous macro factors like policy uncertainty (Bali et al., 2017) and geopolitical risk (McCallen, 2018) can be treated as additional key elements in investment decisions and stock market dynamics. Following Caldara and Iacoviello's (2022) definition, we refer to geopolitical risk as "*the risk associated with wars, terrorism, and tensions among states that affect the normal course of international relations*." We propose two hypotheses about how geopolitical risk cross-sectionally influences the commodity futures return: one is driven by short-term demand change because of the investment behavior of two kind of market participants when geopolitical risk events happen, and it claims a positive geopolitical risk premium. On the opposite, an alternative hypothesis explains the risk premium using the preference-based theory following the intertemporal CAPM framework of Merton (1973), and supports the risk premium being negative.

Using the historical geopolitical risk (GPRH) index (Caldara and Iacoviello, 2022) as a proxy for risk level, we empirically examine the two hypotheses by testing the cross sectional relationship between geopolitical risk and the commodity futures returns. The result of beta exposure shows that among the four commodity categories only energy is positively related to GPRH innovation, while the betas of other categories are much smaller with less volatility. We then conduct a univariate portfolio sorting test to determine the pricing power of the geopolitical risk in commodity futures returns. The result documents a significant pattern that excess return increases as the beta of GPRH increases. This tendency remains when controlling for three commodity futures factors, following Bakshi et al. (2019). The results indicate that the geopolitical risk is a significant positive pricing factor for the commodity futures returns.

A series of tests supports this conclusion by checking the effect of the GPRH index in predicting commodity futures returns. First, we separate the sample period into two parts by time, pre-2000 and post-2000 to test the time-varying character of pricing power as well as the potential impacts brought by commodity financialization in the 2000s. The result indicates that GPRH beta becomes more volatile with a broader region and averages more excess return after 2000. The portfolio alphas in the post-2000 component exceed those in the pre-2000 component, indicating an increased pricing ability of geopolitical risk in the post-2000 sample. This finding is consistent with the argument that the commodity financialization in the 2000s made the market more erratic and risk vulnerable (Tang and Xiong, 2012; Goldstein and Yang, 2022).

In addition to identify the time-varying characteristic of the cross-sectional relationship proposed by Fama and French (1987), we also demonstrate how moving average beta values and excess returns change throughout the sample period. The result shows a regular cycle for geopolitical risk beta in that a U-shaped curve that repeats every 10 years emerges. Also, the GPRH premium tends to be higher than average before economic recessions occur in the United States, and further increases during the corresponding period. Such a cyclical pattern is independent of index variation.

We then replace the basic GPRH index with two sub-indices, GPRHT and GPRHA separately to detect whether such a risk premium can be mainly sourced from threats or actions in geopolitical issues. Overall, the performance of geopolitical threats is more closed to basic geopolitical risk, while geopolitical action is less decisive and significant. The comparison result is consistent with the findings of Schneider and Troeger (2006). Thus, the premium appears to stem mainly from the effect of geopolitical threats, while geopolitical actions deliver supplementary information for detecting the influence of geopolitical issues on the cross-sectional return of commodity futures.

Following Shang et al. (2016), we conduct a robustness check by controlling for several macroeconomic factors, including the US stock market factor, the unexpected real interest rate and the unexpected inflation. The factors we choose along with the GPRH index have small cross-correlations. Instead of being eliminated by the control factors, the performance of GPRH beta becomes more powerful as the portfolios we construct presents larger excess return and alpha. Likewise the Newey and West (1987) *t*-statistics become more significant. Clearly basic macroeconomic factors cannot explain the relationship between the index and commodity futures returns.

Our study contributes to the literature in the following ways. First, it adds to the literature of commodity futures pricing by introducing a new pricing factor, geopolitical risk. Our factor model building and empirical data analysis is based on the three-factor model of Bakshi et al. (2019). Following their work, Zhang et al. (2020) explore the commodity market in China and find the significant abnormal returns for both carry and momentum strategies. Here our study addresses the gap that research of commodity futures needs to take into account more fundamental issues outside the market (Carter, 1999). The positive GPRH premium stems from the change of market participants' expectations on futures commodity prices and their reactive behavior when the risk index level changes, thus the GPRH-related risk premium is different from the negative EPU-induced premium recorded by Bali et al. (2017). Besides, the strong connection between geopolitical risk and commodity futures implies a straightforward economic explanation for commodity futures pricing. Thus, besides trading behavior and contract characters, the study provides a new approach to improving commodity prices' basic understanding from an exogenous global perspective.

We also extend the research of geopolitical risk (Caldara and Iacoviello, 2022) by examining its economic impacts. Most prior studies apply the GPRH index to analyze the influence of geopolitical risks on stocks (Balcilar et al., 2018; Baur and Smales, 2020), bonds (Bouri et al., 2019), and individual categories of commodity futures (Mei et al., 2020; Su et al., 2021), but do not address the connection between the index and the overall commodity futures market. This study provides the first piece of empirical evidence to prove the validity of the geopolitical risk index in asset pricing. Furthermore, the study supports the robust impact of geopolitical risk on the commodity futures market by controlling for the basic factors Bakshi et al. (2019) identified as crucial, as well as other macroeconomic factors.

Finally, we provide a new perspective for the impact of commodity market financialization. Tang and Xiong (2012) and Goldstein and Yang (2022) provide systematic investigations of the financialization of the commodity market since the early 2000s. They find that correlations between the prices of commodities had become stronger since the early 2000s. Our analysis suggests that the increasing positive premium of geopolitical risk in commodity futures market after the twenty first century may be driven by the growing demand of both the speculation of pure financial investors and the traditional commercial hedger in dealing with such kind of risk events. This aligns with the findings of Goldstein and Yang (2022). In addition, Our results of the time-varying characteristics are consistent with the previous findings in literature that commodity market financialization has accelerated since the beginning of 21st century (Tang and Xiong, 2012). The study augments past research by revealing the impact of the financialization process by demonstrating a change in the relationship of commodity futures with geopolitical risk.

The remainder of the paper is organized as follows: Section 2 introduces an overview of the literature review about commodity futures pricing and geopolitical risk, as well as the central hypotheses of this study. Section 3 highlights the data applied. Section 4 describes the methodology and empirical results. Section 5 presents the conclusion.

2. Literature Review and Hypotheses

2.1 Commodity Futures Pricing

The commodities market has garnered extensive attention from both academia and industry in the past few decades because of its value creation and risk management functions (Haase et al., 2016). While the spot market has limitations for physical commodity trading, commodity futures have attracted market participants seeking various advantages (Hull, 2017), such that it has multiplied in trading volume. A large and diverse set of entities, including both financial speculators and commercial hedgers, have engaged in commodity futures investment (Cheng and Xiong, 2014). Though investors pursue different targets like profit arbitraging and risk hedging, the popularity of commodity futures as an asset class has not only made the global financial market prosperous, but also brought increasingly severe financialization and higher volatility of commodity futures prices to the global market (Tang and Xiong, 2012; Goldstein and Yang, 2022). This tendency leads to a rapid development of the commodity futures pricing theory. Fama and French (1987) study monthly returns for 21 commodities futures by examining two models, one based on spot price backwardation/contango estimation, and another based on the theory of storage, but their results indicate only weak statistical significance of corresponding risk premium. Likewise, Gorton et al. (2013) systematically review and analyze the fundamentals of commodity futures excess returns by examine the importance of inventory level, and emphasize two essential theories in commodity futures pricing behavior, the theory of normal backwardation (Keynes, 1930) and the theory of storage (Working, 1948; 1949) by developing a two-period model integrating those theories.

Departing from the traditional theories that trying to explain the commdity futures pricing from basic features, another stream of literature explores the fundamental information of the commodity futures and develops factor models in recent decades. This trend has been associated with the increasing popularity of factor studies in the stock market since the 1980s. For instance, Dusak (1973) extend the theory of storage within the context of the capital asset pricing model and empirically test it in the futures market, resulting in support for the theory. Asness et al. (2013) find a consistent value and momentum risk premium in eight diverse asset classes, including the commodity futures market. They propose that a three-factor model including liquidity, value, and momentum factors might explain such common global risks. Yang (2013) proposes a "slope" factor to explain the average excess returns of commodity futures portfolios sorted by basis. He investigates a multi-factor model to recognize the factor along with investment shocks. Szymanowska et al. (2014) explain the return of commodity futures in two parts, spot premium related to base commodity character and the term premium related to change in the basis. Both studies (Szymanowska et al., 2014; Yang, 2013) support that a high-minus-low (HML) factor largely determines such a spot premium. However, Daskalaki et al. (2014) review and summarize the usual factors in commodity futures, arguing that there is a lack of a model generally explaining the commodity futures returns.

As an increasing number of factors are uncovered, many recent studies try to integrate a unified model for the pricing of commodity futures. Hamilton and Wu (2014) extend a model in terms of oil futures pricing structure, including dollar index, inventories, commodity indices, and risk aversion associated with financial intermediaries. They find that those factors largely drive the likelihood of backwardation/contango. Shang et al. (2016) derive a four-factor model based on the intertemporal capital asset pricing model (Merton, 1973) in an open economy framework. They find that the model allows them to predict commodity futures returns with macroeconomic variables. Bakshi et al. (2019) find that innovations in global equity volatility affect the commodity futures prices, and they combine traditional theories of the commodity to design an asset pricing model including average-return, commodity carry-situation, and commodity-momentum factors. Following Bakshi et al. 's (2019) work, Zhang et al. (2020) empirically examine the cross-sectional excess returns in the Chinese commodity futures market and find that both carry and momentum strategies provide significant returns and explain most cross-sectional variations.

Exploration of which asset pricing model can better reconcile the cross-sectional properties of commodity futures returns continues. Scholars have also focused excessively on pricing in the oil market, neglecting other commodity futures and the futures market as a whole.

2.2 Geopolitical Risk and Asset Pricing

For a long time, studies of geopolitical risk focus on studying specific events in qualitative ways, instead of trying to capture its general pattern on economic impacts by quantitative methods. For example, Schneider and Troeger (2006) investigate the Dow Jones's reaction to armed conflicts. They concluded that international markets could be "indifferent or even cheerful" in the presence of armed conflicts and their escalation. Choudhry (2010) study how different events in World War II affected US stock prices. A number of studies in this vein have investigated the influence of terrorist attacks, finding they tend to induce lower returns and higher volatility to the stock market over the short term (Brounen and Derwall, 2010; Chesney et al., 2011; Goel et al., 2017). However, although those studies contribute to defining geopolitical risk, they have little insight outside of individual geopolitical events. For a long time, no standard and consistent quantitative measure of geopolitical risks over time existed, which prevented researchers from identifying general patterns that persist over time.

Caldara and Iacoviello (2022) created the historical geopolitical risk index, GPRH, which provides a comparable measurement of geopolitical risks by time series, ranging from 1900 to present.[1] They found that GPRH helps predict investment volume in positively exposed industries. More importantly, the GPRH index enables the systematic empirical analysis to examine various market reactions to geopolitical risk and its economic impacts from a universal perspective (McCallen, 2018).

Academics and governments have widely acknowledged the index as a reliable indicator of geopolitical risk in research and practical use. Central bank officials and policymakers, including the European Central Bank, the International Monetary Fund, and the World Bank, highlight and monitor geopolitical risks regularly via the index. McCallen (2018) treat geopolitical risk as an additional factor in Fama and French's (2015) 5-factor (FF-5) model, and found that though the FF-5 model largely absorbs the explanatory power of the GPRH index in US stock returns, the effect of shock of geopolitical risk is still significant and should be separated from the original level index value. Bouri et al. (2019) exploit the influence of geopolitical risk in Islamic bond and equity markets. Antonakakis et al. (2017) compare the influence of the GPRH index on both the West Texas Intermediate Oil index and the Standard & Poor's 500 index, concluding geopolitical tensions had a greater impact on the oil market the. Aloui and Hamida (2021) find that geopolitical incidents lowered the magnitude and

[1] More details of the index will be introduced in Section 3.2.

volatility correlation of oil and stocks in Saudi Arabia.

There is also plenty of literature connecting commodity futures with geopolitical risks. Combining the stock market and futures market, Baur and Smales (2020) find that the effect of geopolitical risk is distinct from the other economic and political risks, and they proposed that precious metal could be a useful tool to hedge against geopolitical risk and geopolitical threats. Das et al. (2019) also investigate this relationship, and further confirmed that precious metals can hedge geopolitical risk due to a unique supply-demand characteristic of the precious metals portfolio. Based on a mixed data sampling modeling framework, Mei et al. (2020) show that the GPRH index could help predict oil futures price volatility in both the short and long term, but that a subindex of the GPRH, geopolitical actions, explains much of that effect. Tiwari et al. (2021) investigate the interdependence of crude oil prices and agricultural commodities and find that the GPRH index negatively influenced their co-movement so that oats, corn, and wheat could hedge against the oil returns downturn resulting from geopolitical unrest. However, while the literature continues to develop, most existing studies focus on areas such as metals, energy, and crude oil. The relationship between the GPRH Index and other commodity futures such as livestock remains largely unexplored.

2.3 Hypothesis Formation

The main advantage of pricing commodity futures by geopolitical risk is that it is an exogenous factor for the investment market. Geopolitical events measured by the GPRH include wars, terrorism, and international tensions. Scholars widely agree that these events have significant impacts on economic growth (Blomberg et al., 2004), but they are unlikely to be caused or predicted by short-term economic fluctuations (Caldara and Iacoviello, 2022). Plenty of literature establishes the exogeneity of geopolitical risk events. For example, Fratianni and Kang (2006) prove that the negative effect of terrorism on the economy is robust in the presence of natural disasters and financial crises. Caldara and Iacoviello (2022) make Granger-causality tests by including a series of macroeconomic, financial, and uncertainty variables, demonstrating that the US economy has no significant impact on the GPRH index. Likewise the results of a similar robustness check by Cheng and Chiu (2018) show that geopolitical risk has no effect on economic contractions in the US. Empirical studies such as Tiwari et al. (2021) and Baur and Smales (2020) suggest that investors could use agriculture and precious metal to hedge geopolitical risk, and their findings support the existence of the risk premium as well.

Therefore, it is reasonable to conclude that the geopolitical risk is independent of most economic developments in the market, including unemployment levels, economic policy uncertainty, and stock market volatility.

We propose two following potential hypotheses that claim positive and negative risk premium separately. Our first hypothesis posits that the risk premium triggered by geopolitical events is positive. Due to the nature of modern geopolitics, a large number of geopolitical conflicts originate from the production and supply of commodity resources, such as the energy (e.g., crude oil) as well as some precious metals and crops. As a result, geopolitical events often occur in the countries and regions with abundant commodities. When geopolitical events occur (the GPRH risk innovation becomes positive), the effect on commodity markets could be often contractionary: on the one side, the long-term demand for commodities by commercial hedgers (e.g., farmers, producers, and consumers who need the commodity in production activity) in the market does not change immediately. However, on the other side, the supply of the commodity may fluctuate sharply in the short term, often significantly, due to the negative effect of geopolitical risks. Therefore, once the information of "rising geopolitical risks" is conveyed to the market, there will be an expectation that the supply of commodities will fall and not recover in time to lower/even sustain higher spot prices in the future. Thus, two channels on the demand side in the short term, commercial hedgers and non-commercial traders, are mutually influenced to raise the price of commodity futures. First, commercial hedgers need to buy commodity futures to hedge their regular commercial production activities for a short period of time in the future in order to cope with supply shortages and higher spot commodity prices due to rising geopolitical risks. Second, based on the same expectations, non-commercial traders (i.e., hedge funds or other purely financial investors in the commodity futures market) will act speculatively, i.e., choose to hold a long position.

Thus, under the dual pressure of "hedge buying by commercial hedgers and speculative buying by non-commercial traders", the short-term demand for commodity futures rises, the inventory level would therefore decrease and lead to the increase of price, resulting in higher short-term positive risk premiums in the commodity market. Therefore, we propose the following hypothesis:

H1(a) Geopolitical risk uncertainty is a positive pricing factor for cross-sectional commodity futures contract returns.

On the contrary, the second hypothesis claims a negative risk premium. Bali et al. (2017) point out that investors care about both mean-variance risks and future economic uncertainty. Following this point, the uncertainty triggered by geopolitical events could influence investment return distribution through the economy state. Thus, the geopolitical risk premium is explainable under the preference-based theory: uncertainty-averse investors demand extra compensation to hold assets that positively correlated with the geopolitical risk. Oppositely, they have to pay higher (or accept lower returns) for the assets that negatively correlated to geopolitical risk, as these assets would be considered safer and less fluctuated during periods of intensive geopolitical risk. Such a risk premium also aligns with the insights from the intertemporal CAPM model (Merton, 1973), as investors prefer to hold assets with greater return when the uncertainty level increases and thus hedge the reduction of future investment and consumption opportunity (Campbell, 1992). According to the above discussion, we state the second hypothesis as below:

H1(b) Geopolitical risk uncertainty is a negative pricing factor for cross-sectional commodity futures contract returns.

3. Data Description

In this study, we empirically examine the relationship between geopolitical risk and commodity futures prices. Thus, we draw on two sources of data: the historical geopolitical risk index and commodity futures returns.

3.1 Commodity Futures Data and Returns Calculation

The monthly commodity futures market data is constructed from end-of-day data, directly available from Bakshi et al.'s (2019) website[2]. Derived from the Chicago Mercantile Exchange (CME) data, the main advantage of this dataset is that it provides a backwardation/contango status so that we can calculate the carry factor. They also conduct a well-designed treatment of the first notice day to avoid a price deviation caused by a potential physical delivery request from the counterparty. This procedure maintains the consistency and continuity of the commodity futures data to overcome the variation of different contracts and better study their changing pattern and connection with geopolitical risk. The database contains 29 commodity futures contracts, covering the categories of agriculture, energy, livestock, and metal. The study period is from January 1970 to December 2011, which allows the sample to maintain at least three commodities in the carry and momentum portfolios. The sample

[2] https://pubsonline.informs.org/doi/suppl/10.1287/mnsc.2017.2840

consists of 12,207 contract-month observations.

Following the method of Bakshi et al. (2019), the calculation of monthly futures returns r for long positions and short positions can be expressed respectively as equation (1):

$$r_{t+1}^{long} = \frac{1}{F_t^{(1)}}\left(F_{t+1}^{(1)} - F_t^{(1)}\right) + r_t^f \qquad \text{(for long positions)}$$

$$r_{t+1}^{short} = -\frac{1}{F_t^{(1)}}\left(F_{t+1}^{(1)} - F_t^{(1)}\right) + r_t^f \qquad \text{(for short positions)} \qquad (1)$$

where $F_t^{(0)}$ is the price of the front-month futures contract and $F_t^{(1)}$ is the price of the next maturity futures contract, both observed at the end of month t. Also, the r_t^f is the interest earned on the fully collateralized futures position (Gorton et al., 2013). As shown in equation (2), the excess return of long and short futures position between the end of month t and $(t+1)$ will be:

$$e_{t+1}^{long} \equiv r_{t+1}^{long} - r_t^f \text{ and } e_{t+1}^{short} \equiv r_{t+1}^{short} - r_t^f \qquad (2)$$

Note that $F_t^{(0)}$ is practically never included in the equations because of the first notice day calendar issues. For each commodity contract, we take a position with the second shortest maturity at the end of month t while guaranteeing that its first notice day is after the end of the month $(t+1)$. Such calculation process follows the method of Bakshi et al. (2019).

The above calculation illustrates a clear measurement of futures returns and the corresponding excess returns so that we can learn more about the situation of the commodity futures market from a tidy and statistical perspective. An asset pricing model of commodity futures can therefore be constructed based on such a process. Moreover, the geopolitical risk factor can be assessed whether it is significantly predictive for the empirical pricing of commodity futures.

Table 1: Descriptive Statistics of Excess Returns

NOTE: The monthly excess returns of commodity futures are calculated using equations (1) and (2). Displayed columns are the number of observations (N), the minimum (Min), the maximum (Max), the mean (Mean), standard deviation (SD), Sharpe ratio (SR), and skewness (SK) of monthly excess return. The data sample starts (ends) in January 1970 (September 2011), resourcing from Bakshi et al. (2019).

Category	Contract	N	Min	Max	Mean	Median	SD	SR	SK
Agriculture	Barley	107	-12.37	9.62	-0.82	-1.16	3.38	-0.24	0.33
	Cocoa	501	-25.01	44.10	0.46	-0.76	9.30	0.05	0.72
	Coffee	457	-27.65	54.70	0.65	-0.59	10.81	0.06	1.18
	Corn	501	-22.80	44.80	-0.06	-0.71	7.48	-0.01	1.11
	Cotton	501	-22.64	36.91	0.39	0.28	7.45	0.05	0.58

	Lumber	466	-26.21	28.03	-0.53	-0.30	8.04	-0.07	0.09
	Oats	500	-25.21	90.60	0.04	-0.27	9.20	0.00	2.30
	Orange Juice	501	-22.24	70.65	0.30	0.00	9.10	0.03	1.82
	Rough Rice	301	-22.82	46.73	-0.20	-0.87	8.29	-0.02	1.27
	Soybean Meal	501	-27.79	82.88	0.69	0.00	9.56	0.07	2.18
	Soybean Oil	501	-25.20	59.09	0.72	-0.15	9.45	0.08	1.40
	Soybeans	501	-23.39	56.88	0.41	0.13	8.24	0.05	1.34
	Sugar	501	-29.70	67.42	0.75	0.18	12.13	0.06	1.17
	Wheat	501	-26.17	42.24	0.04	-0.49	7.82	0.00	0.73
Energy	Crude Oil	342	-32.37	46.01	0.97	1.24	9.66	0.10	0.42
	Heating Oil	390	-30.69	64.85	1.36	0.94	10.36	0.13	1.14
	Natural Gas	257	-35.08	52.31	-0.39	-1.32	14.73	-0.03	0.60
	Propane	230	-36.41	220.36	2.44	0.71	18.73	0.13	6.97
	RBOB Gasoline	71	-41.36	31.74	1.55	2.11	11.77	0.13	-0.58
	Unleaded Gasoline	264	-27.22	54.21	2.15	1.39	11.75	0.18	1.03
Livestock	Feeder Cattle	452	-20.61	16.61	0.22	0.32	4.70	0.05	-0.53
	Lean Hogs	501	-25.95	31.78	0.45	0.32	7.52	0.06	0.04
	Live Cattle	501	-22.22	19.79	0.45	0.32	5.05	0.09	-0.26
	Pork Belly	499	-31.31	44.00	0.17	-0.54	10.61	0.02	0.55
Metal	Copper	501	-36.04	36.45	0.66	0.26	8.07	0.08	0.33
	Gold	441	-21.60	25.97	0.18	-0.36	5.65	0.03	0.49
	Palladium	416	-41.46	47.62	0.96	0.35	10.28	0.09	0.41
	Platinum	501	-38.60	41.06	0.54	0.16	8.04	0.07	0.47
	Silver	501	-47.58	83.00	0.53	-0.13	9.92	0.05	1.47

Table 1 is a descriptive statistics of commodity futures excess returns. While the agriculture category includes the largest number of commodity futures, the average excess return of it is the lowest. The highest excess returns are both from the energy category: the propane (2.44% per month) and unleaded gasoline (2.15% per month), indicating an overall high return in energy category, while the return volatility (SD) of the energy category is also the highest among four categories. Also, the generally low Sharpe ratio reveals that single investments in the commodity futures market are not idealized and attractive. Out of 29 commodities, 26 (except RBOB Gasoline, Feeder Cattle, and Live Cattle) show a positively skewed pattern in their excess returns, consistent with the common long-right tail issue in the financial market.

3.2 Geopolitical Risk Data

The time-series data of geopolitical risk are sourced from Caldara and Iacoviello (2022)[3]. The GPRH index is based on a textual collection of newspaper articles mentioning geopolitical issues starting from January 1985. Specific keywords are set to identify if a newspaper/article should be added to the numerator. They also create subset indices distinguishing geopolitical threats and geopolitical actions by using different groups of keywords in the searching procedure. The GPRH index and its sub-indices have been widely proven to be good proxies for geopolitical risks, which enables empirical research of the cross-sectional relationship between geopolitical risk and commodity futures returns.

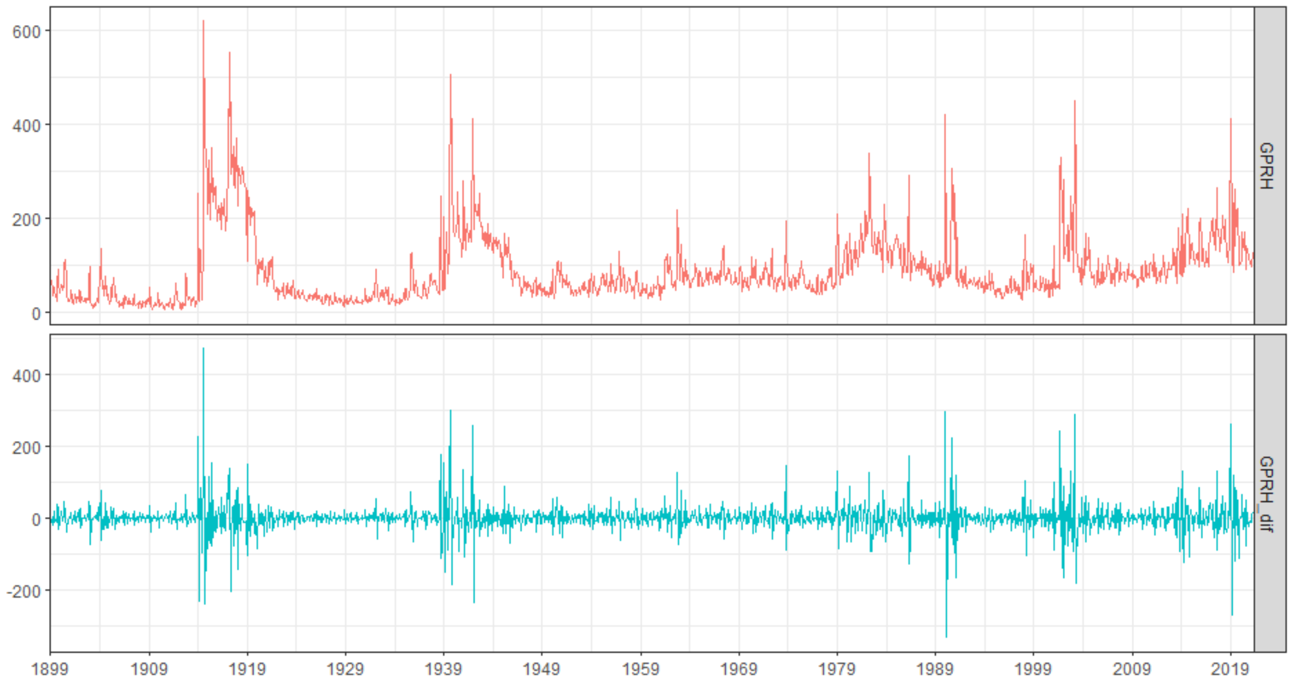
Compared with another widely used indicator, Economic Policy Uncertainty (EPU) index developed by Baker et al., (2016), the GPRH index is different in the following ways. First, it well captures geopolitical events that are more exogenous to the business activity and financial variations, while the EPU index is designed to monitor the fluctuation of economic policy change. For example, the EPU index would not respond to events like 911 attack or ISIS escalation that has been proved to significantly influence financial market. Second, according to Caldara and Iacoviello (2022), while the GPRH index shares a high correlation with the EPU index, the former one still contains additional and independent variation, and is helpful in predicting VIX and EPU index empirically. Third, the Global EPU index starts at 1997, which leaves a shorter window for testing that may leads to biases, while the GPRH index has a much longer time span. Thus, the features of GPRH index makes it a good indicator to consistently identify the financial volatility change. The primary tests also show that the Global EPU fails to explain the variation of cross-sectional return of commodity futures (more details will be discussed in the section 4.7).

This study uses the historical geopolitical risk index (GPRH) to proxy the level of geopolitical risk, as the benchmark GPRH index starts in 1985. The GPRH index is built by computing the share of articles reporting geopolitical risks in three newspapers from ProQuest Historical Newspapers starting from 1900: *The New York Times*, *The Chicago Tribune*, and *The Washington Post*. The index value is normalized to an average of 100 in the 2000-2009 decade as a benchmark. For instance, if the GPRH index is 200, twice as many newspaper articles mentioned geopolitical issues than the average for that decade, meaning a twice intensive geopolitical risk level by estimation (Caldara and Iacoviello, 2022).

[3] https://www.matteoiacoviello.com/GPRH.htm.

Figure 1 presents how the GPRH index varied from 1900 to 2020 in the panel above, along with the innovation of GPRH ($\Delta GPRH,$ or GPRH_dif in the figure) in the panel below. Historically, the GPRH index rose and stayed high in the early stages of the 1910s and 1939 to 1941 when World War I and World War II began, respectively. After 2000, the highest point reached was in March 2003 when the United States invaded Iraq. Other remarkable peaks include April 1986 (US bombing Libya), January 1991 (Operation Desert Storm), and September 2001 (9/11 terror attack) (Baur and Smales, 2020). The figure also shows that the innovation level of the GPRH index is more peaked and volatile whenever the GPRH index goes to a periodic high level during the sample period. We observe that although the recent spikes are not as high as those of the 20th century, on average the index values are higher and have increased more in the past decade than in the preceding few decades, which may imply a more "geopolitical risky" world generally.

Figure 1: The Historical Geopolitical Risk (GPRH) Index



NOTE: The line plots the historical monthly GPRH index (GPRH) and its change (GPRH_dif) in two panels from 1900 to 2020. The index is formed by searching the three newspapers for all articles from 1900 through ProQuest Newspapers: the New York Times, the Chicago Tribune, and The Washington Post (Caldara and Iacoviello, 2022). The index value is normalized to an average of 100 in 2000-2009.

Two sub-indices of the GPRH index, GPRHA measuring geopolitical actions and GPRHT measuring geopolitical threats, are also obtained from Iacoviello's website. Following Schneider and Troeger (2006), Caldara and Iacoviello (2022) suggest that threats tend to increase uncertainty by triggering further corresponding activities, while geopolitical actions would decrease the uncertainty level in the short term. Thus, it is reasonable to conclude that geopolitical actions are conducted to avoid the worst situations caused by threats. Such a dichotomy implies that rational investors would have different or even opposite expectations for the innovations of geopolitical actions and threats. So in the empirical analysis of geopolitical risk, it is necessary to distinguish the impact of geopolitical threats from geopolitical actions (Baur and Smales, 2020; McCallen, 2018). While they are both highly related to the original GPRH index, the GPRHA index and GPRHT index have a relatively low correlation (0.15). This provides us an opportunity to track the source of the geopolitical risk issue that affects the commodity futures market precisely, so that we can answer the question of whether the threats themselves or the subsequent actions associated with the threats should be considered the main source of the price fluctuations.

4. Empirical Results

In this section, we conduct a series of parametric and nonparametric tests to examine the predictive power of geopolitical risk beta over commodity futures returns. A methodology description is provided before the tests demonstrations.

For the empirical results, first, a statistical summary is provided for beta, the exposure of commodity futures returns on the GPRH index. Second, we conduct a univariate portfolio-level analysis to detect the significance of geopolitical risk beta. A sub-sample analysis by time series splitting and two moving average figures are provided for the time-varying pattern of the beta. Then we replace the basic GPRH index with its two sub-indices to make an attribution detection of the source of geopolitical risk premium. In addition, a robustness check is conducted by utilizing macroeconomic factors as controlling variables.

4.1 Methodology Description

The empirical testing part of the study is based on Bakshi et al. 's (2019) model which incorporates an average factor *AVG*, a carry factor *CARRY*, and a commodity-momentum factor *CMOM*. Using this model, the hypotheses can be tested by including an additional pricing factor for the geopolitical risk, $GPRH_{i,t}$, to determine if geopolitical risk maintains explanatory power for the pricing of commodity futures after controlling for other factors.

With the basic model above, portfolio tests are conducted to assess the predictive power of the geopolitical risk betas over future commodity returns. First of all, following Bali et al. (2017), the rolling regression method is applied to obtain the exposures of commodity futures to geopolitical risks. Then using a univariate portfolio-level analysis, the monthly betas β^{GPRH} are used to predict the cross-sectional futures returns in the following month. Based on the hypothesis H1, the coefficient b_{GPRH} is expected to be significantly positive, controlling β^{AVG}, β^{CARRY} and β^{CMOM}, implying a positive relationship between geopolitical risk and commodity futures returns.

Next, this study will conduct a sub-sample test and moving average figures to test if the cross-sectional relation between the geopolitical risk beta and future commodity returns, as well as its risk premium, is state-dependent (non-linear) and varies over time. For hypothesis H2, the expected results would be that the beta would be time-varying (in line with H2a) and that the risk premium tends to be higher during recessions periods (in line with H2b). The business cycle and recession classification are sourced from the National Bureau of Economic Research (NBER) website[4].

Then we will perform risk premium attribution tests using sub-indices, GPRHA and GPRHT. Finally, evidence of a robustness check is provided by introducing macroeconomic variables.

4.2 Basic Statistic Summary

Exposures of commodity excess return to geopolitical risk are obtained by rolling regressing monthly excess returns on $\Delta GPRH$, the shock of one-month-ahead GPRH index (*t-1*) and current GPRH index (*t*), along with other three factors *AVG*, *CARRY*, and *CMOM*, using a 60-month fixed window and 24-minimum-observation condition for estimation. The procedure of rolling regression in this study follows method of Bakshi et al. (2019) and Bali et al. (2017). It avoids the bias generated by using whole-sample and provide more accurate periodic estimation on betas, and so that we can analyze its time-varying characteristics.

Equation (3) provides insight into the equation this study uses in the rolling regression procedure.

$$Return_{excess}^{i,t} = \alpha + \beta_{i,t}^{GPRH}\Delta GPRH + \beta_{i,t}^{AVG}AVG + \beta_{i,t}^{CARRY}CARRY + \beta_{i,t}^{CMOM}CMOM + \varepsilon_{\,i,t} \quad (3)$$

Following Bakshi et al. (2019), the average factor, *AVG*, is the excess return of a long position in all

[4] https://www.nber.org/cycles.html

available commodity futures, calculating equally weighted using equation (2). The commodity carry factor, *CARRY*, is constructed as the return on a portfolio that long five commodities that are most in backwardation and short the ones that are most in contango (the backwardation and contango status of each contracts-month observation is proxied by a log future-spot ratio, provided by Bakshi et al. [2019]). The commodity momentum factor, *CMOM*, is constructed as the return on a portfolio that long the five commodities with the highest cumulative return over the previous six months, and short the ones with the lowest cumulative returns over the previous six months.

With the model setting above, the first set of geopolitical risk betas (β^{GPRH}) are obtained in June 1975. Then these monthly betas are used to predict the cross-sectional stock returns in the following month (July 1975). The exact monthly rolling regression method is used until the end of the data sample, September 2011. Thus, the cross-sectional return predictability results are reported from July 1975 to August 2011.

Table 2 presents a descriptive statistics summary of betas. The geopolitical risk betas of 29 commodities are divided into four categories: agriculture, energy, livestock, and metal. A total sample row is also provided at the bottom. It presents the number of observations (N) in the first column and average (Mean), median, standard deviation (SD), skewness, the minimum and maximum value of the geopolitical risk betas in each category. Though it has the least observations (1406), energy is the only category that shows a positive beta (0.018), indicating a positive relationship between geopolitical risks index change and the excess return of energy futures contracts. The absolute β^{GPRH}value of energy is also the largest among the four categories, indicating that the return of energy contracts is heavily related to the shock of the GPRH index, compared with the other categories. The volatility of the energy category is also the largest, which is consistent with the findings of Mei et al. (2020). On average, the other three categories all present negative and smaller betas, which reveals a weaker and opposite relationship with the GPRH index change compared with the energy category, at least in the sample period.

Table 2: Descriptive Statistics of GPRH Beta

Note: This table summarizes the result of geopolitical risk betas by dividing the contracts into four categories: agriculture, energy, livestock, and metal, while a whole sample row is provided at the bottom. The seven columns present the number of observations (N) in the first column, and average (Mean), median, standard deviation (SD), skewness, the minimum and maximum value of the geopolitical risk betas in each portfolio. The sample period is from July 1975 to August 2011.

Category	N	Mean	Median	SD	Skewness	Minimum	Maximum
Agriculture	5565	-0.0004	-0.0008	0.0315	-0.0683	-0.1814	0.1606

Energy	1406	0.0182	0.0142	0.0412	1.5482	-0.0995	0.4995
Livestock	1729	-0.0082	-0.0077	0.0381	-0.5995	-0.1615	0.1206
Metal	2106	-0.002	-0.0039	0.027	0.6687	-0.0989	0.1259
Total	10806	0.0005	-0.0009	0.0341	0.3613	-0.1814	0.4995

4.3 Univariate Portfolio-level Analysis

Table 3 presents the univariate portfolio results sorting by geopolitical risk betas (β^{GPRH}). For each month, we form a triple portfolio sorting test by sorting on their betas, where the low portfolio contains five contracts with the lowest β^{GPRH} during the previous month, the high portfolio contains five contracts with the highest β^{GPRH} during the previous month, and the medium portfolio contains all the other contracts. This unusual sorting test is adopted due to the small volume of samples, as there are maximally 29 commodity futures contracts observations each month. The first column in Table 3 reports the equal-weight average geopolitical risks betas, and the following four columns present the average excess returns and the alphas on the equal-weighted portfolios and their *t*-statistics, respectively.

The first column of Table 3 shows a significant cross-sectional variation in the average values of β^{GPRH}: the average geopolitical risk beta increases from -0.04 to 0.04. Also, the next-month average excess return increases monotonically from 0.02% to 0.68% per month when moving from the low to high portfolio. The result, therefore, demonstrates a pattern that excess return increases along with the increasing geopolitical risk beta. The average return difference between the high and low portfolios is 0.66% per month, with a Newey-West (1987) *t*-statistic of 5.51. Those results imply that contracts in the High portfolio significantly generate 7.92% higher annual returns than those in the Low portfolio.

Table 3: Univariate Portfolios Sorted by GPRH Beta

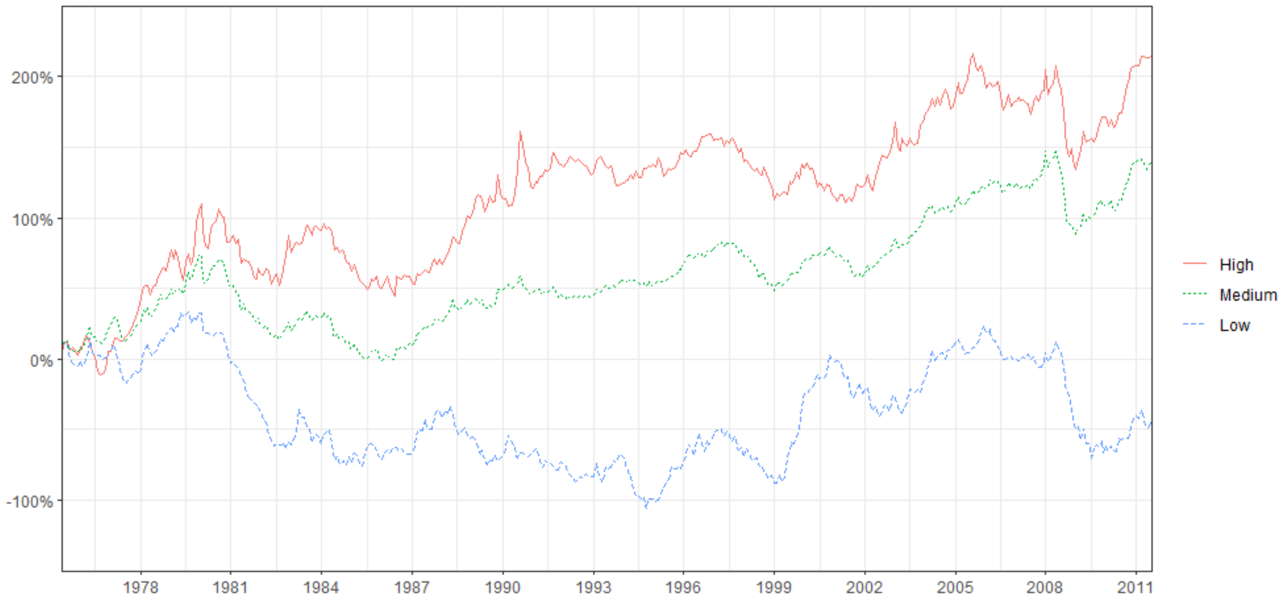
Note: For each month, triple portfolios are formed that are equally weighted by sorting commodity futures contracts based on their geopolitical risk betas (β^{GPRH}), where the low (high) portfolio contains five contracts with the lowest (highest) β^{GPRH} during the previous month, and the medium portfolio contains all the rest of the contracts. The first column reports the average geopolitical risk beta of contracts in each portfolio, and the remaining columns show the average excess return (Exc_Ret), alpha, the respective *t*-value of those values with Newey-West adjustment, and Sharpe ratio. α is the alpha relative to the AVG, CARRY, and CMOM factors of the model from Bakshi et al. (2019). The last row presents a "High minus Low" portfolio. The sample period is from July 1975 to August 2011.

Portfolio	Beta	Exc_Ret	t(Exc_Ret)	Alpha	t(Alpha)	Sharpe Ratio
Low	-0.04	0.02	0.26	-0.01	-0.13	0.005
Medium	0.00	0.39	9.39	0.36	8.70	0.105
High	0.04	0.68	8.01	0.64	7.16	0.111
High-Low	0.08	0.66	5.51	0.64	5.44	0.098

Besides the basic raw excess returns, Table 3 also presents the magnitude and statistical significance levels of the risk-adjusted returns (alphas) relative to a commodity three-factor model from Bakshi et al. (2019). The alpha is the intercept from the regression of excess portfolio returns on a constant, *AVG*, *CARRY*, and *CMOM* factor. The fifth column of Table 3 shows that alpha increases monotonically from -0.01% to 0.64% per month when moving from the low to the high portfolio. The difference in alphas between the high-β^{GPRH} and low-β^{GPRH} is 0.64% per month (or 7.68% per annum) with a Newey-West *t*-statistic of 5.44. The alpha of the high portfolio is significantly positive (with Newey-West *t*-statistic of 7.16). In contrast, the alpha of the low portfolio is not significantly negative, so it appears that the positive spread across the high-β^{GPRH} and low-β^{GPRH} contract comes from the outperformance of high-β^{GPRH} commodity futures contracts. Thus, the empirical result suggests that we should accept the hypothesis H1(a) rather than the H1(b) in section 2.3, and conclude that the risk premium triggered by geopolitical events is positive in the commodity futures market.

Figure 2 depicts the cumulative log-returns of low, medium, and high portfolios from 1975 to 2011. The results demonstrate that high-β^{GPRH} contracts outperform low-β^{GPRH} contracts over the long run, and the cumulative log excess return of the high-beta portfolio would exceed 200%, absent other costs. It is also noticeable that the medium portfolio has a cumulative log return of around 150% at the end of 2011, which reveals a positive geopolitical risk-neutral return of the whole commodity futures market in the past four decades.

Figure 2: Cumulative Log-Returns of Each Portfolio



Note: Figure 2 shows the cumulative log-returns of the corresponding equal-weighted triple sorting portfolios (high, medium, and low) using the geopolitical risk betas. The sample period is from July

1975 to August 2011.

4.4 Is the Risk Premium Time-Varying?

Having determined that there is a significant risk premium of geopolitical risk in the commodity futures market, next, we test if such a cross-sectional relation is time-varying over the sample period. First, the sub-sample univariate test provides a preliminary result of time-varying beta. Then we plot the moving average betas and excess return against time to give a clear illustration of its changing pattern.

Table 4 shows a sub-sample sorting test result by dividing the results obtained in Section 4.2 into two parts. Using the year 2000 as the breaking point, the univariate sorting table is divided into two components: the pre-2000 component on the left includes data from July 1975 to December 1999, and the post-2000 component includes data from January 2000 to August 2011. The time point is chosen to detect the influence of commodity market financialization since the early 2000s (Tang and Xiong, 2012, Goldstein and Yang, 2022) and to see if the cross-sectional relationship between geopolitical risk and commodity futures return changes before and after the 21st century.

Table 4: Sub-Sample Sorting Test Result

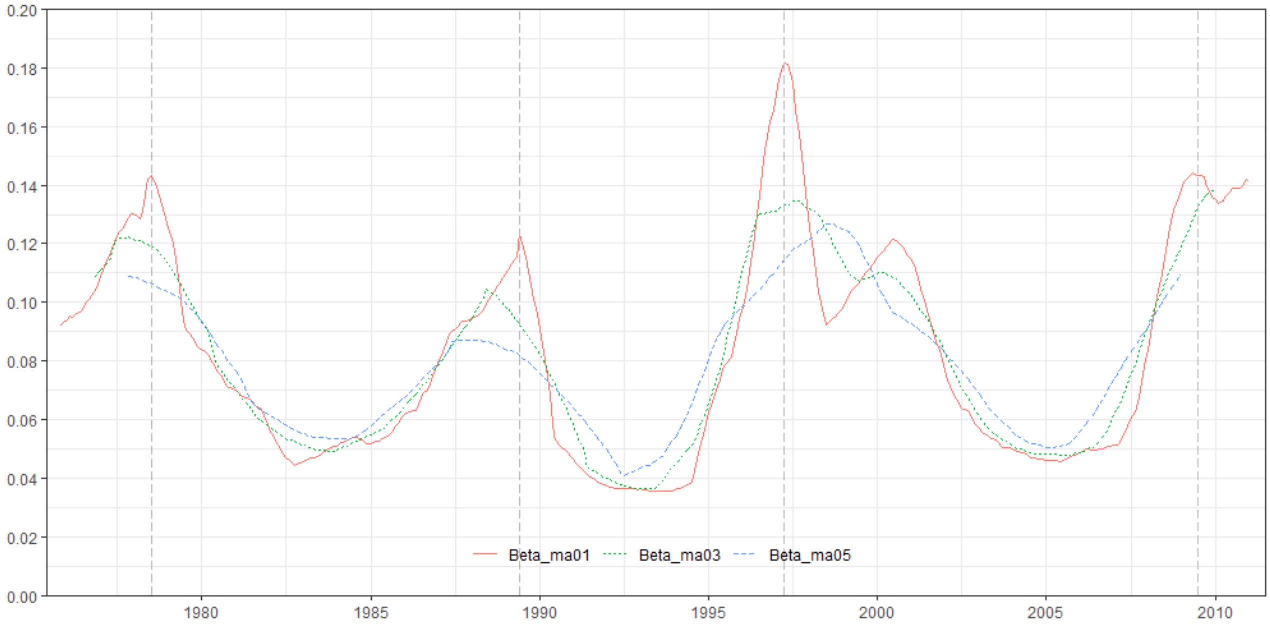
Note: The table is formed by dividing the regression result in part 4.1 using the year 2000 as a breaking point. The pre-2000 component includes data from July 1975 to December 1999, while the post-2000 component includes data from January 2000 to August 2011. For each month, triple portfolios are formed that are equally weighted by sorting commodity futures contracts based on their geopolitical risk betas (β^{GPRH}), where the low (high) portfolio contains five contracts with the lowest (highest) β^{GPRH} during the previous month, and the medium portfolio contains all the rest of the contracts. The last row presents a "High minus Low" portfolio. Newey-West adjusted *t*-statistics are given in parentheses under the respective column.

	Pre-2000 Component			Post-2000 Component		
Portfolio	Beta	Exc_Ret	Alpha	Beta	Exc_Ret	Alpha
Low	-0.039	-0.004	0	-0.044	0.076	-0.037
		(-0.05)	(-0.00)		(0.34)	(-0.17)
Medium	-0.001	0.239	0.231	0.001	0.61	0.536
		(5.71)	(4.15)		(3.54)	(2.28)
High	0.041	0.567	0.494	0.043	0.806	0.831
		(5.16)	(4.52)		(2.97)	(2.43)
High-Low	0.080	0.572	0.494	0.087	0.73	0.868
		(3.04)	(2.62)		(2.79)	(3.41)

The comparison of the two components in Table 4 implies some remarkable differences in commodity futures returns before and after the turn of the 21st century. First, the post-2000 component has a larger region of beta (0.09) than that of the pre-2000 component (0.08), indicating a more considerable variation in geopolitical risk innovation sensitivity. Second, the average excess return of the post-2000 component (0.73% per month) is also higher than the pre-2000 data (0.57% per month), while the Newey-West *t* statistics are all significant. The higher risk premium of geopolitical risk provides some evidence for the argument that under the influence of financialization, the commodity futures market became more vulnerable to geopolitical risk after 2000. In addition, Table 4 shows that the alpha of the High-Low portfolio almost doubled, from 0.49% to 0.87% per month, or 10.42% per annum, while the *t*-statistics (2.62 and 3.41) are both significant in the two periods. The alpha even exceeds the average raw excess return (0.73%) in the post-2000 component. Such a dramatic change indicates that the basic model of Bakshi largely loses its ability in pricing commodity futures under the shock of financialization after the early 2000s (Goldstein and Yang, 2022).

Such a cross-sectional relationship varies regularly in a cycle over time. Figure 3 presents the change of geopolitical risk beta from 1975 to 2011. The lines record 1-year (12 months), 3-year (36 months), and 5-year (60 months) moving average values of β^{GPRH} chosen from the High-Low portfolios (data of row 4, column 1 in Table 3). The tendency of β^{GPRH} variation shows that, instead of staying at a relatively stable level, the geopolitical risk beta is not only time-varying but there is a consistent cyclic pattern of beta changing in the sample period. Specifically, each cycle takes about 8 to 10 years, with relative peak and bottom values in each period. Taking the 1-year moving average beta as an example, it goes straight down from 0.14 in July 1978 to 0.04, the lowest point, in October 1982, then increases back to pinnacle level, 0.12, in June 1989 before declining rapidly again. The moving pattern shares a similar “U-shaped curve” in each cycle, as all peaks are relatively sharp while the bottoms are round. Other moving average lines in Figure 3 also support the same tendency. Taking every periodic peak as a breakpoint, the β^{GPRH} roughly experiences three cycles of “U-shaped curve” in the sample period (1978-1989, 1989-1997, and 1997-2009 separately). Such a pattern of beta change is relatively independent of the tendency of the GPRH index, and it aligns with Fama and French (1987) about the time-varying characteristics of the commodity futures risk premium .

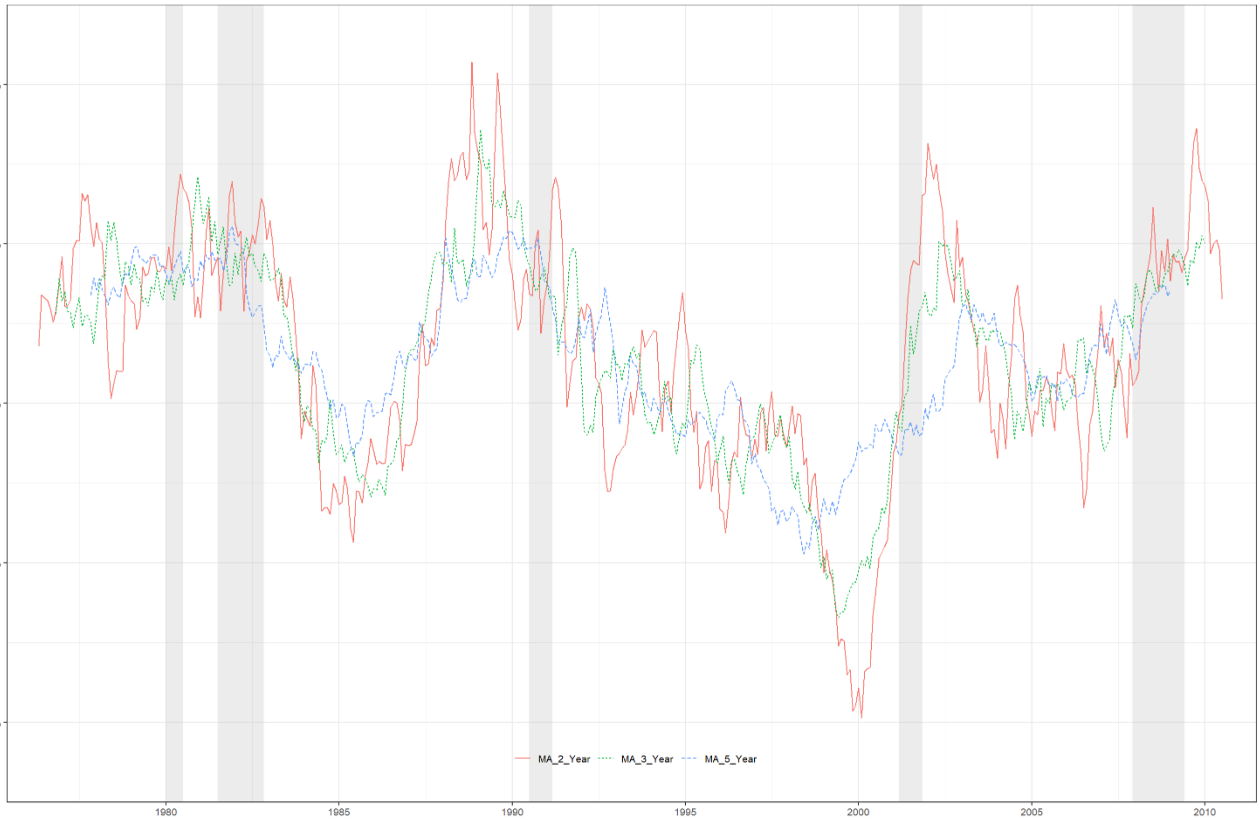
Figure 3: Moving Average GPRH Beta of the High-Low Portfolio



Note: The figure record how geopolitical risk beta changes. The β^{GPRH} is calculated as the portfolio beta of the High-Low portfolio in Table 3. The solid line records 1-year moving average beta, while the dotted and dashed lines record 3-year and 5-year moving average beta. The sample period is from June 1976 to August 2011.

We also build a connection between geopolitical risks premium and economic recessions by demonstrating moving average excess returns in Figure 4. It portrays 2-year, 3-year, and 5-year moving average excess returns of the High-Low portfolio over time, while the economic recession periods are marked as shadow panels. According to the business cycles classified by the NBER website, five recessions occurred during the sample period. Taking 1-year moving average value as an example, we find that the excess returns are above average (0.66%) initially before every economic recession and that they increase dramatically in the recession period. One exception appears in 2001, where the excess return was lower than zero before the recession (March 2001) but increased rapidly to more than 2% when the recession ended in November 2001. Similar situations appear in each recession period when looking at 3-year and 5-year moving average lines in Figure 4. The united pattern leads to the conclusion that the premium for geopolitical risk tends to be higher than average during economic downturns, and that the risk premium usually increases further and significantly. We believe this insight along with the change of moving average betas, pointing out a solid way for the market to form reasonable expectations and make use of the change in geopolitical risk premium. However, whether the change of risk premium is related to other influential factors remains to be investigated.

Figure 4: Moving Average Excess Return of the High-Low Portfolio



Note: The figure record of how the excess return of the high-low portfolio changes. The high-low portfolio is constructed based on the beta of geopolitical risk presented in Table 3. The solid line records 2-year moving average excess return, while the dotted and dashed lines record 3-year and 5-year moving average excess return. The shadow panels are the recession periods classified and sourced from the NBER website. The sample period is from June 1976 to August 2011.

4.5 The Source of Geopolitical Risk Premium

So far, we have tested the significance of the geopolitical risk beta as a different determinant of the cross-section of commodity futures returns and how it varies over time at the portfolio level. The primary advantage of conducting portfolio analysis is that it is nonparametric so that we do not have to impose an assumed functional form on the relation between the uncertainty beta and commodity futures returns.

Next, we replace the basic GPRH index with two sub-indices, GPRHA and GPRHT, in the rolling regression procedure to get their beta exposure separately. The replacement could help us identify the critical source of geopolitical risk issues that trigger price changes in the commodity futures market.

A basic summary of beta statistics is provided in Table 5, comparing the betas of GPRHA (β^{GPRHA})

and GPRHT (β^{GPRHT}) on commodity futures returns by giving two components. Similar to the rolling regression procedure in Section 4.1, the geopolitical index variable is constructed as a difference form. The GPRHA and GPRHT indices are applied separately while the other three controlling variables from Bakshi et al. (2019) are kept. The detail of the two equations is shown as equations (4) and (5).

$$Return_{excess}^{i,t} = \alpha + \beta_{i,t}^{GPRHA}\Delta GPRHA + \beta_{i,t}^{AVG}AVG + \beta_{i,t}^{CARRY}CARRY + \beta_{i,t}^{CMOM}CMOM + \varepsilon_{\,i,t} \quad (4)$$

$$Return_{excess}^{i,t} = \alpha + \beta_{i,t}^{GPRHT}\Delta GPRHT + \beta_{i,t}^{AVG}AVG + \beta_{i,t}^{CARRY}CARRY + \beta_{i,t}^{CMOM}CMOM + \varepsilon_{\,i,t} \quad (5)$$

Though the relationship of geopolitical actions and geopolitical threats with commodity futures return is similar in general, there are divergences at several time points. First, though the difference is not so significant, the mean value of geopolitical threats beta is positive (0.0005) and higher than the betas of geopolitical actions. In particular, concerning each category, the average beta of metal contracts is less sensitive to the transfer from β^{GPRHA} to β^{GPRHT} (-0.0041 to -0.004), while such a change has a greater influences on the other three categories. It is noticeable that the beta of agriculture category transformed from negative (-0.0003 for β^{GPRHA}) to positive (0.0004 for β^{GPRHT}). Second, compared with β^{GPRHA}, β^{GPRHT} shows a more extensive range (0.57) and standard deviations (0.04) in the total sample. The outperformance of GPRHT suggests that geopolitical threats bring more uncertainty and cause a more considerable fluctuation of price change in the commodity futures market. In the meantime, the market responds to geopolitical actions less sensitively, which aligns with the findings of Schneider and Troeger (2006) and Caldara and Iacoviello (2022). The same situations also remain in all divided categories, suggesting that the comparable drop-off from the result of GPRHT to the result of GPRHA is not restricted in some categories specifically, but has a holistic impact on the whole market.

Table 5: Descriptive Statistics Summary of Sub-Indices

Note: This table summarizes the result of geopolitical actions (GPRHA) betas and geopolitical threats (GPRHT) betas by giving two components. The contracts are divided into four categories: agriculture, energy, livestock, and metal, while a whole sample row is provided at the bottom. The four columns in each component present the average value (Mean), median, SD and range (calculated as the difference between maximum and minimum value) of betas in each portfolio. The sample period is from July 1975 to August 2011.

	Betas of geopolitical actions (β^{GPRHA})				Betas of geopolitical threats (β^{GPRHT})			
Category	Mean	Median	SD	Range	Mean	Median	SD	Range
Agriculture	-0.0003	-0.0009	0.0184	0.2015	0.0004	-0.0003	0.0345	0.3762
Energy	0.0097	0.0104	0.0286	0.3468	0.0178	0.0130	0.0420	0.4380
Livestock	-0.0021	-0.0028	0.0184	0.1333	-0.0123	-0.0088	0.0394	0.2396

Metal	-0.0041	-0.0050	0.0194	0.1649	-0.0004	-0.0031	0.0285	0.1876
Total	0.0000	-0.0012	0.0206	0.3620	0.0005	-0.0008	0.0362	0.5650

Consequently, Table 6 presents univariate portfolio results of geopolitical action beta (β^{GPRHA}) and geopolitical threats beta (β^{GPRHT}) in two separate panels. While both β^{GPRHA} and β^{GPRHT} show cross-sectional variations, the latter one has a larger span of beta (0.089) from low to high portfolio, which is consistent with the upper finding. However, we find that the beta of geopolitical actions along with the commodity futures returns has no clear relationship. Instead, the excess return and alpha first decrease then increase from the low, to the median, to the high portfolio. The result of comparison confirms the argument that geopolitical actions are expected to remit the level of risk triggered by geopolitical threats, so that the risk premium would be lower when the value of β^{GPRHA} is close to zero, in other words, when the connection of commodity futures to the change of GPRHA is relatively minor.

Table 6: Univariate Portfolios of Commodity Sorted by Sub-Indices

Note: The table demonstrates portfolio sorting results for betas of geopolitical actions and geopolitical threats. For each month, triple portfolios are formed that are equally weighted by sorting commodity futures contracts based on betas (β^{GPRHA} and β^{GPRHT}), where the Low (High) portfolio contains five contracts with the lowest (highest) betas during the previous month, and the Medium portfolio contains all the rest of the contracts. The first column reports the average betas of contracts in each portfolio, while the other two columns show the average excess returns (Exc_Ret) and Alphas. The alpha is related to the model from Bakshi et al. (2019). Newey-West adjusted *t*-statistics are given in parentheses under the respective column. The last row presents a "High minus Low" portfolio. The sample period is from July 1975 to August 2011.

	Betas of geopolitical actions (β^{GPRHA})			Betas of geopolitical threats (β^{GPRHT})		
Portfolio	Beta	Exc_Ret	Alpha	Beta	Exc_Ret	Alpha
Low	-0.026	0.537	0.491	-0.043	0.021	-0.001
		(6.67)	(5.66)		(0.28)	(-0.02)
Medium	-0.000	0.399	0.371	0.000	0.398	0.370
		(9.52)	(8.82)		(9.52)	(8.82)
High	0.027	0.910	0.888	0.046	0.495	0.465
		(8.86)	(8.23)		(5.68)	(4.84)
High-Low	0.053	0.373	0.397	0.089	0.474	0.467
		(2.73)	(2.98)		(3.67)	(3.54)

Overall, the performance of GPRHT beta is more compelling and more consistent with the previous findings in Section 4.2, compared with that of GPRHA beta. The excess return monotonically increases from 0.021% to 0.495% per month as the beta of geopolitical threats increases, while the alpha also increases from -0.001% to 0.465% per month. Considering the relatively weak performance of

GPRHA, it appears that geopolitical threats are the dominating factor that drives the influence of geopolitical risk on the commodity futures market. In addition, the excess return and alpha of the High-Low portfolio sorted by β^{GPRHT} (0.47 and 0.47) are less than those of the basic β^{GPRH} (0.66 and 0.64), and the respective Newey-West t-statistics are also less significant. The performance of the two indices implies that as an integrated index, the GPRH index performs better than the GPRHT index does in pricing commodity futures returns. It also confirms that geopolitical action could be a good supplement for geopolitical threats when capturing information about geopolitical risk issues and provide exogenous stimulation to the financial market, which is in line with the conclusion of Caldara and Iacoviello (2022).

4.6 Robustness Checks

In this section, we test the robustness of the pricing ability of GPRH beta by adding several macroeconomic factors into the rolling regression procedure. Following Shang et al. (2016), three macro factors are chosen and constructed: *MKT*, the market factor of the U.S. stock market, is obtained from Kenneth R. French's data library website[5], calculated as the market return of the U.S. stock market, including NYSE, AMEX, and NASDAQ, in excess of the 1-month Treasury bill rate; *URInt*, the unexpected real interest rate, is calculated as the difference of real interest rate in the current *t* and previous (*t-1*) periods; *UInf*, the unexpected inflation is the nominal inflation rate minus the expected inflation rate. The real interest rate is the nominal interest rate minus inflation, where the nominal interest rate is proxied by the 3-month Treasury bill rate, and the inflation rate is proxied by CPI. The T-bill rate and expected inflation rate are obtained from the Federal Reserve Economic Database. The CPI is obtained from the US Department of Labor. Table 7 presents the correlation matrix of the macro factors along with $\Delta GPRH$. All these factors have very low cross-correlations. Notice that here the sample period starts in January 1978 due to data availability.

Table 7: Correlation Matrix of Macroeconomic Factors

Note: The table presents the correlation matrix of the macro factors along with $\Delta GPRH$. *MKT* is the market factor of the US stocks, constructed as the market return of the US stock market in excess of the 1-month Treasury bill rate; *URInt*, the unexpected real interest rate, is calculated as the difference of real interest rate in the current (*t*) and previous (*t-1*) periods; *UInf*, the unexpected inflation is the nominal inflation rate minus the expected inflation rate. The sample period is from January 1978 to September 2011.

	MKT	*UInf*	*URInt*	$\Delta GPRH$

[5] https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html

MKT	1.000	-	-	-
UInf	0.032	1.000	-	-
URInt	-0.055	-0.143	1.000	-
$\Delta GPRH$	-0.095	-0.023	-0.066	1.000

To determine the potential influence of macroeconomic factors on the pricing power of geopolitical risk, Table 8 presents the univariate portfolios with and without control for the macro factors using a data sample from December 1982 to September 2011. To be more specific, the left component is sorted by a β^{GPRH} roll regressed by equation (3), while the right component presents the results with additional controlling factors *MKT*, *UInf*, and *URInt*, or the equation (6) as follows:

$$Return_{excess}^{i,t} = \alpha + \beta_{i,t}^{GPRH}\Delta GPRH + \beta_{i,t}^{AVG}AVG + \beta_{i,t}^{CARRY}CARRY + \beta_{i,t}^{CMOM}CMOM$$
$$+ \beta_{i,t}^{MKT}MKT + \beta_{i,t}^{URInt}URInt + \beta_{i,t}^{UInf}UInf + \varepsilon_{\,i,t} \quad (6)$$

The comparison of two components in Table 8 provides some robustness evidence on the pricing ability of the geopolitical risk factor. First, the beta spans of the two components are nearly the same (0.0817% and 0.0824% per month), indicating that the macro factors made a relatively small impact on the correlation of geopolitical risk with commodity futures returns. Second, the excess return and alpha of the High-Low portfolio is 0.54% (with Newey-West *t*-statistic of 3.26) and 0.52% (3.04) per month when controlling for the macro factors, compared with 0.408% (2.70) and 0.413% (2.65) per month when omitting those controls. Thus, excess return and alpha are more significant when macro factor control exists, along with the more significant *t*-statics. As a result, instead of being diversified and reduced, the pricing ability of geopolitical risk on commodity futures return is made more solid and potent by controlling those macroeconomic factors.

Table 8: Univariate Portfolios with and without the Control

Note: The table presents univariate portfolios of commodity futures returns sorted by β^{GPRH}, with and without macro factor controls in the two components. The controlling macro factors include *MKT* (the US stock market), *URInt* (the unexpected real interest rate), and *UInf* (the unexpected inflation rate). The first column in each component, Beta, is the average β^{GPRH} value within each portfolio, while the Exc_Ret and Alpha present the average excess return and the alpha of Bakshi et al. (2019)'s model within each portfolio. Newey-West adjusted *t*-statistics are given in parentheses under the respective column. The last row presents a "High minus Low" portfolio. The sample period is from December 1982 to August 2011.

	Without Controlling for Macro Factors	With Controlling for Macro Factors

Portfolio	Beta	Exc_Ret	Alpha	Beta	Exc_Ret	Alpha
Low	-0.039	0.180	0.157	-0.040	0.057	0.051
		(2.07)	(1.88)		(0.64)	(0.57)
Medium	0.001	0.409	0.384	0.001	0.409	0.384
		(8.73)	(7.75)		(8.73)	(7.75)
High	0.042	0.587	0.571	0.042	0.599	0.568
		(5.41)	(4.13)		(5.26)	(3.90)
High-Low	0.082	0.408	0.413	0.082	0.542	0.517
		(2.70)	(2.65)		(3.26)	(3.04)

One unexpected difference of Table 8 remains in the data of two low portfolios, as the excess return (alpha) is reduced from 0.18% (0.16%) to 0.06% (0.05%) per month when controlling factors are added. The decrease suggests that when a negative relationship remains in the return of commodity futures and geopolitical risk innovations, the return tends to be less sensitive to the geopolitical risk innovations when controlling for macroeconomic factors.

4.7 Comparison with the GEPU index

Compared with the situation of the GPRH index discussed in Section 4.3, Table 9 indicates that the Global Economic Policy Uncertainty (GEPU) index (Baker et al., 2016) fails to explain the cross-sectional variation of commodity futures returns. Using similar rolling regression and sorting methods in Section 4.3, Table 9 presents the univariate portfolio results of GEPU betas. Though the GEPU index is proved to share similar characteristics with the GPR index in predicting financial market volatility and consumer sentiment (Caldara and Iacoviello, 2022), the performance of GEPU in predicting commodity futures returns is relatively poor compared with that of the GPRH index. Neither the excess returns nor the alphas show a monotonically changing pattern crossing the low, medium, and high portfolios. The high-minus-low portfolio sorted by the GEPU betas has a lower excess return (0.11% per month) and alpha (0.25% per month) than those sorted by the GPRH betas, while the New-West *t*-statistics of the former one (0.24, 0.59) are also insignificant. Although the highest excess return and alpha both appear in the medium portfolio, which may imply a high risk-neutral return, their corresponding New-West *t*-statistics are not significant enough to support the assumption. Thus, the comparison between the GEPU and GPRH index confirms our hypothesis from another perspective and further reveals that GPRH is a good indicator to consistently identify the influence of exogenous geopolitical events on the commodity futures returns.

Table 9: Univariate Portfolios Sorted by GEPU Beta

Note: For each month, triple portfolios are formed that are equally weighted by sorting commodity futures contracts based on their global economic policy uncertainty betas (β^{GEPU}), where the low (high) portfolio contains five contracts with the lowest (highest) β^{GEPU} during the previous month, and the medium portfolio contains all the rest of the contracts. The first column reports the average global economic policy uncertainty beta of contracts in each portfolio, and the remaining columns show the average excess return (Exc_Ret), alpha, and the respective t-value of those values with Newey-West adjustment. α is the alpha relative to the AVG, CARRY, and CMOM factors of the model from Bakshi et al. (2019). The last row presents a "High minus Low" portfolio. The sample period is from January 1997 to August 2011.

Portfolio	Beta	Exc_Ret	t(Exc_Ret)	Alpha	t(Alpha)
Low	-0.09	0.63	1.00	0.43	0.55
Medium	0.00	0.83	3.46	0.72	1.89
High	0.09	0.74	2.31	0.68	1.78
High-Low	0.18	0.11	0.24	0.25	0.59

5. Concluding remarks

Literature has explored the economic effect of geopolitical risk events. For example, Carney (2016) shows that an "uncertainty trinity" system including geopolitical, economic, and policy uncertainty could influence the national economy negatively. Caldara and Iacoviello (2022) contributed to this research by designing a historical geopolitical risk (GPRH) index measuring real-time geopolitical risk. The index enables the systematic empirical analysis to combine the risks exposed by geopolitical factors with economic outcomes, as well as to get a better understanding of the global market investment. The index has been widely applied to examinations of the commodity market (see for example, Baur and Smales, 2020; Su et al., 2021: Mei et al., 2020). Yet to the best of our knowledge, gaps remain in the research of asset pricing of commodity futures combining the index with the whole commodity futures market. The existing literature lacks a general and systematic analysis of how such a risk source will influence the price change in a pool of commodity futures contracts instead of individual commodity contracts or categories.

Based on a three-factor model of Bakshi et al. (2019), our study investigates the role of geopolitical risk in the cross-sectional asset pricing of commodity futures contracts. The empirical results show that the resulting risk beta, β^{GPRH}, predicts a significant proportion of the cross-sectional dispersion in futures return. The excess return tends to increase as the beta increases: the constructed "High-Low" portfolio yields an annualized risk-adjusted return of 7.92%. Cumulative log excess return of such a portfolio exceeds 200% from 1976 to 2011. The risk premium triggered by geopolitical risk is hardly explained or eliminated by the basic model of Bakshi et al. (2019). Therefore, the empirical result verifies our hypothesis that such a risk premium can be accounted for the demand change because of the dual pressure from the commercial hedgers and non-commercial speculators. This interpretation is also consistent with the traditional literature on the convenience yield (Working, 1949) that the extra yield increases when potential inventory level decreases, while such a decrease is due to the occurrence of geopolitical risk events and the subsequent increase in short-term demand.

The cross-sectional relationship between geopolitical risk and commodity futures is detected to be time-varying: the moving average β^{GPRH} illustrates an obvious 10-year cycle pattern in the change of geopolitical risk beta. In addition, the monthly risk premium triggered by geopolitical risk tends to be higher than average before recession periods, and to increase rapidly over the course of a recession, which is consistent with Popp and Zhang's (2016) assertion that the adverse effects of incremental uncertainty are quantitatively larger during recessions. Such a pattern is independent of GPRH index variation, so it could benefit the commodity market by helping investors form the right expectations and make good use of the changing pattern of GPRH premium.

Moreover, such a risk premium is primarily attributed to the geopolitical threats instead of geopolitical actions, which is consistent with the conclusions of Schneider and Troeger (2006) and Caldara and Iacoviello (2022) that threats cause more geopolitical risk, while actions tend to lease the investment uncertainty pressed by geopolitical issues. This conclusion is different from the result of McCallen (2018) that the geopolitical action is the main pricing factor in the stock market, highlighting the uniqueness of the commodity market. By introducing three additional macroeconomic factors, the result reveals that the pricing power of geopolitical risk beta is kept and furtherly exaggerated when controlling for these macroeconomic factors. This result implies that the geopolitical risk is exogenous from the economic system and cannot be explained or absorbed by other usual macroeconomic risk issues.

Overall, the study findings align with the expectation that high geopolitical risk-related commodity futures require extra compensation, and the market is willing to pay a higher price to invest in those commodity futures contracts. Investors could benefit from the insights of this study in that it will improve their ability to analyze commodity futures and optimize asset allocation efficiency in their investment portfolios.

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