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by Beatrice Bertelli, Costanza Torricelli

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Geopolitical risk in financial markets: an analysis of commodity hedging and stock returns in Europe[§]

Beatrice Bertelli*[◦], Costanza Torricelli*^{◦§}

* University of Modena and Reggio Emilia

[◦] Cefin, Banking and Finance Research Center, Modena

[§] CeRP, Center for research on Pensions and Welfare policies, Turin

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Abstract

Against the backdrop of rising geopolitical uncertainty and increased commodity market volatility, this paper aims to quantify European firms' exposure to commodity price risk and to examine the effects of hedging by means of commodity derivatives. The empirical analysis is based on pooled OLS on a balanced dataset of 57 publicly listed firms operating in commodity-intensive sectors, over the period 2010–2024. Results can be summarized as follows. First, European firms exhibit a statistically significant exposure to commodity price risk, which is on average positive for Oil & Gas, Materials and Industrial Products firms, and on average negative for Utilities. Further, a year-by-year analysis reveals that around major geopolitical events (e.g. the 2014 oil price collapse and the 2022 Russia–Ukraine conflict), the proportion of firms with statistically significant exposure tends to increase. Second, the role of commodity hedging varies substantially across sectors: while hedging significantly reduces the long-run exposure to commodity price risk in the Materials and Utilities sectors, during the Russia–Ukraine war it is associated with lower stock returns in the Oil & Gas sector and with higher stock returns in the Industrial Products sector. These results highlight the importance of actively managing commodity price risk, particularly during periods of heightened geopolitical uncertainty, and the valuable yet heterogeneous role of hedging strategies across sectors and market conditions.

Keywords: Geopolitical risk, Commodity price risk, Hedging strategies, Stock returns

JEL: C23, F51, G32

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1. Introduction

Recent geopolitical tensions have multifaceted impacts since they not only drive conflict and policy uncertainty but also reshape trade, investment, and supply chain dynamics. In this context, geopolitical risk defined by Caldara and Iacovello (2022) as the “threat, realization, and escalation of adverse events associated with wars, terrorism, and any tensions among states and political actors that affect the peaceful course of international relations” represents a crucial concern for businesses and financial markets worldwide.

An increase in geopolitical risk may threaten macrofinancial stability as geopolitical tensions may disrupt cross-border trade and increase uncertainty in global markets, leading to sharp asset price adjustments and higher market volatility (European Central Bank, 2024; International Monetary Fund, 2025). Specifically, asset prices are affected by means of an economic channel and a channel related to market sentiment (International Monetary Fund, 2025). The effects of the first channel spread through restrictions on trade and financial flows or through actual damage to infrastructure and production facilities. The market sentiment channel works by increasing uncertainty and risk aversion among investors and businesses.

Commodity markets are particularly sensitive to geopolitical disruptions, because their production is often geographically concentrated and their demand is relatively inelastic, as many commodities are essential inputs in key technologies and household consumption (International Monetary Fund, 2023). Geopolitical tensions therefore tend to amplify commodity price volatility, although the magnitude and direction of these effects vary across commodity classes and market conditions (Özdemir et al., 2025; Liu et al., 2024, 2021; Parnes and Parnes, 2025). Moreover, as commodities have become increasingly integrated into financial portfolios, geopolitical shocks are further amplified through financial channels (Tang and Xiong, 2012; Adams and Glück, 2015; Wang et al., 2022; Gong and Xu, 2022).

The Russia-Ukraine war, begun in February 2022, provides a clear example of such dynamics. The conflict worsened the European natural gas crisis as Russian energy supplies were disrupted, driving natural gas and electricity prices to record levels and raising other energy and commodity prices significantly. As a result, firms using commodities as production inputs faced higher costs, making commodity risk management particularly important (Caldara et al., 2022; Henderson, 2024; Boungou and Yatié, 2024).

More broadly, geopolitical risk can adversely affect both companies and financial institutions. As for companies, geopolitical risk may undermine global supply chain resilience, compromise companies’ optimal investment decisions, reduce firm value and also increase firm bankruptcy risk (Chang et al., 2025; Nguyen et al., 2025; Pringpong et al., 2023; Roy et al., 2024).

As for financial institutions, Phan et al. (2022) empirically demonstrate a negative association between geopolitical risk and bank stability. This potential negative effect of geopolitical risk on the banking sector is further confirmed by the recent European Central Bank's announcement to evaluate geopolitical risk management practices across 110 directly supervised banks (European Central Bank, 2025). In particular, in 2026 the ECB will launch a reverse stress test in which banks will have to identify specific geopolitical scenarios capable of reducing their Common Equity Tier 1 (CET1) capital by 300 basis points or more.

A relevant issue about geopolitical risk concerns its quantification. The most common measure is represented by the Geopolitical Risk Index (GPR) proposed by Caldara and Iacoviello (2022), which reflects the news coverage about a specific conflict or threats, tensions, and escalations related to potential conflicts.¹ It is measured monthly through the relative frequency of articles published by leading newspapers in the US, UK, and Canada that mention a specific set of words associated with geopolitical events and situations receiving significant media coverage. A more recent measure is the GPR Sentiment Index proposed by Culver et al. (2025), which builds on the framework of Caldara and Iacoviello (2022) by incorporating sentiment analysis techniques. While the GPR Index captures the intensity of geopolitical events through media coverage, the GPR Sentiment Index aims to disentangle the tone of geopolitical news by distinguishing between positive and negative sentiment associated with geopolitical developments. This allows for a more nuanced assessment of geopolitical risk by distinguishing whether geopolitical developments represent risks or opportunities.

In order to mitigate the adverse effects of asset prices fluctuations, particularly in commodity markets, firms may rely on risk management strategies involving derivative instruments (Białkowski et al., 2023). The literature generally supports the view that hedging reduces firms' exposure to price volatility and stabilizes cash flows, although its impact on firm value and stock returns remains subject to debate and may vary across industries and business models (Bartram, 2005; Aretz and Bartram, 2010; Laing et al., 2020).

Against this backdrop, this paper investigates stocks' commodity price risk exposure and the role of commodity hedging strategies for a sample of European non-financial firms over the period 2010–2024. By using a balanced panel of 57 publicly listed firms operating in commodity-intensive sectors, we estimate a multi-factor model that captures firms' sensitivity to commodity price movements while controlling for market and exchange rate risk. The model is then augmented to include a variable capturing firms' hedging policy which is interacted with both the commodity risk factor and a war period dummy. Thus, we are able to assess whether hedging

¹ An extensive discussion and comparison of geopolitical risk measures is provided by Karagozoglu et al. (2022).

alters firms' exposure to commodity price risk and to test whether firms' hedging strategies are associated with an incremental or decremental effect on stock returns during the Russia–Ukraine conflict. Unlike much of the previous literature, which often relies on two-stage estimation approaches or focuses on single-industry or U.S.-centric data, this study integrates commodity price exposure and hedging activity within a unified panel regression model encompassing different European countries. Further, the inclusion of the war period enables us to examine firms' responses during an episode of acute geopolitical turmoil, thereby expanding the existing literature, which has predominantly focused on pre-conflict periods.

Based on our empirical framework we aim to answer to two main research-questions:

RQ1. Do firms exhibit exposure to commodity price risk and, if so, does the sign and magnitude of this exposure vary over time and across different sectors?

RQ2. Does commodity hedging reduce firms' exposure to commodity price risk, and is it associated with different stock returns during the Russia-Ukraine war period?

Our main results can be summarized as follows. First, European firms exhibit a statistically significant exposure to commodity price risk, with heterogeneity across sectors, both in terms of sign and in terms of the intensity of the relationship. In particular, exposure is on average positive for Oil & Gas, Materials and Industrial Products firms, and on average negative for Utilities, a highly regulated sector, predominantly downstream in the commodity supply chain, where commodity inputs, especially natural gas and electricity, represent cost components rather than revenue driver. Further, a year-by-year analysis reveals that around major geopolitical events (e.g. the 2014 oil price collapse and the 2022 Russia–Ukraine crisis), the proportion of firms with statistically significant exposure tends to increase. Second, the role of commodity hedging varies substantially across sectors. While hedging significantly reduces the long-run exposure to commodity price risk in the Materials and Utilities sectors, during the Russia–Ukraine war it is associated with lower stock returns in the Oil & Gas sector and with higher stock returns in the Industrial Products sector. This result can be interpreted by recalling that the Russia-Ukraine war intensified a severe natural gas crisis, particularly in Europe, that shaped the association between commodity hedging and stock returns differently among sectors.

The remainder of the paper is organized as follows. Section 2 provides an overview of the relevant literature, Section 3 presents the dataset collected and provides a focus on the construction of one of the most relevant variables, i.e. the *Hedge* one. Section 4 describes the methodology adopted, Section 5 presents the results of the empirical analyses, while Section 6 provides robustness checks. Section 7 concludes.

2. Literature review

A growing body of literature documents that geopolitical risk exerts a significant influence on commodity market volatility, with effects that differ across commodity categories. For instance, Özdemir et al. (2025) examines the volatility of commodity futures using EGARCH models over the 2010–2023 period and find asymmetric effects, whereby negative geopolitical shocks generate larger volatility increases than positive ones. The direction of the effects varies markedly across commodities: gold, silver, and natural gas are negatively affected, while wheat, corn, crude oil, and most industrial metals exhibit positive responses. Consistent with these findings, Liu et al. (2024) show that geopolitical risk and its sub-indices significantly affect the long-run volatility of major natural resource prices, with different components of geopolitical risk (threats vs. acts) having heterogeneous influences on assets such as crude oil and natural gas. Similarly, Liu et al. (2021) find a significant impact of geopolitical uncertainty on the long-term volatility of key energy commodities, underscoring that geopolitical tension is an important driver of energy market instability beyond fundamental and financial factors. An analysis on the returns of 14 different commodity future contracts and two commodity future indices (S&P Goldman Sachs Commodity Index - GSCI and the Commodity Research Bureau - CRB) is provided by Parnes and Parnes (2025). They find that, over the period 2000-2023, commodities and indices show different associations (both in terms of sign and statistical significance) with measures of geopolitical risks. The two indices and few commodities, also show safe haven properties against geopolitical risks being positively or negatively related with extreme variations in geopolitical risk measures.² Moreover, evidence suggests this relationship between geopolitical risk and commodities exhibits a non-linear nature, thus complicating the formulation of forecasts about future market dynamics in high geopolitical risk scenarios (Abid et al., 2023; Mo et al., 2024).

Given the strong empirical relationship between geopolitical risk and commodity prices, another strand of the literature focuses on the exposure of firms to commodity price risk. Most of the studies refer to exposure to single commodity price risks. As for gold price risk, Tufano (1998) analyse 48 North American gold mining firms in the period 1990-1994 and find that exposure differs over time and across firms and is higher for firms with greater financial leverage. Two studies focusing on Australian gold mining firms report quite similar estimates of gold price sensitivity: Fang et al. (2007), covering the period 1995–2000, find a

² Contrary to previous studies, Parnes and Parnes (2025) consider also negative associations with extreme variations in geopolitical risk measures since they also allow short positions for hedging purposes.

sensitivity greater than 1, while Baur (2014), over 1980–2010, reports a sensitivity of approximately 1. As for exposure to oil and gas price movements, Jin and Jorion (2006), using a sample of 119 US oil and gas firms over 1998–2001, find that commodity price exposure is predominantly statistically significant, with approximately 92% of oil price betas and 95% of gas price betas being positive. Mohanty and Nandha (2011), using a four-factor model augmented with oil price and interest rate factors on a sample of 40 US oil and gas firms over 1992–2008, confirm predominantly positive and significant oil price exposures, while also highlighting substantial variation across firms, subsectors, and over time. Shaeri et al. (2016) extend the analysis to US financial and non-financial industries over the period 1983–2015, finding that oil price sensitivity differs markedly across subsectors, with non-financial industries showing considerably larger exposures than financial ones. For Canadian oil and gas firms, Boyer and Filion (2007) document positive associations between stock returns and crude oil and natural gas price appreciations. Sanusi and Ahmad (2016) reach similar conclusions for UK oil and gas companies over 2004–2015, further documenting asymmetric effects of oil price increases and decreases on stock returns. Turning to multi-country evidence, Akhtaruzzaman et al. (2021) show that oil supply industries generally benefit from positive oil price shocks, whereas oil user and financial industries react negatively, with COVID-19 moderating these exposures across both financial and non-financial sectors worldwide. Similarly, Demirer et al. (2015), using firm-level data from Gulf Cooperation Council stock markets from 2004 to 2013, find that oil price exposure is priced in stock returns, with absolute exposure, rather than its direction, driving return premia. As for exposure to jet fuel prices, empirical evidence shows that fuel price risk represents a major source of uncertainty for airlines, given the high incidence of fuel costs in operating expenses. Carter et al. (2006) and Treanor et al. (2014) document significant exposure to jet fuel price risk among US airlines, while Berghöfer and Lucey (2014), extending the analysis to 64 airlines across North America, Europe, and Asia over 2002–2012, find that North American carriers exhibit the highest negative exposure, followed by Asian and European airlines. Few studies, on the other hand, examine the exposure to multi-commodity price risk. Bartram (2005) provides an analysis using a large sample of German non-financial firms over 1987–1995, finding that while several firms exhibit significant commodity price exposures, these are not statistically more important than foreign exchange or interest rate exposures, despite commodity prices being considerably more volatile. Laing et al. (2020) document significant and time-varying commodity price exposure over a sample of 32 oil and gas firms in the period 2000–2015, with mean absolute exposure levels rising sharply during the Global

Financial Crisis, reaching a median value of 0.868 in 2008 with 90% of firms significantly exposed. Han et al. (2023) extend this evidence to a large multi-country and multi-industry sample covering 23 OECD countries, finding the energy sector being the most exposed, where 38% of firms show significant sensitivity, driven primarily by fluctuations in crude oil, natural gas, and jet fuel prices.

Together, previous studies highlight the pervasiveness of commodity price risk across firms and industries, underscoring the relevance of commodity hedging, mainly through derivatives, as a potential strategy to reduce such exposure. One of the earliest contributions is Tufano (1998) who finds a significant negative association between gold mining firms' exposure to changes in the price of gold and the amount of hedging done by the firm. Similarly, Fang et al. (2007) document that firms hedging a larger share of their gold reserves exhibit lower exposure to gold price fluctuations. Other studies focusing on the oil and gas sector confirm a negative relationship between the use of hedging strategies and exposure to commodity risk (e.g. Laing et al., 2020; Jin and Jorion, 2006). In particular, Laing et al. (2020) find that financial hedging, measured through derivative positions, significantly reduces commodity price exposure, while operational hedging, proxied by multinationality, proves ineffective. Further, Shao et al. (2019), examining Chinese non-financial firms across multiple industries, distinguish between hedging and speculative use of commodity futures based on firms' voluntary disclosures and find that derivative use for hedging purposes is able to reduce commodity price exposure, whereas speculative derivative positions have little impact on risk reduction. This negative relationship between hedging and commodity exposure tends to persist even during periods of heightened volatility, such as the Global Financial Crisis, which was accompanied by an increase in hedging intensity (Laing et al., 2020), although the benefits of financial hedging appear to weaken during such turbulent periods, consistent with Hutson and Laing (2014). More broadly, the effectiveness of hedging strategies appears to vary with market conditions: Chang et al. (2010), analysing energy futures markets, find that hedging is more effective during bull markets than bear markets. Wang and Zhou (2022) identify utilities, energy, consumer staples and materials as the sectors most exposed to commodity price risk and typically more inclined to engage in financial hedging activities.

A complementary strand of literature examines how the use of commodity hedging can contribute to reducing stock price volatility of listed companies, particularly in the utilities and materials sectors (Wang and Zhou, 2022; Biguri et al., 2022; Bartram, 2019).

Against this literature, the present paper provides a focus on cross-sector European firms over the period 2010-2024, whereby the sample period encompasses several major geopolitical events, including the Russia–Ukraine war and the natural gas crises in Europe. From a methodological perspective, while prior studies typically estimate commodity price exposure and analyse hedging behaviour in separate empirical stages, this paper adopts an integrated framework that allows hedging policies to directly condition firms’ sensitivity to commodity price movements. This approach enables a more direct assessment of the possible risk-mitigating role of commodity hedging, while accounting for firm heterogeneity, sectoral differences, and time variation in commodity market dynamics.

3. Dataset

The dataset used in the empirical analysis is based on a selection of firms from the STOXX Europe 600 index (data source: Bloomberg). First, firms are extracted from four industry groups: Oil & Gas, Materials, Industrial Products and Utilities.³ The choice of these industries is motivated by evidence from the literature, which identifies these sectors as the most exposed to commodity price risk (Han et al., 2023; Wang and Zhou, 2022). Second, in order to have a balanced panel and to avoid potential biases arising from missing data, only firms with continuous availability of firm-level information over the entire sample period (2010–2024) are kept. The resulting dataset is a balanced panel of 57 European non-financial firms over the period November 2010–December 2024.⁴ The relatively small size of the sample is consistent with prevalent studies in the literature: Laing et al. (2020) and Jin and Jorion (2006) analyse 32 and 119 companies in the Oil & Gas industry respectively; Berghöfer and Lucey (2014) 64 companies in the aviation industry and Tufano et al. (1998) 48 gold mining companies.

As for the information on commodity risk management strategies, no database was found to provide the required metrics for the analysis. Consequently, the variable *Hedge* is constructed based on the screening of firms’ business report to identify companies that explicitly recognize commodity price risk as a significant risk factor for operating activities in their corporate risk policy. Hence, the variable is hand-collected, as in most studies investigating an association between hedging and exposure to commodity movements over a limited number of companies (e.g. Tufano, 1998; Laing et al., 2020; Jin and Jorion, 2006).

³ In order to identify industry groups, we use the classification provided by the Bloomberg Industry Classification System (BICS) Level 2.

⁴ To be noted that in the final sample we exclude Antofagasta PLC, a company involved in the extraction and processing of mineral resources. Although it is listed in the UK, it owns and operates four mines located in Chile, implying a geopolitical exposure substantially different from that of European-based firms.

By following Wang and Zhou (2022), *Hedge* is a binary variable, which takes a value of 1 if firm i uses commodity derivatives for hedging purposes in period t , and 0 otherwise.⁵ Moreover, we intend to distinguish the use of derivatives for hedging purposes from the holding of derivatives for speculation, in line with Shao et al. (2019). Specifically, the coding procedure is as follows:

- The variable takes value 1 when a firm explicitly declares the adoption of a formal commodity price risk management policy for hedging purposes and, at the same time, reports open positions in commodity derivatives at the balance-sheet date. It is important to note that hedge designation under International Financial Reporting Standards No. 9 (IFRS9) represents a sufficient, but not necessary, condition. Indeed, many firms, while not applying hedge accounting, explicitly disclose the existence of derivative positions that are not formally designated as hedges for accounting purposes but are nonetheless undertaken with hedging objectives. In the present analysis, a substance-over-form approach is adopted: firms are classified as hedgers even if they do not comply with the strict accounting designation requirements, provided that they explicitly state the use of derivatives to hedge cash flows or fair value exposures.
- The variable takes value 0 when a firm declares the absence of commodity hedging instruments, thereby signalling a strategic decision to remain fully exposed to commodity price fluctuations. Consistent with the objectives of the study, speculative positions, namely derivative positions held for trading purposes to exploit short-term market opportunities, are included in this group.

Since the information is collected at an annual frequency, data are converted to a monthly frequency by assuming that the risk management policy disclosed in the annual report remains unchanged throughout the twelve months of the corresponding year.

Table 1 reports the composition of the final dataset by industry group, presenting both absolute and relative frequencies. The Materials group accounts for the largest share of the sample (29.82%), primarily comprising firms operating in the mining and chemical industries. This is followed by Oil & Gas companies (27.59%), which are active across different stages of the oil and gas value chain. The Utilities industry group (24.14%) includes firms engaged in the production and distribution of electricity, while the Industrial Products

⁵ The sample analysed by Wang and Zhou (2022) is much larger (4952 nonfinancial public companies listed on the NYSE and NASDAQ), hence they build the corresponding *Hedge* variable by means of textual analysis of firm financial reports.

category (17.24%) consists of firms characterized by high commodity input intensity, such as steel producers.

Table 1. Distribution of firms by Bloomberg industry group

Industry group	N	(%)
Materials	17	29.82
Oil & Gas	16	28.07
Utilities	14	24.45
Industrial Products	10	17.54
Total	57	100

Notes: The table reports the distribution of firms across different industry groups (Level 2 of Bloomberg’s BICS classification), expressed in absolute terms and percentages.

Table 2 reports descriptive statistics for the *Hedge* variable by industry group. At the aggregate level, the sample exhibits a substantial propensity to use commodity derivatives, with hedging firms accounting for 64.47% of total observations.

A clear degree of sectoral heterogeneity emerges in the adoption of commodity hedging strategies, consistent with differences in structural exposure to commodity risk across business models, in line with Wang and Zhou (2022). In particular, the Utilities and Oil & Gas sectors appear to be the most active in commodity hedging practices, with hedging frequencies of 78.09% and 71.26%, respectively. This evidence suggests that, for these firms, the high volatility of energy commodity prices, which are typically among the most unstable, represents a critical determinant of operating margin stability.

By contrast, the Industrial Products group exhibits a substantially lower hedging frequency (38.04%), which may indicate a more limited intrinsic exposure to commodity price risk. The Materials sector occupies an intermediate position, with a hedging rate of 62.41%, reflecting the heterogeneous nature of the activities and business models characterizing this industry group.

Figure 1 shows clear upward trend in the proportion of firms adopting financial hedging instruments over the period 2010–2024. A first mild increase (from less than 60% to around 65%) is apparent after the annexation of Crimea by Russia in 2014. The second more marked one (reaching a peak of 73.68% in 2023) corresponds with the intensification of global geopolitical tensions, culminating in the outbreak of the Russia–Ukraine conflict in February

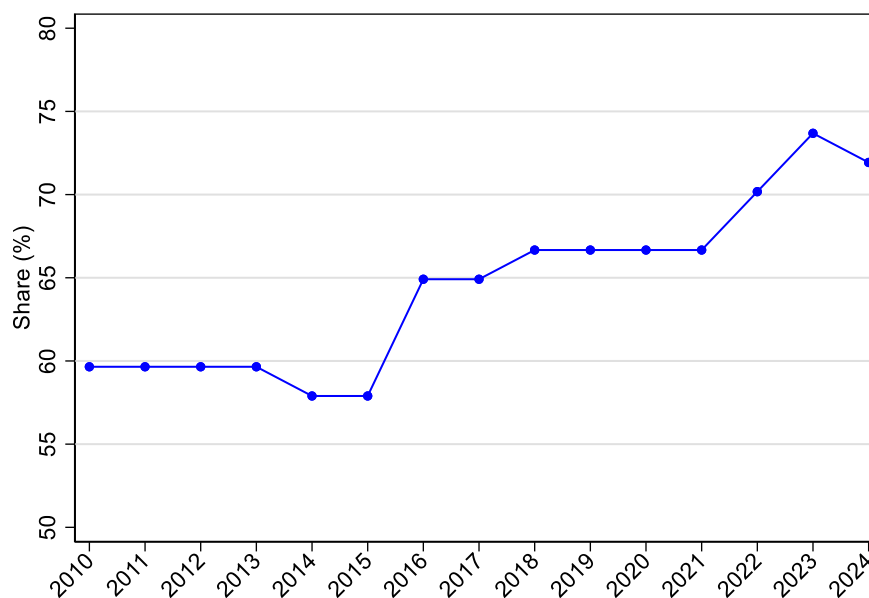
2022. At the firm level, hedging behaviour is largely stable: in our sample, 45 out of 57 firms maintain a constant pattern throughout the period, while 12 firms exhibit some variation over time. Given the overall upward trend in the proportion of hedging firms in Figure 1, these changes likely reflect a shift from non-hedging to hedging, which appears to be connected with important geopolitical events.

Table 2. Industry-level statistics for the Hedge variable

	Tot Obs. (N)	Hedge (N)	No Hedge (N)	Hedge (%)	No Hedge (%)
Materials	3043	1899	1144	62.41	37.59
Oil & Gas	2864	2041	823	71.26	28.74
Utilities	2506	1957	549	78.09	21.91
Industrial Products	1790	681	1109	38.04	61.96
Total	10203	6578	3625	64.47	35.53

Notes: The table reports industry-level observations of the *Hedge* variable in absolute terms (N) and percentages (%), distinguishing between firms that adopt commodity hedging strategies (*Hedge*) and those that do not (*No Hedge*).

Figure 1. Evolution of the share of hedging firms (2010–2024)



4. Methodology

Most of the previous studies on firms' exposure to financial risk factors (e.g. Jorion, 1990; Tufano, 1998; Laing et al., 2020; Han et al., 2023) adopt a two-stage empirical approach. In the first stage, firms' exposure to specific risk (e.g. foreign currency risk,

commodity risk) is estimated by means of time-series regressions of stock returns on relevant risk factors. In the second stage, the estimated exposures are treated as dependent variables and their firm-level determinants are analysed using cross-sectional or panel regressions.

Rather than relying on a two-stage estimation procedure, this paper adopts a unified panel framework based on the two-factor model proposed by Jorion (1990). In particular, the model proposed by Jorion (1990) represents an extension of the traditional CAPM, in which the author introduces a second risk factor (the exchange rate s_t) in addition to the standard market factor R_t , in order to more effectively isolate firms' exposure to specific sources of risk. In this paper, the model is implemented in a panel setting, enabling the simultaneous estimation of risk exposures across firms and over time, as formalized in Equation (1).

$$r_{it} = \alpha_o + \alpha_1 R_t + \alpha_2 s_t + e_{it} \quad (1)$$

where

r_{it} denotes the logarithmic return of stock i at time t ;

R_t represents the return of the Euro STOXX 600 index at time t ;

s_t is the logarithmic change in the euro–U.S. dollar exchange rate at time t .

In line with Laing et al. (2020) and Han et al. (2023), and in order to address the first research question, Equation (1) is further extended by including an index K_t that captures movements in commodity markets:

$$r_{it} = \alpha_o + \alpha_1 R_t + \alpha_2 s_t + \alpha_3 K_t + e_{it} \quad (2)$$

where the variable K_t represents the return on the S&P GSCI index, which is employed as a global benchmark for commodity markets.

This specific index is selected due to its high liquidity and its broad representativeness of global commodity markets. Despite encompassing 24 exchange-traded commodity futures contracts across five sectors, the S&P GSCI index is heavily weighted towards energy commodities (Parnes and Parnes, 2025), which makes it well-suited to explain the stock returns of firms in our sample, whose sectors (Oil & Gas, Materials, Utilities, and Industrial Products) are closely linked to energy and commodity price dynamics. All time-series are obtained from Bloomberg at a monthly frequency and denominated in euros. Equation (2) allows for the estimation of firm-specific coefficients of exposure to commodity price risk over the period 2010–2024.

The interpretation of the sign of α_3 is crucial for characterizing firm-level risk exposure and to answer the first research question (RQ1). In particular, a positive and statistically

significant coefficient (i.e. $\alpha_3 > 0$) indicates that stock returns tend to move in the same direction as commodity prices. From an economic perspective, this suggests that the firm primarily operates on the supply side of the commodity market (i.e. in upstream segments of the commodity supply chain), with commodities representing an output, e.g. firms in the energy or mining sectors. Conversely, a negative and statistically significant coefficient (i.e. $\alpha_3 < 0$) reflects an inverse relationship. In this case, commodity price movements act as a cost shock to the firm's production factors, as commodities represent an input (typical of utilities or manufacturing firms that generally operate in downstream segments of the commodity supply chain) so that an increase in the GSCI index adversely affects stock returns.

To address the second research question (RQ2) about the role of commodity hedging strategies, the model in (2) is further extended in (3) to include a variable capturing firms' hedging policy and its interactions with both commodity price risk and a dummy capturing the post-February 2022 period associated with the Russia-Ukraine war. This specification allows us to jointly assess whether commodity hedging mitigates exposure to commodity price risk and whether it is associated with stock returns during periods of extreme commodity market stress.

$$r_{it} = \alpha_0 + \alpha_1 R_t + \alpha_2 s_t + \alpha_3 K_t + \alpha_4 Hedge_{it} + \alpha_5 (Hedge_{it} \times K_t) + \alpha_6 W_t + \alpha_7 (Hedge_{it} \times W_t) + e_{it} \quad (3)$$

where

$Hedge_{it}$, as defined in Section 3, is a binary variable indicating whether firm i uses commodity hedging at time t ;

W_t is a binary variable that equals 1 starting from February 2022, the outbreak of the Russia-Ukraine war, and 0 otherwise.

In particular, $Hedge_{it}$ allows for a distinction between hedging and non-hedging firms, thereby enabling the estimation of differences in commodity price risk exposure between the two groups, whereas W_t allows to focus on the period of the Russia-Ukraine war. This period is characterized by an increase in commodity price volatility driven by supply disruptions, geopolitical uncertainty and heightened energy market tensions. In fact, the period after February 2022 includes also a severe natural gas crisis, particularly in Europe. The disruption of Russian gas supplies and the resulting energy concerns led to unprecedented price spikes and volatility in natural gas markets, with significant spillovers to electricity prices and other energy-intensive commodities.

The interaction term $Hedge_{it} \times W_t$ captures whether firms' hedging activities are significantly associated with stock returns during the war period, conditional on market, currency and commodity price movements. In particular, $\alpha_7 < 0$ suggests that hedging represents a costly strategy that limits potential gains under the specific macroeconomic conditions characterizing the war period volatility. For instance, during the natural gas crisis, firms in the upstream segment of the commodity supply chain that are naturally long on natural gas and hold short hedging positions would be penalized by rising prices, as their hedges prevent them from fully benefiting from price increases. On the contrary, $\alpha_7 > 0$ suggests that hedging firms exhibit higher stock returns during the war period, indicating that hedging strategies may enhance firms' resilience to extreme market conditions. For instance, firms for which natural gas represents a key input may benefit from hedging strategies that protect them against sharp price increases, thereby stabilizing costs and supporting profitability during the crisis.

The interaction term $Hedge_{it} \times K_t$ allows us to test whether firms' use of derivatives for hedging purposes alters the sensitivity of stock returns to changes in the commodity index. Specifically, for non-hedging firms, the sensitivity of stock returns to commodity price movements is captured by α_3 , whereas for hedging firms it is given by the sum $\alpha_3 + \alpha_5$. Therefore, a negative and statistically significant α_5 implies that the use of commodity derivatives effectively reduces firms' exposure to commodity price risk.

However, since some firms within the panel exhibit commodity risk exposure coefficients with opposite signs, an additional adjustment is introduced to account for the direction of risk exposure. Specifically, when we consider a sample of firms with opposite signs in the exposure to commodity price risk, in equation (3) our focus is on the absolute value of commodity risk exposure, thereby allowing us to test the hypothesis that hedging activity reduces the absolute magnitude of the coefficient α_3 , attenuating it and pushing it toward zero. To this end, a directional adjustment is applied to the GSCI explanatory variable (i.e. K_t): for firms with $\alpha_3 < 0$ in equation (2), the GSCI time series is multiplied by -1 , while for firms with positive exposure it is left unchanged. This adjustment allows us to capture firms' structural exposure to commodity price fluctuations which is also relevant for hedging decisions. This approach is theoretically justified by the objective that firms should pursue risk minimization regardless of the direction of exposure. Consequently, the

effectiveness of a hedging strategy should be evaluated based on its ability to reduce the absolute magnitude of commodity price risk exposure.⁶

The estimation is conducted using pooled OLS. This choice is motivated by the results of the Lagrange Multiplier test for random effects (Breusch and Pagan, 1980), applied to both models (2) and (3), which fails to reject the null hypothesis that firm-specific unobserved effects are jointly zero. This suggests that accounting for individual-level heterogeneity through random or fixed effects specifications does not improve the model, making pooled OLS an appropriate baseline estimator. Then, the presence of heteroskedasticity in the residuals is assessed by using the Breusch–Pagan test (Breusch and Pagan, 1979) and the White test (White, 1980). They both reject the null hypothesis of homoskedasticity, indicating that the variance of the idiosyncratic error term is not constant across observations, which may lead to inconsistent standard errors. Finally, we test for serial correlation in the idiosyncratic error term by means of the Wooldridge test (Wooldridge, 2002) and we do not reject the null hypothesis of no first order autocorrelation.⁷ Accordingly, in the results presented in Section 5 we report heteroskedasticity-robust standard errors, while in the robustness analysis presented in Section 6 we report results with standard errors clustered at the firm level, which are robust to both heteroskedasticity and within-firm autocorrelation.

Potential endogeneity concerns in the present framework may arise from omitted variables relative to unobserved firm-level features such as structural business characteristics or risk-management culture that may be correlated with hedging activity. However, the empirical focus of this study is not on identifying the causal effect of hedging itself on stock returns, but on assessing heterogeneous exposure to commodity price movements ($Hedge_{it} \times K_t$) and heterogeneous associations with stock returns during the Russia-Ukraine war ($Hedge_{it} \times W_t$) between hedging and non-hedging firms. $Hedge_{it} \times K_t$ substantially mitigates omitted-variable concerns, as commodity price movements (K_t) are exogenous, vary only over time, and do not respond to individual firms' decisions, making it unlikely that unobserved firm characteristics are correlated with the interaction term. In contrast, $Hedge_{it} \times W_t$ is more exposed to this source of endogeneity because it may reflect a

⁶ Even Laing et al. (2020) and Han et al. (2023), who adopt a two-stage approach, in the second stage they use a transformation of the exposure to commodity price risk based on its absolute value in order to account for both positive and negative commodity exposure.

⁷ As an additional robustness check, also because the STATA command *xtserial* for the Wooldridge test does not allow the presence of dummy variables, we regress the residuals on their one-period lag and found that the lagged coefficient is not statistically significant, confirming the absence of first-order autocorrelation.

combination of hedging decisions but also other unobserved firm features that become relevant precisely in periods of geopolitical stress. Hence, the interaction term $\text{Hedge}_{it} \times W_t$ is interpreted conservatively as capturing an association between hedging strategy during the war and stock returns, rather than a causal effect.

Regarding other potential sources of endogeneity, simultaneous causality does not affect our results. War is exogenous and does not respond to firms' returns or hedging decisions. Further, it is true that firms with greater exposure to commodity price risk may be more likely to adopt hedging strategies, but it does not represent simultaneous causality, because, in equation (3), exposure to commodity price risk is not the dependent variable of the model, but is inferred from the sensitivity of stock returns to exogenous commodity price fluctuations. This latter concern is more likely to emerge in two-stage approaches that estimate exposure in a first step and subsequently relate it to hedging activity in a second-stage, particularly when exposure is treated as time-invariant or estimated without rolling windows.

5. Results

This section presents the results of the empirical analyses aimed to address the two research questions outlined in Section 1, which are discussed in the following two subsections, respectively.

5.1. What is firms' exposure to commodity price risk?

The first research question (RQ1) aims to test whether, and to what extent, the European firms included in the sample are significantly exposed to fluctuations in commodity prices. To this end, Table 3 reports the estimated coefficients from the model specified in Equation (2). Column (1) presents results for the full sample, while columns (2)-(5) present results by sector based on the second-level BICS classification (Oil & Gas, Utilities, Materials, and Industrial Products) in order to investigate potential sectoral differences suggested by the descriptive statistics reported in Table 2, which highlight heterogeneity in the adoption of commodity hedging strategies and more generally point to sector-specific characteristics. In this initial specification, the objective is to examine the sensitivity of European firms' stock returns to systematic risk factors, prior to introducing variables related to commodity hedging strategies.

Table 3. Exposure to commodity price risk

	(1)	(2)	(3)	(4)	(5)
Variables	Full sample	Oil & Gas	Materials	Utilities	Industrial Products
STOXX Europe 600	1.028*** (0.025)	0.860*** (0.059)	1.157*** (0.044)	0.848*** (0.040)	1.330*** (0.052)
EUR/USD	0.394*** (0.031)	0.326*** (0.065)	0.558*** (0.059)	0.428*** (0.050)	0.176** (0.071)
GSCI	0.198*** (0.017)	0.440*** (0.035)	0.286*** (0.030)	-0.124*** (0.030)	0.111*** (0.039)
Constant	-0.002*** (0.001)	-0.004*** (0.001)	-0.004*** (0.001)	-0.001 (0.001)	0.003 (0.002)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared	0.299	0.290	0.365	0.250	0.377

Notes: Pooled OLS model (equation 2) for the period 2010-2024. Column (1) presents results for the full sample, while columns (2)-(5) present results by sector. Robust standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

The analysis for the full sample in Column (1) yields three key empirical findings. First, the coefficient α_1 associated with the EURO STOXX 600 index is positive and highly statistically significant, with an estimated value of 1.028. This result is fully consistent with standard financial theory (CAPM): a coefficient close to unity indicates that, on average, the portfolio of firms under analysis exhibits a level of systematic risk broadly aligned with that of the reference market benchmark, thus confirming that the dataset construction preserved representativeness. Second, the variable capturing exchange rate risk displays a positive coefficient α_2 (0.394), which is statistically significant at the 1% level. This finding confirms that the returns of the sample firms are sensitive to exchange rate fluctuations, suggesting that currency risk represents an important additional risk component for these firms. Third, and most relevant for the purposes of this study, the coefficient α_3 is estimated at 0.198 and is statistically significant at the 1% level. This result provides strong support to answer the first research question: even after controlling for market risk and exchange rate risk, the firms in the sample exhibit, on aggregate, a statistically significant exposure to commodity price fluctuations. Specifically, *ceteris paribus*, a 1% increase in the commodity index is associated with an average increase of approximately 0.20% in stock returns.

The results on each sector subsample (Column 2,3,4 and 5) confirm the high statistical significance of all the estimated coefficients. In particular, the coefficients associated with

market risk and exchange rate risk retain similar signs and magnitudes across sectors, whereas the coefficients capturing exposure to commodity price risk display substantial heterogeneity both in the sign and in the magnitude, in line with the findings of Han et al. (2023). As expected, the Oil & Gas sector exhibits the highest and most statistically significant positive exposure within the entire sample ($\alpha_3 = 0.440$). Firms operating in this sector are predominantly active in upstream activities (extraction and production) and therefore benefit directly from increases in commodity prices. For similar reasons, the Materials industry group also displays a positive and highly significant exposure to commodity price risk ($\alpha_3 = 0.286$). The Industrial Products sector shows a positive and statistically significant, though more moderate, exposure ($\alpha_3 = 0.111$). Although many firms in this sector may face rising input costs as commodity prices increase, the positive sign of the aggregate coefficient may reflect the predominance of a demand-side effect. Periods of rising commodity prices often coincide with phases of global economic expansion, during which higher input costs may be more than offset by revenue growth. This interpretation is consistent with the evidence reported in Table 3, where approximately 62% of observations for the *Hedge* variable in this sector correspond to firms that do not adopt hedging strategies. Utilities firms exhibit the only negative exposure coefficient ($\alpha_3 = -0.124$). This result confirms the downstream nature of the sector (i.e., firms primarily engaged in the final distribution of gas and electricity to end consumers) and may be interpreted in line with the presence of regulated or semi-regulated pricing schemes, which may limit firms' ability to pass higher input costs on to final consumers.

Further, Table 4 indicates that the sign of commodity price exposure is highly concentrated within sectors. In most cases, a clear majority of firms share the same exposure sign, with only a small fraction of firms exhibiting an opposite exposure.

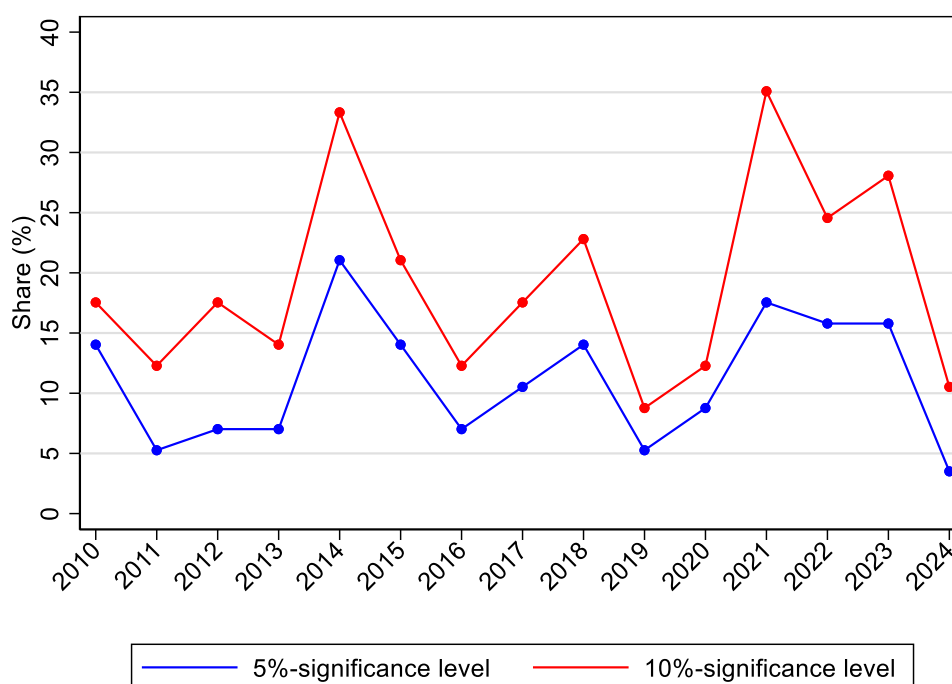
Finally, to capture the dynamic evolution of commodity price risk exposure, equation (2) is estimated annually using time-series OLS regressions over the period 2010–2024. Figure 2 summarizes the results of this analysis by reporting the percentage of firms in the sample with a statistically significant commodity risk exposure coefficient. The trend analysis reveals a first notable peak in 2014, corresponding to the oil price shock and the geopolitical tensions associated with the Crimea crisis. Subsequently, the prevalence of statistically significant exposure increases again in a more structural manner during the 2021–2023 period. This phase initially reflects post-pandemic tensions in global supply chains and is later driven by the energy shock triggered by the Russia–Ukraine conflict.

Table 4. Within-Sector Differences in Commodity Price Risk Exposure

Exposure	Oil & Gas	Materials	Utilities	Industrial Products	Total
Negative	1	1	12	1	15
(%)	6.25%	5.88%	85.71%	10.00%	26.32%
Positive	15	16	2	9	42
(%)	93.75%	94.12%	14.29%	90.00%	73.68%
Total	16	17	14	10	57
(%)	100.00%	100.00%	100.00%	100.00%	100.00%

Notes: the table reports, for each sector, the number of firms with a structural positive or negative exposure to commodity price fluctuations represented by coefficient α_3 in equation (2).

Figure 2. Evolution of the share of firms with statistically significant exposure (full period 2010–2024)



5.2 Relevance and effectiveness of commodity hedging

In light of the results obtained on the first research question, it is interesting to examine whether the adoption of commodity hedging strategies contributes to mitigating firms' exposure to commodity price fluctuations and, more broadly, whether it is associated with differential stock returns during the Russia-Ukraine war. Thus, in order to address the second research question (RQ2), we estimate the model in Equation (3), which includes the *Hedge* variable and its interactions with both commodity price risk and a dummy capturing the post-February 2022

period associated with the Russia–Ukraine war. Results are reported in Table 5. Column (1) presents results for the full sample, while columns (2)-(5) present results by sector.

Table 5. The role of commodity hedging

VARIABLES	(1) Full sample	(2) Oil & Gas	(3) Materials	(4) Utilities	(5) Industrial Products
STOXX Europe 600	1.064*** (0.024)	0.895*** (0.058)	1.179*** (0.042)	0.831*** (0.041)	1.333*** (0.053)
EUR/USD	0.374*** (0.031)	0.308*** (0.064)	0.542*** (0.058)	0.437*** (0.050)	0.173** (0.070)
Hedge	-0.000 (0.002)	0.002 (0.004)	0.003 (0.003)	-0.004 (0.003)	-0.001 (0.004)
GSCI (Adj.)	0.334*** (0.025)	0.472*** (0.068)	0.394*** (0.045)	0.207*** (0.035)	0.146*** (0.047)
Hedge * GSCI (Adj.)	-0.083*** (0.032)	-0.049 (0.078)	-0.162*** (0.057)	-0.101** (0.050)	-0.056 (0.088)
War	-0.002 (0.003)	0.012* (0.007)	-0.011 (0.008)	-0.005 (0.005)	-0.006 (0.006)
Hedge * War	-0.001 (0.004)	-0.016* (0.009)	0.005 (0.009)	-0.000 (0.006)	0.014* (0.008)
Constant	-0.001 (0.001)	-0.006* (0.003)	-0.005** (0.002)	0.003 (0.002)	0.003 (0.003)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared	0.317	0.292	0.370	0.253	0.379

Notes: Pooled OLS model (equation 3) for the period 2010-2024. Column (1) presents results for the full sample and columns (2)-(5) present results by sector. In columns (1)-(5) the model is estimated over firms with both positive and negative exposure to commodity price risk, therefore, the GSCI index is adjusted to reflect absolute exposure levels. Robust standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

As for the full sample, the coefficients associated with the market factor and the exchange rate factor remain positive and similar in magnitude to those obtained in the baseline specification reported in Table 3, confirming the robustness of these effects across model specifications. The coefficient α_3 , associated with commodity price risk, increases slightly relative to the baseline specification, while remaining statistically significant at the 1% level. This higher coefficient may reflect the adjustment made to the GSCI index to capture absolute exposure and neutralize potential effects arising from heterogeneity in the signs of exposure coefficients. Without this adjustment, aggregating positive and negative exposures may mechanically attenuate the estimated exposure to commodity price risk and obscure the interaction effect between hedging activity and commodity price movements. The coefficient α_4 on the *Hedge* dummy alone is not

statistically significant. This finding is consistent with a strand of the literature documenting mixed or weak evidence on the firm value effects of derivative-based hedging (Bartram, 2005; Ahmed et al., 2020; Aretz and Bartram, 2009). By contrast, the coefficient of the interaction Hedge * GSCI (Adj.) is negative ($\alpha_5 = -0.083$) and statistically significant, in line with expectations and with prevalent results in the literature (e.g. Laing et al., 2020; Tufano, 1998; Jin and Jorion, 2006). The negative sign confirms that commodity hedging activity acts as a mitigating factor for commodity price risk. Furthermore, across the entire sample, the outbreak of war between Russia and Ukraine has no statistically significant association with stock returns, not even for companies with commodity hedging strategies (coefficients α_6 and α_7 are not statistically significant).

Columns (2)-(5) report sector-level estimates. Despite the richer specification relative to Table 3, the coefficients on the market, exchange rate, and commodity price factors are overall comparable to the ones of the baseline specification reported in Table 3.⁸ In addition, it emerges substantial heterogeneity in the effectiveness of hedging across industries. In particular, the mitigating effect of hedging is statistically significant only for Materials and Utilities firms. The estimates suggest that the implementation of hedging strategies reduces firms' sensitivity to commodity price movements by approximately 41% (i.e. $0.162/0.394$) in the Materials sector and by about 49% (i.e. $0.101/0.207$) in the Utilities sector. In contrast, For Oil & Gas and Industrial Products firms, the interaction term Hedge * GSCI (Adj.) is not statistically significant, suggesting that hedging does not materially alter the exposure to commodity price risk in these sectors. Conversely, Oil & Gas and Industrial Products are the only sectors for which the interaction Hedge * War is statistically significant although with opposite signs: during the war period, hedging is associated with lower average returns (approximately 1.6%) for Oil & Gas firms and higher average returns (approximately 1.4%) for Industrial Products firms, relative to their non-hedging counterparts. These latter results can be interpreted by recalling that the Russia-Ukraine war intensified a severe natural gas crisis, particularly in Europe, that shaped the association between commodity hedging and stock returns differently among sectors. Specifically, in the Oil & Gas sector, where firms are typically upstream producers, hedging primarily protects against sharp price declines, but it also prevented firms from capturing upside gains, thus exhibiting a negative association with stock returns. In contrast, for Industrial Products firms, which are predominantly downstream and use commodities as production inputs, hedging

⁸ To be noted that the exposure to commodity price risk is now positive for all sectors by construction, because of the adjustment to the GSCI index.

mitigated input cost uncertainty during the war period, thereby supporting profitability and being positively related to stock returns.

Taken together, the results suggest that the role of commodity hedging differs markedly across sectors. In Utilities and Materials, hedging reduces the structural exposure to commodity price risk, while in Oil & Gas and Industrial Products, hedging does not significantly alter long-run commodity price exposure but plays a role in shaping the association with firms' stock returns during the war period characterized by high commodity market volatility.

6. Robustness

Robustness checks are conducted along two main lines. First, we augment both models represented in equation (2) and (3) with year dummy variables (i.e., year fixed effects) to absorb common macroeconomic and period-specific shocks. Results with time dummy variables are reported in Table 6 and Table 7. Second all regressions are re-estimated using clustered standard errors at the firm level. With clustered standard errors, general forms of within-firm serial dependence and heteroskedasticity are controlled, even though the Wooldridge test fails to reject the null hypothesis of no first-order serial correlation. While clustered standard errors are frequently used in panel settings, caution is warranted when interpreting statistical significance in industry subsamples characterized by a relatively small number of clusters (see, e.g., Cameron and Miller, 2015). Inference with a limited number of clusters may be unreliable and overly conservative. Results with cluster-robust standard errors are reported in Tables 8 and 9.

Table 6. Exposure to commodity price risk with year dummy variables

	(1)	(2)	(3)	(4)	(5)
Variables	Full sample	Oil & Gas	Materials	Utilities	Industrial Products
STOXX Europe 600	1.056*** (0.027)	0.890*** (0.066)	1.200*** (0.044)	0.867*** (0.040)	1.344*** (0.053)
EUR/USD	0.386*** (0.032)	0.343*** (0.067)	0.529*** (0.058)	0.432*** (0.052)	0.147** (0.071)
GSCI	0.184*** (0.018)	0.439*** (0.037)	0.250*** (0.031)	-0.117*** (0.031)	0.084** (0.042)
Constant	0.005* (0.003)	-0.008 (0.005)	0.017*** (0.005)	-0.014*** (0.004)	0.029*** (0.006)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared	0.303	0.298	0.383	0.261	0.384

Notes: Pooled OLS model (equation 2) for the period 2010-2024. Column (1) presents results for the full sample, while columns (2)-(5) present results by sector. Coefficients on year dummies are omitted for brevity. Robust standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

Table 7. The role of commodity hedging with year dummy variables

VARIABLES	(1) Full sample	(2) Oil & Gas	(3) Materials	(4) Utilities	(5) Industrial Products
STOXX Europe 600	1.091*** (0.025)	0.934*** (0.064)	1.228*** (0.043)	0.853*** (0.042)	1.337*** (0.054)
EUR/USD	0.370*** (0.031)	0.323*** (0.066)	0.516*** (0.058)	0.441*** (0.052)	0.147** (0.071)
Hedge	-0.001 (0.002)	0.003 (0.004)	0.002 (0.003)	-0.003 (0.003)	-0.001 (0.004)
GSCI (Adj.)	0.321*** (0.025)	0.458*** (0.070)	0.358*** (0.044)	0.201*** (0.036)	0.123** (0.048)
Hedge * GSCI (Adj.)	-0.078** (0.032)	-0.047 (0.078)	-0.170*** (0.056)	-0.100** (0.050)	-0.037 (0.090)
War	-0.021* (0.012)	-0.012 (0.029)	-0.045** (0.018)	-0.009 (0.017)	0.014 (0.028)
Hedge * War	-0.001 (0.004)	-0.017** (0.008)	0.006 (0.009)	0.001 (0.007)	0.014* (0.008)
Constant	0.006** (0.003)	-0.009 (0.006)	0.016*** (0.005)	-0.011*** (0.004)	0.030*** (0.007)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared	0.322	0.300	0.389	0.262	0.386

Notes: Notes: Pooled OLS model (equation 3) for the period 2010-2024. Column (1) presents results for the full sample and columns (2)-(5) present results by sector. In columns (1)-(5) the model is estimated over firms with both positive and negative exposure to commodity price risk, therefore, the GSCI index is adjusted to reflect absolute exposure levels. Coefficients on year dummies are omitted for brevity. Robust standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

Table 8. Exposure to commodity price risk with clustered standard errors

Variables	(1) Full sample	(2) Oil & Gas	(3) Materials	(4) Utilities	(5) Industrial Products
STOXX Europe 600	1.028*** (0.041)	0.860*** (0.060)	1.157*** (0.078)	0.848*** (0.047)	1.330*** (0.049)
EUR/USD	0.394*** (0.046)	0.326*** (0.067)	0.558*** (0.119)	0.428*** (0.044)	0.176* (0.079)
GSCI	0.198*** (0.041)	0.440*** (0.087)	0.286*** (0.050)	-0.124*** (0.026)	0.111** (0.044)
Constant	-0.002*** (0.001)	-0.004** (0.002)	-0.004*** (0.001)	-0.001 (0.001)	0.003* (0.001)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared	0.299	0.290	0.365	0.250	0.377

Notes: Pooled OLS model (equation 2) for the period 2010-2024. Column (1) presents results for the full sample, while columns (2)-(5) present results by sector. Clustered standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

Table 9. The role of commodity hedging with clustered standard errors

VARIABLES	(1) Full sample	(2) Oil & Gas	(3) Materials	(4) Utilities	(5) Industrial Products
STOXX Europe 600	1.064*** (0.036)	0.895*** (0.070)	1.179*** (0.072)	0.831*** (0.047)	1.333*** (0.048)
EUR/USD	0.374*** (0.046)	0.308*** (0.065)	0.542*** (0.120)	0.437*** (0.044)	0.173* (0.081)
Hedge	-0.000 (0.002)	0.002 (0.004)	0.003 (0.003)	-0.004** (0.002)	-0.001 (0.003)
GSCI (Adj.)	0.334*** (0.052)	0.472** (0.187)	0.394*** (0.077)	0.207*** (0.023)	0.146** (0.057)
Hedge * GSCI (Adj.)	-0.083 (0.056)	-0.049 (0.194)	-0.162** (0.071)	-0.101** (0.041)	-0.056 (0.071)
War	-0.002 (0.004)	0.012 (0.009)	-0.011** (0.004)	-0.005** (0.002)	-0.006 (0.004)
Hedge * War	-0.001 (0.004)	-0.016 (0.010)	0.005 (0.006)	-0.000 (0.004)	0.014** (0.005)
Constant	-0.001 (0.002)	-0.006 (0.004)	-0.005* (0.003)	0.003** (0.001)	0.003 (0.003)
Observations	10,203	2,864	3,043	2,506	1,790
Adjusted R-squared					

Notes: Notes: Pooled OLS model (equation 3) for the period 2010-2024. Column (1) presents results for the full sample and columns (2)-(5) present results by sector. In columns (1)-(5) the model is estimated over firms with both positive and negative exposure to commodity price risk, therefore, the GSCI index is adjusted to reflect absolute exposure levels. Clustered standard errors are reported in parentheses. ***, ** and * represent significance at 1, 5, 10% levels, respectively.

Overall, the main findings regarding the exposure to commodity price risk and the role of commodity hedging remain substantially qualitatively unchanged.

7. Conclusions

In a prolonged context of increased geopolitical uncertainty and shocks to global commodity markets, understanding firms' exposure to commodity price risk and the effectiveness of hedging strategies has become increasingly relevant.

This study aims to quantify the exposure of European firms to commodity price risk, to assess whether the use of derivative hedging instruments is effective in reducing this exposure, and to assess whether hedging activity is associated with stock returns during the period characterized by the Russia–Ukraine war. In particular, the paper aims to answer two main research-questions: Do firms exhibit exposure to commodity price risk and, if so, does the sign and magnitude of this exposure vary over time and across different sectors? Does commodity

hedging reduce firms' exposure to commodity price risk, and is it associated with different stock returns during the Russia-Ukraine war period?

The analysis is conducted by using pooled OLS regressions with robust standard errors on a dataset of 57 listed non-financial European companies, classified according to Bloomberg's BICS system (Level 2) into the Oil & Gas, Materials, Utilities, and Industrial Products sectors, over the period February 2010–December 2024. Two are the main results.

First, we find a statistically significant exposure to commodity price fluctuations for the firms included in the panel, which is heterogeneous across sectors, both in terms of sign and in terms of the intensity of the relationship. In particular, exposure is on average positive for Oil & Gas, Materials and Industrial Products firms, with the greatest magnitude (0.440) for the Oil & Gas sector, reflecting its upstream position in the commodity supply chain and the direct link between commodity prices and revenues. By contrast, exposure is on average negative for Utilities, a sector that is predominantly downstream and characterized by commodity inputs, especially natural gas and electricity, entering primarily as cost components rather than revenue driver. Unlike other downstream sectors, utilities operate in a highly regulated environment, where output prices are often subject to price caps or public intervention, limiting their ability to fully offset commodity price increases through revenues. Further, the dynamic (year-by-year) analysis reveals that the exposure to commodity risk is not constant over time but intensifies during exogenous shocks, particularly of a geopolitical nature. Indeed, peaks in statistical significance are observed around the 2014 oil price collapse and the 2022 Russia–Ukraine crisis, periods that are also characterized by an increased propensity of firms to engage in financial hedging.

Second, the role of commodity hedging varies substantially across sectors. In Materials and Utilities sectors, hedging reduces the exposure to commodity price risk by approximately 41% and 49%, respectively. Conversely, hedging in the Oil & Gas and Industrial Products sectors, does not affect long-run commodity price exposure, but shows different associations with stock returns during the war: Oil & Gas hedgers exhibit 1.6% lower returns, while Industrial Products hedgers exhibit 1.4% higher returns compared to non-hedgers. This can be interpreted by recalling that the Russia-Ukraine war intensified a severe natural gas crisis, particularly in Europe, that shaped the association between commodity hedging and stock returns differently among sectors. Specifically, in the Oil & Gas sector, where firms are typically upstream producers, hedging primarily protects against sharp price declines, but it also prevented firms from capturing upside gains, thus exhibiting a negative association with stock returns. In contrast, for Industrial Products firms, which are predominantly downstream and use commodities as production inputs, hedging

mitigated input cost uncertainty during the war period, thereby supporting profitability and being positively related in stock returns. Results are robust when the models are augmented with year dummy variables and re-estimated with clustered standard errors.

The findings of this study carry relevant implications for both firms operating in commodity-intensive industries and financial investors. For firms, the presence of a statistically significant exposure to commodity price risk across sectors highlights the importance of actively monitoring and managing this source of market risk, particularly during periods of heightened geopolitical uncertainty. In fact, an increase in geopolitical risk tends to generate higher volatility in commodity prices, with significant repercussions for firms that are strongly exposed to commodity risk, both at the operational and financial levels. In this context, the adoption of commodity hedging strategies emerges as a valuable risk-management tool to mitigate excessive sensitivity to commodity price movements, even though it may prevent firms from fully benefiting from favourable price movements. For financial investors, information on firms' commodity exposure and hedging behaviour may be relevant for portfolio selection and asset allocation decisions. During periods of geopolitical tension, investors may benefit from distinguishing between firms with different exposure profiles and risk-mitigation strategies, enabling more resilient portfolio construction and improved risk diversification.

From a policy perspective, the results of this study emphasize the importance of corporate transparency and disclosure regarding risk management strategies related to geopolitical risk. This may enhance capital providers' ability to assess risk and efficiently allocate capital, especially during periods of geopolitical uncertainty. Moreover, effective hedging strategies based on derivatives plays a crucial role for financial stability, given that they allow firms to absorb external shocks, stabilize cash flows, and reduce the transmission of commodity price volatility to equity markets.

A limitation of the analysis concerns the construction of the hedge variable. Although it follows a methodology aimed at identifying firms' risk management policies, this variable does not provide information on the intensity of hedging, thus not allowing for a fully comprehensive assessment of hedging strategies.

Future research may explore geopolitical risks more directly, for instance by integrating measures such as the Geopolitical Risk Index into the empirical framework. Further, a more granular classification of firms along the upstream–downstream dimension could further refine the analysis of commodity price exposure and hedging behaviour, although such classification may involve a degree of subjectivity, as many firms operate across multiple segments of the supply chain.

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