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On the Determinants of Trade in Natural Gas: A Political Economy Approach ☆

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Abstract

This paper aims to analyze the determinants of trade in natural gas through a political economy lens. Indeed, in addition to the economic determinants of trading in natural gas, the latter could be affected by political determinants such as the economic sanctions and the institutional gap between the trading partners. Moreover, while the literature considers the effect of tariffs, less attention has been attributed to non-tariff measures (NTMs) that might also be imposed for political reasons. To quantify the impact of these different determinants on natural gas trade, we use a gravity model that explains bilateral trade for pipeline natural gas (PNG) and liquefied natural gas (LNG) over the period 2000-2017. We also consider the zero trade flows of natural gas by using the Poisson Pseudo Maximum Likelihood estimator. Our results show that economic sanctions have reduced bilateral LNG trade by 24%, on average. We also find that the institutional gap between trading partners exerts a significant negative effect on bilateral PNG and LNG trade, pointing out that institutions could be considered as fixed export costs in the natural gas market. Moreover, our results indicate that, in addition to tariffs, non-tariff measures have a significant negative effect on trade in natural gas.

Keywords: natural gas, gravity model, institutions, economic sanctions.

JEL classification : F14, C55, Q34, Q35, Q43

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1. Introduction

Over the past decade, the importance of natural gas in the global energy system as a relatively clean-burning fossil fuel has grown substantially. Indeed, global natural gas consumption increased from 2,432 billion cubic meters (BCM) in 2000 to 3,823 BCM in 2020, recording a total growth of 57% (BP, 2021). To meet this rapidly increasing consumption, natural gas trade has also grown in importance due to the uneven distribution of natural gas resources. In 2020, about one-third of natural gas consumption was covered by natural gas trade, leading to a high interdependence between exporting and importing countries (BP, 2021). In fact, natural gas is traded regionally through pipelines in a gaseous state (henceforth Pipeline Natural Gas (PNG)) or internationally via ships as a liquid (henceforth Liquefied Natural Gas (LNG)). While the former is transported with a fixed infrastructure connecting neighboring countries, the latter is more flexible without any geographical restrictions and, thus, contributes to the integration of the gas market (Zhang et al., 2018; Barnes and Bosworth, 2015). The future development of the global natural gas market is relatively optimistic. According to the IEA's New Policies Scenarios, it is projected that global natural gas consumption will continue to grow with a rate of 1.6% per year until 2040, substantially higher than that of oil (0.5%) and coal (0.1%). Meanwhile, global natural gas trade will grow by around two-third by 2040, with an average growth of 2.3% a year (IEA, 2018).

Considering these trends, understanding the determinants of natural gas trade is essential, especially with the strong path-dependency between the trading partners. Research has increasingly analyzed the market structure and the security of gas supplies in the literature using two main approaches: numerical modeling and econometric regressions. The numerical approach includes partial equilibrium models that simulate market parameters like supply, trade, infrastructure, and demand. These models allow simulating either perfect or imperfect competitive behavior in the gas market and include Columbus (Hecking and Panke 2012) and the Global Gas Model (Egging, 2010) at the global level, whereas TIGER (Lochner and Bothe, 2007) and GSAM (Gabriel et al., 2003) at the European and North American levels, respectively. Many studies use these models to analyze the effect of policy changes, infrastructure development, or changes to the energy system on the gas market (e.g., Schulte and Weiser, 2019; Berk and Schulte, 2017; Schlund and Schönfisch, 2021). On the other hand, the econometric approach uses historical data to analyze the impact of different factors on trade volume between the trading partners. Among this family of models, the gravity one has become the workhorse baseline econometric model to study the determinants of bilateral trade.

According to this model, trade volume between trading partners is directly proportional to their economic size and inversely proportional to the trade costs between them (Yotov et al., 2016). Some recent studies have employed the gravity model to examine the effect of different economic and energy demand factors on bilateral natural gas trade, focusing mainly on LNG (e.g., Najm and Matsumoto, 2020; Zhang et al., 2018).

Against this background, there is little empirical work, for both numerical and econometric models, on how political economy could affect the trade in natural gas. To date, few studies assess the effect of geopolitical relations on the gas market, limiting their analysis mainly to the European scale (e.g., Richter and Holz, 2015). To fill this gap, the objective of this paper is to use the econometric approach to quantify the effect of political economy on the global trade in PNG and LNG. Thus, we contribute to the literature in three ways. First, we combine political-economic factors and quantify their effects on the global trade in natural gas using a comprehensive dataset. Second, we distinguish between the impact of those factors on the two commodities traded in this market, namely PNG and LNG, by estimating separate regressions for each one. Thirdly, from a methodological perspective, we contribute to the econometric literature on the gas market by considering the zero natural gas trade flows. We do so by employing the Poisson Pseudo-Maximum Likelihood Estimator (PPML) to estimate our gravity model.

From a political economy lens, we cover three factors. The first one is related to the existence of economic sanctions between trading partners. Such sanctions are frequently used as an instrument within the context of geopolitical relations to undermine political regimes and impose economic pressures on sanctioned countries (Doornich and Raspotnik, 2020; Fischhendler et al., 2017). Therefore, we hypothesize that economic sanctions could affect the probability and the volume of the trade in natural gas between the sanctioning and sanctioned trading partners. This is in line with the seminal definition of Victor et al. (2006) for the geopolitics of natural gas. They argue that "*countries that commit to importing large volumes of gas place the security of their energy systems partly in the hands of others, which in turn gives both suppliers and users of gas a stake in the internal political stability of one another*".

The second factor is the institutional gap between trading partners. In fact, natural gas resources are concentrated mainly in regions characterized by the low quality of institutions and political instability. In the meantime, natural gas is primarily traded based on bilateral contractual agreements. Thus, the institutional gap between trading partners could pose a threat to the natural gas market and energy security. According to the literature, we hypothesize that this institutional gap between the trading partners could increase the uncertainty in their interactions and, accordingly, increase the transaction costs associated with the trade in natural gas (i.e., price discovery costs and the lack of full enforcement of contracts) (De Groot et al., 2004; Levchenko, 2007; Karam and Zaki, 2019). The third factor includes tariffs and non-tariff measures (NTMs) imposed on natural gas trade flows by importers. We focus on tariffs because they act as a price shifter, and, sometimes, they could be used politically by the importing countries to restrict natural gas trade with a specific exporter. For example, in 2019, China imposed tariffs of 25% on imports of US LNG in retaliation to political tensions between the two countries (Guo and Hawkes, 2019). Furthermore, the NTMs include all policy measures, other than tariffs, that could affect the quantity of traded commodities, their prices, or both (Cadot et al., 2018). In this context, we hypothesize that both tariffs and NTMs have a negative impact on the trade volume of natural gas.

The main results of this paper provide evidence that, in addition to the economic determinants, global natural gas trade could be affected by political-economic factors. Also, we find that the effect of those factors is different between PNG and LNG trade. For example, our results show that the economic sanctions have reduced bilateral LNG trade by 24%, on average, whereas they do not affect bilateral PNG trade. Moreover, our findings indicate that the institutional gap between the trading partners has a higher negative effect on bilateral PNG trade than bilateral LNG trade. In terms of volume effects, a 1% increase in the institutional gap between the trading partners will decrease the bilateral trade in LNG and PNG by 0.18% and 0.27%, respectively. We also find evidence that tariffs and NTMs have a significant negative impact on natural gas trade.

The remainder of the paper is structured as follows. Section 2 reviews the literature. Section 3 discusses the data and variables used in the analysis. Section 4 presents the econometric specifications. Section 5 presents and discusses the results, and Section 6 concludes.

2. Literature review

Our paper bridges the gap between three strands of the literature, aiming to analyze the effect of political economy on the global trade in natural gas. The first strand of the literature is related to the effect of geopolitical relations in general and economic sanctions in particular on the global and domestic energy markets. The second strand is related to the impact of the institutional gap between trading partners on bilateral trade flows in the context of imperfect contracts. The third one is on the econometric analysis of the global natural gas market using gravity models.

Many recent empirical studies examine the effect of economic sanctions and geopolitical relations on global energy markets. Larch et al. (2021) analyze the impact of economic sanctions on international trade in the mining sector using a gravity model. They find that trade sanctions effectively impede the trade in this sector and reduce bilateral mining trade by about 44%, on average. In the same line, Mityakov et al. (2011) investigate the effect of economic sanctions on global oil trade patterns. The study's findings show that the political distance and economic sanctions have an adverse impact on trade in oil. For the effect of geopolitical relations on the global natural gas market, Guo and Hawkes (2019) focus on the impact of political tensions between China and the U.S. on the worldwide trade of natural gas using an agent-based model. More specifically, they analyze how the 25% US-China import tariffs would affect global gas trade dynamics. They consider two different demand future scenarios: a baseline scenario following current policy pledges until 2060 and a low demand scenario where demand shifts to a lower level in 2030. Under the first scenario, the results indicate that the Chinese market is affected after 2045 by a notable price increase compared to the scenario without tariffs. In contrast, import tariffs affect China only mildly in the near future under the second scenario due to the additional supplies from other exporters. Some studies also investigate the direct effect of economic sanctions on the domestic energy markets. Wen et al. (2020) examine how the imposition of international sanctions affects the energy security of the target countries. They measure energy security as energy imports divided by energy use. Their results show that economic sanctions have a significant negative impact on the energy security of target countries. Furthermore, Felbermayr et al. (2019) quantify the general equilibrium effects of imposing economic sanctions on Iran's trade and sectoral value-added using a structural gravity model. Their model predicts that ending these sanctions would increase the value-added of the gas sector by 40%. Ahmadi (2018) analyzes the effect of imposing U.S. and U.N. sanctions on Iran and finds that they negatively affect the production and exports of Iran's oil and gas sectors.

On the effect of institutions, several previous studies have analyzed the impact of the institutional quality gap between trading partners on bilateral trade relations in the context of imperfect contracts. Karam and Zaki (2019) investigate the effect of the institutional gap on trade flows between the Middle East and North Africa (MENA) countries and their trading partners. Their findings indicate that the institutional gap could be considered as fixed export costs that help explain the zero probability of trade for some countries. In the same vein, Álvarez et al. (2018) investigate the extent to which the institutional gap affects aggregate and sectoral bilateral trade using the gravity model. They find that bilateral trade in natural resources is significantly affected by the institutional gap between the trading partners. Levchenko (2007) analyzes the effect of institutional differences by extending the Ricardian model of comparative advantage, given that the institutional gap is modeled as a source of comparative advantage and within the framework of contract incompleteness. The findings of this study provide evidence that the institutional gap is an essential determinant of bilateral trade flows. Moreover, De Groot et al. (2004) examine the bilateral effect of institutional distance on trade patterns using a gravity model. Their results show that having a similar institutional framework can increase bilateral trade by 13%, on average. Some recent studies focus on the effect of institutional quality and political country risks on energy markets. For instance, Zhang et al. (2021) examine the impact of country risk on bilateral trade between energy trading partners. Their results show that country risk significantly affects the trade patterns of energy importers and exporters. Zaman and Kalirajan (2019) analyze the impact of the average of institutions' strengths in trading partners on energy trade in the South-though-East Asian (StEA) countries. They find that a better average of institutional quality positively affects intraregional energy trade flows.

Recent studies have used the gravity model to analyze the determinants of trade in natural gas. Najm and Matsumoto (2020) measure the effect of the ratio of renewable energy to total energy usage in importing countries on bilateral trade flows of LNG. The findings of this study indicate that LNG and renewable energy are substitutes to each other. Zhang et al. (2018) employ the gravity model to define the global LNG trade factors. Their analysis shows that these factors include the economic size of importers, import prices of LNG, research and development investments, political risks of exporters, and the domestic natural gas market of the trading partners. In the same line, Barnes and Bosworth (2015) investigate whether LNG trade contributed to the de-regionalization of the global natural gas market. They find that increased LNG trade helped integrate the global gas market.

However, we see a methodological shortcoming in the previous studies that have used the gravity model to analyze the natural gas market. In fact, they estimate the log linearized gravity model using the Ordinary Least Squares (OLS) estimator. Therefore, they do not take into consideration the zero trade volumes of natural gas. Estimating the log-linearized gravity models could provide biased estimates due to two main reasons. First, if zero values observations are not randomly distributed, then omitting these observations could lead to biased results due to the sample selection problem (Burger et al., 2009). Second, the estimated coefficients by log-linearized models could also be biased because of the heteroscedasticity, which is usually associated with trade data (Santos Silva and Tenreyro, 2006; Burger et al., 2009). From a conceptual perspective, zero trade values reflect information on high transportation costs, political-economic factors between the trading partners, and/or domestic market conditions that prevent natural gas trading. Hence, zero trade flows should not be excluded when analyzing the global natural gas market. In this context, Barnes and Bosworth (2015) 's study is the only one considering the zero trade flows of natural gas. They include these values using only two cross-sectional models. However, the cross-sectional analysis is insufficient because it cannot account for the unobserved heterogeneity among the countries in the global gas market.

Three main conclusions stand out from this literature review. First, geopolitical relations and economic sanctions between trading partners affect global and domestic energy markets in several ways. Second, the quality of institutions affects contract-dependent sectors, including natural resources. This is because the risks associated with trade will increase due to the lack of full enforcement of contracts, which would increase the transaction costs. Third, the gravity model is an appropriate empirical tool in modeling bilateral trade in natural gas.

3. Data and Stylized Facts

This study combines data from different sources. We use annual data during 2000-2017 for a panel of 53 exporters and 77 importers of natural gas[1]. The main dependent variable is the volume of natural gas trade flows in billion cubic meters (BCM). We use a comprehensive dataset on bilateral PNG and LNG trade flows provided as a proprietary dataset by Rystad Energy[2] [3]. Figure 1a depicts the development of natural gas trade over the investigated period and shows that both PNG and LNG trade volumes rapidly increased over that period. More precisely, PNG trade volume grew from about 390 BCM in 2000 to 740 BCM in 2017, while LNG trade volume increased from 137 BCM in 2000 to more than 390 BCM over the same period. Therefore, the total growth rate of LNG trade is two times higher than that of PNG trade. Figure 1b illustrates the shares of PNG and LNG trade volumes in the gas market. It indicates that LNG's share of the global natural gas trade has continued growth, increasing from 22% in 2000 to 35% in 2017. This growing trend and rising share of LNG trade volume have contributed to the integration and de-regionalization of the global natural gas market.

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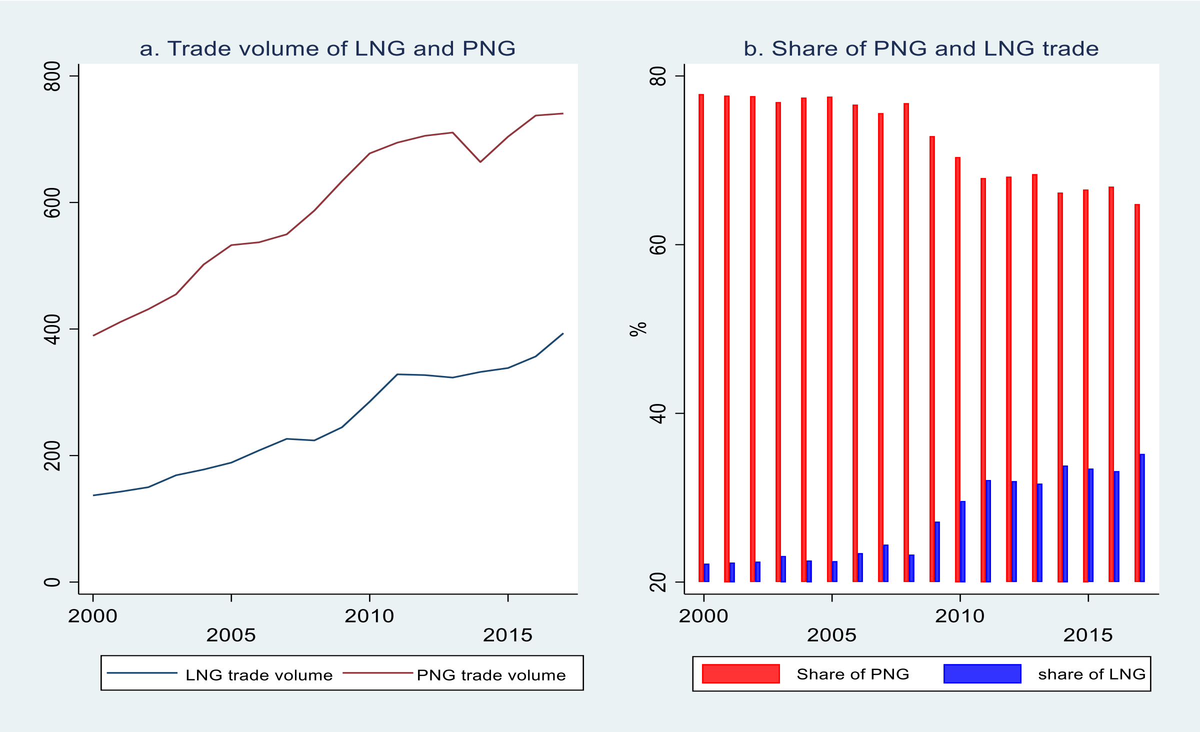
[1] For a description of the list of exporters and importers included in the dataset, please refer to Appendix 1.
[2] The data are obtained from https://www.rystadenergy.com/
[3] According to our dataset, natural gas trade flows are reported on a contractual basis. Therefore, we would like to highlight three points: (1) transit countries are not included in our dataset; (2) re-exports are counted in our observations; and (3) the trade flows may not correspond to physical gas flows between the trading partners.

Figure 1: Natural gas trade over the period 2000 – 2017



Source: Own construction based on data obtained from Rystad Energy.

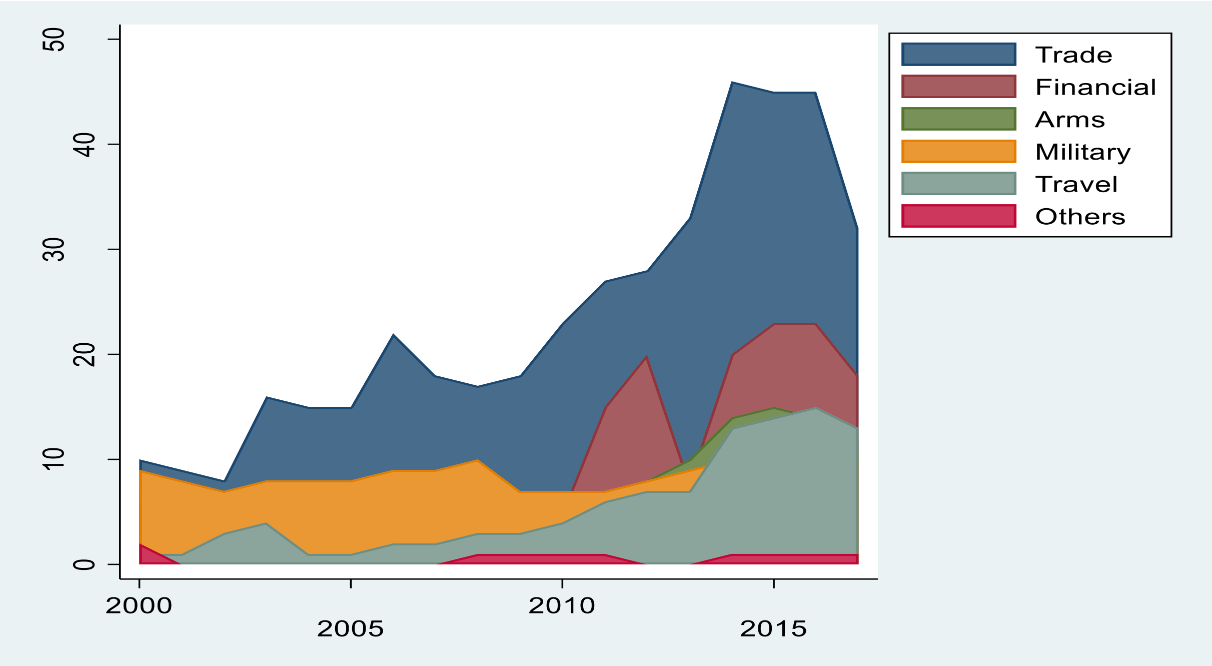
We have three variables of interest. The first one is the existence of economic sanctions between the trading partners, and it comes from the newly created database of Kirilakha et al. (2021). This database covers the cases of effective economic sanctions (i.e., excluding threats) over the period 1950 – 2019 [4]. It also classifies these sanctions into six categories: trade, financial, military assistance, arms, travel, and other sanctions. According to this database, we find 113 cases of economic sanctions between natural gas exporters and importers over the period 2000 – 2017[5]. These economic sanctions last, on average, about six years between the trading partners in the natural gas market. The longest episode of economic sanctions is 18 years (e.g., the USA against Iran and France), whereas the shortest episode is one year (e.g., Russia against Belarus; and the United Arab Emirates against Qatar). Figure 2 presents the evolution of the six types of economic sanctions between natural gas importers and exporters for the period 2000 - 2017. The figure reveals that there is a considerable increase in the cases of economic sanctions in the gas market over that period. It also shows that trade sanctions were imposed more frequently than the other sanctions types and increased substantially between 2003 and 2016.

[4] The data is available at https://www.globalsanctionsdatabase.com/

[5] For a description of the list of economic sanctions included in our dataset, please refer to Appendix 1.

This trend has been triggered by the trade sanctions imposed by Russia against some trading partners, including Moldova, Ukraine, Georgia, and EU importers (as a counteract measure to their sanctions), the sanctions imposed by western countries against some exporters in the MENA region including Iran, Egypt, Libya, and Yemen, and the sanctions imposed by Japan against Russia and the USA. In contrast, the frequency of the other five types of sanctions was relatively lower over that period.

Figure 2: Yearly number of economic sanctions by type (2000 - 2017)



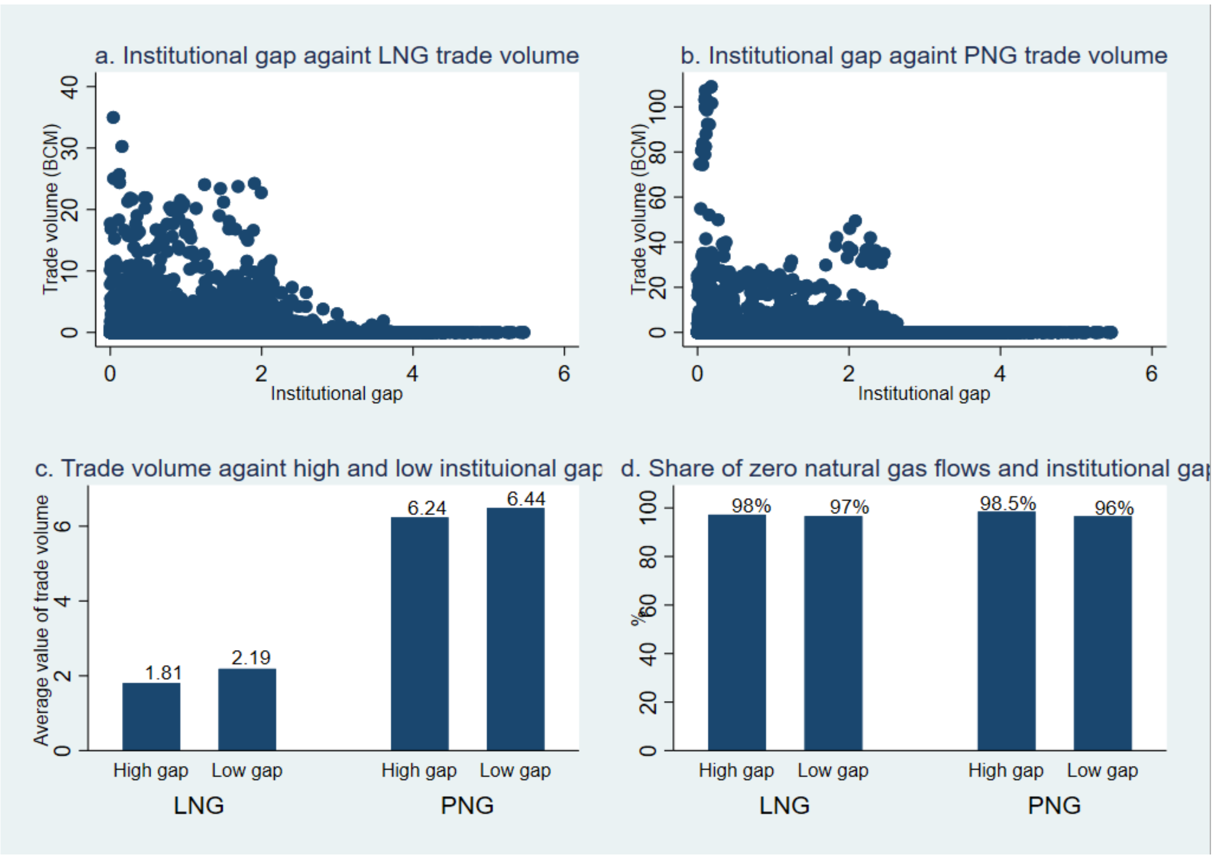
Source: Own construction based on Kirilakha et al. (2021).

The second variable is the institutional quality gap between the trading partners. We rely on the World Governance Indicators (WGI) to measure the quality of institutions (Kaufmann et al., 1999)[6]. The WGI covers six dimensions of governance: political stability and absence of terrorism, government effectiveness, control of corruption, the rule of law, regulatory quality, and voice and accountability. Using the Principal Component Analysis (PCA), we create a combined index of the six dimensions by aggregating them for each exporter and importer. We hypothesize that similarities in institutional structures could positively impact bilateral natural gas trade. Therefore, the institutional gap is calculated as the absolute difference of our institutional quality index between the exporting and importing gas countries.

[6] The data is available at https://info.worldbank.org/governance/wgi/

Figure 3 illustrates how the institutional gap could affect trade in natural gas. Figures 3a and 3b show that the highest volumes of PNG and LNG are traded at the lowest levels of the institutional quality gap, pointing out that there could be a negative relationship between the two variables. The highest volume of PNG was traded between the USA and Canada (e.g., 109.02 BCM in 2001), whereas the highest volume of LNG was traded between Japan and Australia (e.g., 34.98 BCM in 2017). In contrast, the lowest volume of PNG was traded between Argentina and Uruguay (e.g., 0.02 BCM in 2002), and the lowest volume of LNG was traded between Brunei and China (e.g., 0.00002 BCM in 2015). Moreover, Figure 3c shows that the average volumes of PNG and LNG over the investigated period are relatively higher with the low levels of the institutional gap. In contrast, Figure 3d indicates that the shares of zero PNG and LNG trade flows are relatively higher with the high levels of the institutional gap, suggesting that the institutional disparity could be perceived as a fixed export cost that explains the zero trade volumes of some trading partners[7].

Figure 3: Institutional quality gap against natural gas trade volumes



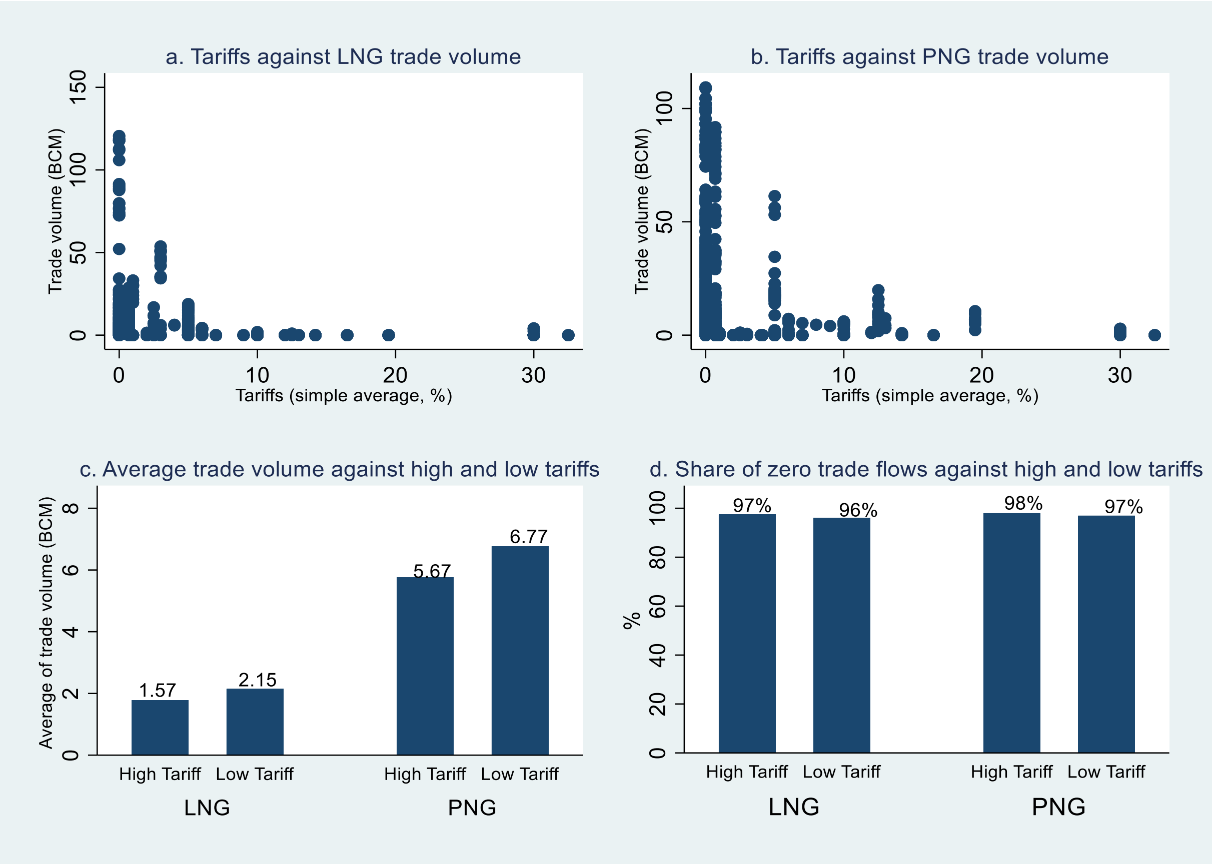
Source: Own construction based on data obtained from the WGI and Rystad Energy.

[7] The high and low levels of the institutional gap variable are estimated using the median value of that variable as a threshold.

The third set of variables relates to energy trade policy, including bilateral import tariffs and non-tariff measures (NTMs) imposed on PNG and LNG imports. We construct the dataset on tariffs and NTMs using the 6-digit harmonized system (H.S. codes: 271121 for PNG and 271111 for LNG).

We obtain data on bilateral import tariffs from the World Trade Organization (WTO) [8]. Figures 4a and 4b depict the trade flows in PNG and LNG (BCM) against import tariffs. They show that the highest volumes of PNG and LNG are traded at the lowest levels of tariffs. Overall, the highest value of tariffs in the PNG market is 32% (imposed by Morocco), whereas the highest value of tariffs in the LNG market is 30% (imposed by Jordan). Figure 4c shows that the average trade volumes of PNG and LNG are relatively higher with the low levels of import tariffs. Furthermore, Figure 4d indicates that the shares of zero trade flows are somewhat higher with lower tariffs[9].However, it should be noted that the role of import tariffs in explaining the zero trade flows is relatively low because tariffs are perceived as a variable cost.

Figure 4: Import tariffs against natural gas trade volumes



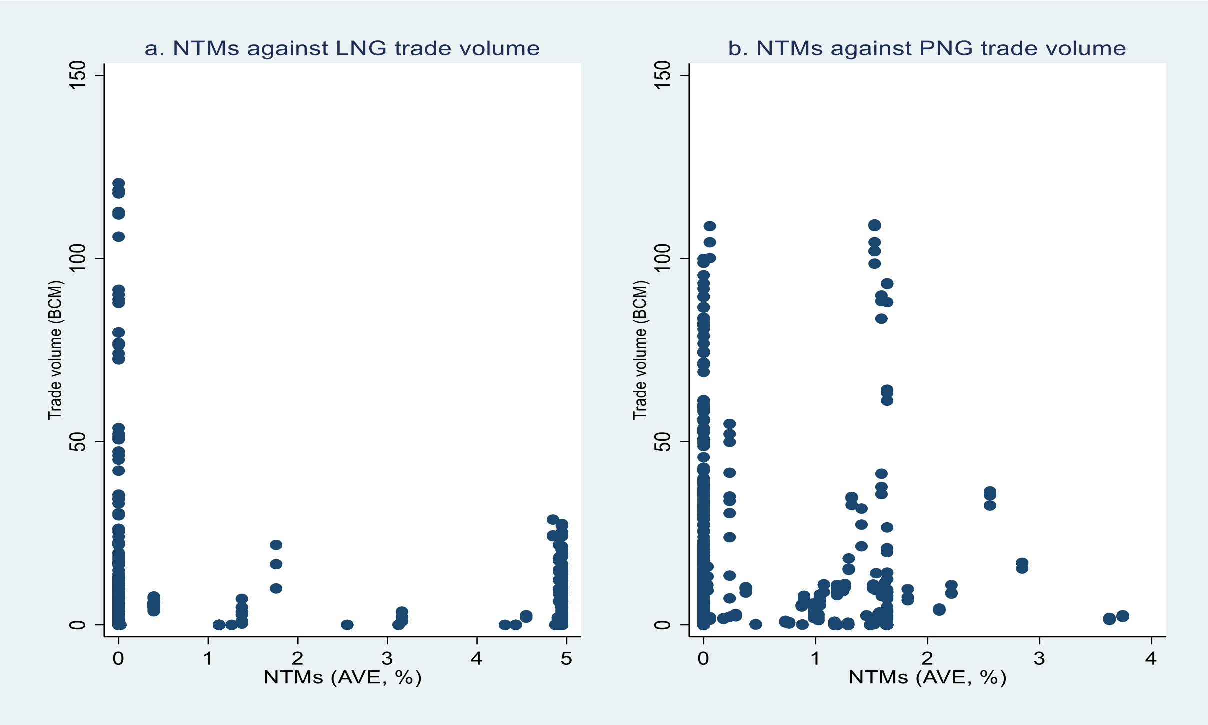
Source: Own construction based on data obtained from WTO and Rystad Energy.

[8] The data is available at https://data.wto.org/

[9] The high and low levels of tariffs are estimated using the median value of that variable as a threshold.

Regarding NTMs, we have data on this variable as ad valorem equivalent (AVE) estimated by Niu et al. (2018). This variable measures the quantitative restrictions in price control measures, quantity restrictions, and monopolistic measures that natural gas importers can apply. According to Cadot et al. (2018), the AVE of NTMs is defined as "*the proportional rise in the domestic price of the goods to which it is applied, relative to a counterfactual where it is not applied*". Also, Figure 5 presents NTMs against trade volumes of PNG and LNG over the period 2000 – 2017. Overall, it does not provide a clear direction for the relationship between NTMs and natural gas trade volumes, especially for the LNG market. This is why it is important to investigate this relationship further empirically.

Figure 5: NTMs against natural gas trade volumes



Source: own construction based on data obtained from Niu et al. (2018) and Rystad Energy

4. Methodology

The methodology used in this paper relies on the gravity model of international trade. Anderson (1979) introduces the first attempt to provide a theoretical economic underpinning for this model[10]. It assumes that the trade volume between trading partners is directly proportional to their respective market size and inversely proportional to the bilateral trade costs between them.

[10] We also refer the reader to Anderson (2011) for a detailed discussion of the theoretical foundation of the gravity model.

As it has been mentioned before, unlike previous studies that estimate a gravity model for natural gas trade using the OLS estimator, we estimate our gravity model using the PPML estimator, which has three main advantages. First, it controls for the information contained in the zero bilateral trade observations due to its multiplicative form (Burger et al., 2009). Second, it accounts for potential inconsistencies in the presence of heteroskedasticity, which often plagues trade data. Third, it asserts that the gravity-fixed effects are identical to their structural counterparts (Yotov et al., 2016; Santos Silva and Tenreyro, 2006). Thus, we use the PPML estimator to estimate the following gravity model:

$$EXP_{NG_{ijt}} = \exp\left[\beta_o + \beta_1 SANC_{ijt} + \beta_2 \log\left(INS_{ijt}\right) + \beta_3 \log\left(Tariff_{jit} + 1\right) + \beta_4 \log\left(NTM_{jit} + 1\right) + \beta_5 \log(NG\ rents\ \%GDP_{it} + 1) + \beta_6 \log\left(NG\ rents\ \%GDP_{jt} + 1\right) + \beta_7 \log\left(Rnewables_{\ jt} + 1\right) + \beta_8 TEMP_{jt} + \beta_9 \log(GDP_{it}) + \beta_{10} \log\left(GDP_{jt}\right) + \beta_{11} WTO_{ijt} + \beta_{12}\, Infra_{ijt}\right] + u_{ijt} \quad (1)$$

Where $EXP_{NG_{ijt}}$ represents the exports of natural gas from country (i) to country (j) in time (t)[11]; $SANC_{ijt}$ is the existence of economic sanctions between the trading partners in time t; INS_{ijt} is the political-institutional quality gap between the trading partners in time t; $Tariff_{ijt}$ is the bilateral import tariffs imposed by the importing country j on exporting country i in time t; NTM_{jit} is the AVE of the NTMs imposed by the importing country j in time t; $NG\ rents\ \%GDP_{it}$ and $NG\ rents\ \%GDP_{jt}$ are the percentage of the GDP that comes from the production of natural gas for the exporting and importing countries, respectively; $Rnewables\ \%_{jt}$ is the percentage of renewable energy to total energy use in the importing countries; GDP_{it} and GDP_{jt} are the real GDP of exporters and importers, respectively, in year t; WTO_{ijt} is a dummy variable that measures if the two countries are members in the WTO in time t, respectively; $Infra_{ijt}$ is the existence of infrastructure to trade natural gas between the trading partners in time t. We estimate this model for the total, PNG, and LNG natural gas trade.

[11] Our dataset on bilateral natural gas trade is organized in a way that each unilateral relationship is unique. For example, the observation when Canada exports PNG to the USA is included separately from that when the USA exports PNG to Canada.

Yet, it is important to highlight the rationale behind some explanatory variables. Indeed, to get accurate estimates of the effect of our variables of interest on trade flows of natural gas, we need to extend the basic trade gravity model to control for the domestic market conditions of both exporting and importing countries. If the domestic production is (not) sufficient to cover the domestic market, then this leads to an increase in (imports) exports of natural gas (Barnes and Bosworth, 2015; Zhang et al., 2018). Therefore, following Barnes and Bosworth (2015), we control for the domestic market conditions by using the percentage of the GDP that comes from natural gas production. We use this variable as a proxy for the supply ability of the trading partners. We obtain data on this variable from the World Bank[12]. Moreover, following Najm and Matsumoto (2020), we control for the heating/cooling degree days and the renewable energy policies in the importing countries. The heating/cooling degree days is an essential factor in the natural gas market because natural gas prices are affected by extraordinary temperatures (i.e., cold temperatures can increase the demand of the heating sector and, accordingly, increase the demand for natural gas) (Brown and Yücel, 2008; Nick and Thoenes, 2014). We obtain data on this variable from the Climate Change Knowledge Portal of the World Bank[13]. The variable is constructed by taking the annual average of each country. Then, we use the inverse hyperbolic sine transformation to consider the negative temperature values. As for renewable energy policies, we construct this variable as the ratio of renewable energy to total energy usage in importing countries. We obtain the data from the U.S Energy Information Transformation (EIA). The intuition behind this variable is that more intermittent renewable energy resources (e.g., solar and wind) in the importing countries imply more demand for natural gas in order to achieve power balance. This is because gas-fired power plants are assumed to serve as the main backup for intermittent renewables since they have higher ramping rates and are more efficient than coal-fired power plants (Gonzalez-Salazar et al., 2018). Finally, we control for the cross-exchange rate ratio that is likely to affect the relative price of natural gas. We assume that higher values of the real cross exchange rate ratio imply cheaper imports and more costly exports. We obtain data on the real effective exchange rate for importers and exporters from Darvas (2012). The cross-ratio is constructed by dividing the real exchange of importers by that of exporters and then taking the natural logarithm of this ratio.

From a methodological perspective, as our analysis considers the zero trade flows in natural gas, one of the main factors causing these observations is the non-existence of infrastructure

[12] The data is available at https://data.worldbank.org/indicator/NY.GDP.NGAS.RT.ZS
[13] The data is available at https://climateknowledgeportal.worldbank.org/

between the trading partners (i.e., a pipeline in the case of PNG) or the non-existence of required facilities in one of the trading partners (i.e., a liquefaction station in the exporting country and a regasification station in the importing country). For example, China started to import LNG in 2006 after constructing the first regasification plant (GIIGNL annual report, 2006). Therefore, we create a variable for both the PNG and LNG trade that measures the availability of required infrastructure to have bilateral trade in natural gas. For PNG trade, the availability of pipelines is collected from different reports, websites, and articles. The variable is constructed as a dummy variable that takes the value one if there is a pipeline and zero otherwise. For LNG trade, data on the availability of liquefaction stations in the exporting countries and regasification stations in the importing countries are obtained from the International Group of Liquified Natural Gas Importers (GIIGNL). We create two dummy variables (i.e., one for liquefaction and one for regasification). Then, we aggregate the two variables into one variable. Therefore, if this variable equals 1 in a specific year, then the two countries can trade LNG together.

Finally, we control for the World Trade Organization (WTO) membership to capture the effect of the international institutional framework. Following the theoretical foundation of the gravity model, we also include the GDP of the trading partners in our models to capture the impact of their economic scale[14] [15].

We include three fixed effects in our regression models. The first one is the year fixed effect to control for the global shocks or trends that could affect the international trade flows in natural gas (e.g., global changes in transportation costs). The second one is the pair-fixed effects that are included for two reasons. First, they would mitigate the potential endogeneity problem resulting from the unobserved heterogeneity in trade flows or omitted variables with respect to the bilateral variables in the gravity model (Baier and Bergstrand, 2007; Baier et al. 2019). Second, they account for all observable and, more importantly, unobservable time-invariant bilateral trade costs between the trading partners that are included standardly in the gravity model, such as geographical distance, cultural ties, colonial links, and trade restrictions[16]. In this context, Yotov et al. (2016), Egger and Nigai (2015), and Agnosteva et al. (2014) confirm that pair-fixed effects provide more accurate and comprehensive estimates of all bilateral trade costs than the standard set of gravity variables. The third fixed effect is the commodity fixed

[14] The data is available at https://data.worldbank.org/indicator/NY.GDP.MKTP.KD

[15] Table A2 in the Appendix provides summary statistics for the main variables used in our empirical analysis.

[16] This is why equation (1) does not include these variables because they are captured and absorbed by the pair-fixed effects.

effect that is introduced only in the regressions of the total gas market to account for PNG and LNG commodities.

We implement the empirical analysis in five steps. First, we start with estimating the effect of our main variables of interest on the bilateral natural gas trade. Second, we focus on two alternative measures for the impact of institutional quality: the difference in institutional quality and the levels of institutional quality of both the exporter and the importer. Also, apart from measuring the effect of the combined index of institutional quality, we provide estimation results where the *political stability and absence of violence* dimension is included separately in our analysis. Third, we examine the impact of trade sanctions on bilateral natural gas since it was frequently imposed in the gas market compared to other economic sanctions. Fourth, we measure the effect of the interaction between our institutional gap index and economic sanctions on the natural gas trade. Finally, our empirical analysis reproduces the estimated results obtained in the first step with two different specifications. The first one measures the domestic market of natural gas differently using the residual demand of natural gas. The second specification, which follows previous studies, uses the OLS estimator instead of the PPML estimator. Accordingly, we estimate the following model:

$$\log\left(EXP_{NG_{ijt}}\right) = \beta_o + \beta_1 SANC_{ijt} + \beta_2 \log\left(INS_{ijt}\right) + \beta_3 \log\left(Tariff_{jit} + 1\right) + \beta_4 \log\left(NTMS_{jit} + 1\right) + \beta_5 \log\left(NG\ rents\ \%GDP_{it} + 1\right) + \beta_6 \log\left(NG\ rents\ \%GDP_{jt} + 1\right) + \beta_7 \log\left(Rnewables_{\ jt} + 1\right) + \beta_8\, TEMP_{jt} + \beta_9 \log\left(GDP_{it}\right) + \beta_{10} \log\left(GDP_{jt}\right) + \beta_{11} WTO_{ijt} + u_{ijt} \quad (2)$$

The dependent variable in equation (2) is the natural logarithm of trade flows of natural gas from country i to country j instead of trade flows of natural gas in levels. Therefore, this specification does not take into account the zero observations.

5. Empirical Results

Tables 1 – 4 report our findings for the effect of our variables of interest on trade in natural gas. Each table includes five specifications. The first four specifications include only one of our main independent variables (i.e., economic sanctions, absolute institutional gap, tariffs, and NTMs) to single out each variable's effect. Yet, the fifth specification combines the four variables.

Table 1 presents the results of the effect of our main variables on the total trade volumes in natural gas. Column 1 indicates that the coefficient of economic sanctions is negative but insignificant. However, when we control for the other variables of interest, its coefficient becomes significant (column 4). This result implies that economic sanctions reduce the bilateral trade volumes of natural gas between the sanctioning and sanctioned countries by 17%, on average[17]. As per institutions, columns (2) and (5) show that the institutional quality gap between the trading partners has a significant negative impact on the total natural gas trade. This means that a higher level of the institutional gap between the trading partners will increase the uncertainty inherent to the interaction between them and increase the transaction costs associated with the bilateral natural gas trade. In terms of volume impacts, a 1 % increase in the institutional gap between the trading partners will decrease the bilateral trade in natural gas by 0.24%, on average. Therefore, the institutional quality gap could be a significant impediment to bilateral trade in natural gas. At the trade policy level, columns (3), (4), and (5) indicate that the coefficients of bilateral import tariffs and NTMs are consistent with the theoretical foundation of the gravity theory. This means that bilateral tariffs and NTMs are indeed a significant impediment to bilateral natural gas trade. More concretely, a 1% decrease in the bilateral tariffs and NTMs results in a 0.63% and 0.23% increase in the bilateral trade volumes of natural gas, respectively, on average. Overall, these findings indicate that economic sanctions, institutional gap, tariffs, and NTMs have negative effects on bilateral natural gas trade.

As per the other control variables, the three variables that explain the domestic natural gas market effect present the expected signs and are statistically significant. This result implies that natural gas exports (imports) increase (decrease) as the production of natural gas increases (decreases). We also find that the temperature of importing countries has a negative and significant effect on the trade volume of natural gas. This is due to the use of natural gas as a heating fuel, and means that natural gas imports are likely to rise in colder years. The coefficient of the infrastructure variable is positive and statistically significant, indicating its importance for bilateral natural gas trade. Finally, the cross-ratio of the exchange rate, WTO, and the share of renewable energy in the importing countries have insignificant coefficients.

[17] We estimate this effect by exponentiating the coefficient obtained by the PPML estimator ($(e^{-0.185} - 1) \times 100$).

Table 1: The effect of our political economy factors on bilateral natural gas trade – PPML estimator

	(1)	(2)	(3)	(4)	(5)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions	-0.108				-0.185*
	(0.107)				(0.101)
Absolute Institutional gap		-0.241*			-0.237*
		(0.133)			(0.139)
Ln (Tariff +1)			-0.596***		-0.629***
			(0.0725)		(0.0723)
Ln (NTMs +1)				-0.197***	-0.228***
				(0.0575)	(0.0572)
Ln (GDP_exp)	0.232	0.240	0.261	0.227	0.277
	(0.187)	(0.186)	(0.195)	(0.186)	(0.190)
Ln (GDP_imp)	1.447***	1.396***	1.454***	1.406***	1.371***
	(0.242)	(0.242)	(0.259)	(0.243)	(0.261)
Ln (NG rents %GDP_imp)	-0.743***	-0.820***	-0.242	-0.759***	-0.130
	(0.195)	(0.188)	(0.227)	(0.189)	(0.231)
Ln (NG rents %GDP_exp)	0.773***	0.766***	0.627***	0.803***	0.705***
	(0.108)	(0.106)	(0.117)	(0.104)	(0.113)
Ln (Cross ratio of exchange rate)	-0.108	-0.107	-0.160	-0.100	-0.162
	(0.145)	(0.146)	(0.150)	(0.146)	(0.148)
Temperature	-0.663*	-0.698*	-0.704*	-0.784**	-0.674*
	(0.354)	(0.356)	(0.381)	(0.348)	(0.379)
WTO	0.0998	0.0355	0.0153	0.0890	0.149
	(0.106)	(0.0948)	(0.0934)	(0.0938)	(0.103)
Ln (Renewables+1)	0.835	0.793	1.068	0.575	1.156
	(1.233)	(1.232)	(1.235)	(1.247)	(1.243)
Infrastructure	5.761***	5.786***	5.862***	5.752***	5.895***
	(0.405)	(0.406)	(0.408)	(0.405)	(0.409)
Constant	-49.85***	-48.32***	-50.50***	-48.19***	-48.65***
	(7.519)	(7.564)	(7.831)	(7.550)	(7.884)
Pseudo R2	0.8188	0.8150	0.8188	0.8154	0.8199
Observations	133,804	133,700	132,348	133,804	132,348

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects, pair-fixed effects, and commodity-fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

Table 2 displays the differential marginal effect of our political economy variables on the PNG and LNG bilateral trade. The intuition behind this regression is to understand the marginal impact of these variables on the PNG and LNG bilateral trade in the same regression model. To do so, we create a dummy variable that takes the value one with bilateral LNG trade and zero with bilateral PNG trade. Then, we interact this variable with our key variables of interest. As evident in Table 3, the significant results of these interaction terms suggest that the conditional effect of our main variables is different between PNG and LNG markets. This also confirms the heterogeneous impact of the underlying political economy factors on the two commodities. Therefore, it is worth estimating separate regressions for PNG and LNG bilateral trade. For example, Column (5) of Table (2) indicates that economic sanctions have a larger effect on bilateral LNG trade relative to that on bilateral PNG trade. More concretely, the marginal effect of economic sanctions on bilateral natural gas trade subject to the mode of transport is given by (0.04 – 1.73×LNG). Hence, the marginal impact of economic sanctions on LNG trade is -1.69, whereas the marginal effect on PNG is 0.04. Moreover, it is essential to note that the coefficient of the dummy variable (LNG=1) is negative and statistically significant. This result means that the average bilateral natural gas trade volume is significantly lower for LNG than PNG.

Table 3 presents the results for the effect of our political economy variables on bilateral LNG trade. Columns (1) and (5) indicate that the impact of economic sanctions is negative and statistically significant. Regarding the volume effect, this finding means that, on average, economic sanctions have reduced bilateral trade volume in LNG between the sanctioning and sanctioned countries by 24%. This result suggests that geopolitical relations could reduce the trade volume in LNG between the trading partners in terms of economic sanctions. Columns (2) and (6) report that the institutional gap between trading partners exerts a significant negative effect on bilateral LNG trade. This result points out that trading partners with similar institutional structures might trade more LNG because this will decrease the associated transaction costs (e.g., Australia's LNG exports to Japan and South Korea vs. Yemen's LNG exports to Japan and South Korea). Therefore, our results suggest that if the institutional gap increases by 1%, bilateral LNG trade will decrease by 0.18%, on average. Moreover, from a trade policy perspective, columns (3), (4), and (6) indicate that bilateral tariffs have an adverse effect on bilateral LNG trade [18]. Accordingly, a 1% increase in the bilateral tariffs results in a 0.33% decrease in the bilateral LNG trade, on average. This finding is consistent with what happened in the LNG market in 2019. Indeed, in September 2018, China imposed a 10% tariff on US LNG imports, raising it to 25% in June 2019. As a result, US LNG imports to China dropped significantly from 3 BCM in 2018 to 0.4 BCM in 2019 (BP, 2020). Therefore, bilateral import tariffs act as price shifters in the LNG market, reducing the trade volume between the trading partners. In contrast, for LNG, columns 5 and 6 of Table 3 indicate that NTMs have a statistically insignificant effect on its bilateral trade.

[18] It should be noted that the number of observations in columns (3) and (6) is relatively low. This is because the PPML regression dropped 58,975 separated observations in one iteration because of the collinearity with the pair fixed effects. To ensure that this does not affect the robustness of the estimated coefficient of the tariffs variable, column (4) provides the estimate for the effect of bilateral tariffs without controlling for the pair fixed effects.

Table 2: The effect of interaction between our main variables and a dummy variable – PPML estimator

	(1)	(2)	(3)	(4)	(5)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions × LNG=1	-1.622***				-1.727***
	(0.325)				(0.290)
Absolute Institutional gap × LNG=1		0.533***			0.580***
		(0.0731)			(0.0693)
Ln (Tariff +1) × LNG=1			-0.0999		-0.286***
			(0.0924)		(0.108)
Ln (NTMs +1) × LNG=1				-0.343***	-0.282***
				(0.0978)	(0.0932)
Economic sanctions	0.126				0.0403
	(0.0872)				(0.0841)
Absolute Institutional gap		-0.387***			-0.384***
		(0.134)			(0.137)
Ln (Tariff +1)			-0.580***		-0.558***
			(0.0759)		(0.0739)
Ln (NTMs +1)				0.0556	-0.0502
				(0.0760)	(0.0722)
LNG=1	-1.048***	-1.591***	-1.156***	-0.967***	-1.330***
	(0.0582)	(0.0950)	(0.0652)	(0.0670)	(0.104)
Ln (GDP_exp)	0.232	0.245	0.262	0.225	0.263
	(0.185)	(0.188)	(0.195)	(0.184)	(0.188)
Ln (GDP_imp)	1.447***	1.382***	1.454***	1.416***	1.318***
	(0.241)	(0.240)	(0.259)	(0.244)	(0.255)
Ln (NG rents %GDP_imp)	-0.743***	-0.824***	-0.239	-0.789***	-0.213
	(0.195)	(0.178)	(0.227)	(0.187)	(0.216)
Ln (NG rents %GDP_exp)	0.773***	0.766***	0.626***	0.770***	0.661***
	(0.106)	(0.0999)	(0.117)	(0.101)	(0.108)
Ln (Cross ratio of exchange rate)	-0.108	-0.0960	-0.161	-0.0976	-0.142
	(0.147)	(0.143)	(0.150)	(0.144)	(0.145)
Temperature	-0.663*	-0.707**	-0.705*	-0.755**	-0.722**
	(0.356)	(0.338)	(0.381)	(0.340)	(0.357)
WTO	0.0997	0.0371	0.0153	0.0549	0.196**
	(0.102)	(0.102)	(0.0939)	(0.0953)	(0.0995)
Ln (Renewables +1)	0.835	0.822	1.058	0.864	1.543
	(1.223)	(1.237)	(1.235)	(1.255)	(1.233)
Infrastructure	5.761***	5.785***	5.862***	5.759***	5.906***
	(0.405)	(0.404)	(0.408)	(0.404)	(0.408)
Constant	-49.59***	-47.65***	-50.25***	-48.24***	-46.35***
	(7.474)	(7.473)	(7.857)	(7.589)	(7.829)
Pseudo R2	0.8170	0.8179	0.8189	0.8160	0.8257
Observations	133,804	133,700	132,348	133,804	132,348

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

Regarding the effect of our control variables, the coefficient on the renewable energy ratio variable is negative and statistically significant. This implies that a 1% increase in the renewable energy ratio in the importing countries decreases LNG imports by around 7%, *ceteris paribus*. This finding means that renewable energy and LNG represent substitutes, resulting in lower demand for LNG. An explanation for this result is that LNG could be more expensive than coal in some major LNG importers (e.g., China and India). Therefore, coal-fired power plants could be used to back up the intermittency of renewable energy resources in those countries (Gonzalez-Salazar et al., 2018). Moreover, this result is generally in accordance with this of Najm and Matsumoto (2020), who find that LNG and renewable energy are substitutes.

The coefficients on natural gas production of the exporter and the temperature in the importing countries have consistent coefficients with our expectations. However, the variable of natural gas production of importers is positive and significant. The counterintuitive sign of this variable may stem from the collinearity with the pair-fixed effects. Therefore, column (4), where we do not control for the pair-fixed effects, reports that this coefficient is negative and significant. We also find that membership in the WTO has a positive and significant effect, underlying that WTO membership is indeed LNG trade promoting. Accordingly, if the two countries are members of the WTO, this will increase the bilateral LNG trade, on average, by 70%. This finding confirms the relevance of the international institutional framework in the LNG market.

The estimated coefficients of exporter and importer's GDP are in line with our prior expectations, and they are comparable to corresponding variables from the literature of gravity models. These findings indicate that the economic size of both the importer and exporter is found to have a high impact on the trade volume in LNG. This also implies that the larger economic size of exporters and importers might increase their investments in the required liquefaction and regasification technologies. Our results also show that the cross-ratio of the exchange rate has a negative and significant effect on the bilateral trade volumes in LNG. Therefore, a 1% decrease in this ratio will increase bilateral LNG by 0.46%, on average. This means that the appreciation of the exporter's currency will decrease the relative price of LNG and increase the bilateral trade volume.

Table 3: The effect of our political economy factors on bilateral LNG trade–PPML estimator

	(1)	(2)	(3)	(4)	(5)	(6)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions	-0.224**					-0.268**
	(0.108)					(0.110)
Absolute Institutional gap		-0.186*				-0.183*
		(0.104)				(0.105)
Ln (Tariff +1)			-0.350***	-0.263**		-0.334***
			(0.116)	(0.127)		(0.113)
Ln (NTMs +1)					0.0290	0.0176
					(0.0381)	(0.0380)
Ln (GDP_exp)	0.749***	0.764***	0.723***	0.392***	0.750***	0.731***
	(0.143)	(0.144)	(0.139)	(0.110)	(0.143)	(0.138)
Ln (GDP_imp)	2.223***	2.183***	2.225***	1.979***	2.256***	2.168***
	(0.218)	(0.217)	(0.219)	(0.205)	(0.221)	(0.219)
Ln (NG rents %GDP_imp)	1.562***	1.552***	1.551***	1.173***	1.550***	1.525***
	(0.422)	(0.416)	(0.418)	(0.453)	(0.420)	(0.404)
Ln (NG rents %GDP_exp)	1.228***	1.230***	1.247***	0.742***	1.227***	1.212***
	(0.112)	(0.108)	(0.113)	(0.101)	(0.112)	(0.110)
Ln (Cross ratio of exchange rate)	-0.403***	-0.424***	-0.437***	0.0630	-0.395***	-0.456***
	(0.140)	(0.142)	(0.140)	(0.141)	(0.141)	(0.145)
Temperature	-1.328**	-1.270**	-1.247**	-0.606	-1.322**	-1.118**
	(0.550)	(0.549)	(0.541)	(0.566)	(0.549)	(0.543)
WTO	0.522***	0.429**	0.433**	0.274	0.419**	0.550***
	(0.180)	(0.171)	(0.183)	(0.180)	(0.175)	(0.183)
Ln (Renewables +1)	-5.907***	-6.293***	-7.449***	-6.197***	-5.886***	-7.410***
	(1.355)	(1.355)	(1.425)	(1.344)	(1.363)	(1.412)
Infrastructure	5.328***	5.317***	5.302***	5.261***	5.304***	5.323***
	(0.414)	(0.413)	(0.413)	(0.412)	(0.413)	(0.415)
Constant	-84.55***	-83.68***	-83.91***	-69.56***	-85.44***	-82.78***
	(7.745)	(7.633)	(7.799)	(5.576)	(7.933)	(7.771)
Pseudo R2	0.8787	0.8787	0.7852	0.7803	0.8787	0.7855
Observations	66,902	66,850	7,199	7,199	66,902	7,199

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. We omit the estimates of all fixed effects for brevity but are available by request. The estimates in column (4) do not employ the pair-fixed effects.

Results of the PNG market are presented in Table 4. Columns (1) and (4) indicate that the coefficient of economic sanctions is fairly small and statistically insignificant. This means that economic sanctions do not affect bilateral PNG trade, on average. Three main points could explain this result. First, high costs are associated with the loss of substantial capital investments in fixed infrastructure with high specificity to transport only natural gas. Second, there might be limited options for the exporter and importer to have alternatives to this trade. For example, many European countries are highly dependent on Russian PNG, and, in the meantime, Russia is dependent on energy revenues from the European market. Third, in some cases, there might be a higher loss of reducing the trade volumes due to the compensation of the transit countries

(Fischhendler et al., 2017; Lochner and Dieckhöner, 2012). Columns (2) and (5) suggest that the trading partners' institutional gap has a negative impact on bilateral trade in PNG, leading to an increase in the transaction costs associated with this market. Therefore, a 1% increase in the absolute institutional gap reduces bilateral trade in PNG, on average, by 0.27%. This is in line with the fact that PNG is mainly traded between trading partners with a relatively high gap in their institutional quality (e.g., PNG trade between Libya and Italy; Russia and EU countries; Algeria and Spain; Algeria and Italy; USA and Mexico). Whereas the impact of tariffs is significant and negative on bilateral PNG trade, column (5) shows that the effect of NTMs is significant but economically smaller. This result implies that procedural costs could impact bilateral trade in PNG through price/quantity restrictions and/or monopolistic measures. Therefore, a 1% decrease in the tariffs and NTMs results in a 0.12% and 0.098% increase in the volume of PNG trade, respectively, on average.

The effect of the domestic market of natural gas on bilateral PNG trade has the expected results. Also, the coefficient of the GDP of importing countries is positive and significant, whereas the GDP of exporting countries is insignificant. This result indicates that the economic size of the demand side drives trade in PNG.

Since the PNG market is dominated by the bilateral trade between Russia and European countries, Table 5 estimates our main variables' effect on Russian natural gas exports[19]. Columns (1), (4), and (5) indicate that the coefficient of economic sanctions and NTMs are statically insignificant. In contrast, the coefficients on tariffs and the institutional gap are statistically significant. Therefore, a 1% increase in the institutional gap between Russia and its trading partner will decrease bilateral PNG trade by 0.32%, on average. Furthermore, if the tariffs imposed by European countries decrease by 1%, bilateral PNG imports from Russia increase by 0.18%, on average.

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[19] Two variables, Russia’s GDP and infrastructure, are removed from this regression due to high collinearity with the pair fixed effects.

Table 4: The effect of our political economy factors on bilateral PNG trade – PPML estimator

	(1)	(2)	(3)	(4)	(5)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions	-0.0417				-0.0564
	(0.0581)				(0.0575)
Absolute Institutional gap		-0.268***			-0.265***
		(0.0985)			(0.0979)
Ln (Tariff +1)			-0.104**		-0.115**
			(0.0517)		(0.0539)
Ln (NTMs +1)				-0.0854	-0.0982*
				(0.0524)	(0.0519)
Ln (GDP_exp)	-0.296	-0.275	-0.331	-0.281	-0.264
	(0.216)	(0.214)	(0.219)	(0.215)	(0.211)
Ln (GDP_imp)	1.333***	1.263***	1.340***	1.325***	1.261***
	(0.207)	(0.210)	(0.208)	(0.206)	(0.210)
Ln (NG rents %GDP_imp)	-0.745***	-0.805***	-0.659***	-0.757***	-0.665***
	(0.156)	(0.147)	(0.168)	(0.151)	(0.174)
Ln (NG rents %GDP_exp)	0.592***	0.598***	0.539***	0.610***	0.596***
	(0.0665)	(0.0659)	(0.0749)	(0.0664)	(0.0740)
Ln (Cross ratio of exchange rate)	-0.131	-0.123	-0.129	-0.125	-0.122
	(0.118)	(0.118)	(0.117)	(0.119)	(0.117)
Temperature	-0.533**	-0.538**	-0.563**	-0.562**	-0.531**
	(0.220)	(0.219)	(0.222)	(0.220)	(0.226)
WTO	0.0362	0.00721	0.0159	0.0342	0.0617
	(0.0659)	(0.0647)	(0.0636)	(0.0647)	(0.0646)
Ln (Renewables +1)	0.893	1.007	1.010	0.800	1.247
	(0.974)	(0.968)	(0.948)	(0.969)	(0.960)
Infrastructure	4.760***	4.809***	4.739***	4.754***	4.773***
	(1.014)	(1.020)	(1.013)	(1.014)	(1.018)
Constant	-30.39***	-28.84***	-29.46***	-30.49***	-29.10***
	(7.038)	(7.123)	(6.981)	(6.996)	(7.009)
Pseudo R2	0.9337	0.9338	0.9337	0.9337	0.9339
Observations	66,902	66,850	66,174	66,902	66,174

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

In line with our expectations, the estimates in Table 5 indicate that the coefficient of the renewable energy ratio in the importing countries is positive and statistically significant. Therefore, an importer with a 1% increase in the ratio of renewable energy is associated with a 3.90% increase in PNG imports, *ceteris paribus*. This result implies that natural gas complements and back-ups electricity production from intermittent renewable resources in the European countries, resulting in a higher demand for natural gas with a higher ratio of renewable energy. This complementarity relation could be explained by the role played by natural gas with the clean energy transition and phasing out carbon-based electricity generation in the European countries (Gonzalez-Salazar et al., 2018).

Table 5: The effect of our political economy factors on the Russian PNG exports – PPML estimator

	(1)	(2)	(3)	(4)	(5)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions	0.117				0.0159
	(0.0716)				(0.0772)
Absolute Institutional gap		-0.363***			-0.324***
		(0.0967)			(0.0937)
Ln (Tariff +1)			-0.224***		-0.178**
			(0.0840)		(0.0854)
Ln (NTMs +1)				-0.121	-0.0268
				(0.0813)	(0.0901)
Ln (GDP_imp)	1.032***	0.847***	0.923***	0.953***	0.805***
	(0.200)	(0.186)	(0.191)	(0.201)	(0.189)
Ln (NG rents %GDP_imp)	0.230	0.128	0.104	0.152	0.0663
	(0.459)	(0.441)	(0.442)	(0.463)	(0.408)
Ln (ross ratio of exchange rate)	0.440	0.603**	0.675**	0.482*	0.732**
	(0.294)	(0.283)	(0.309)	(0.288)	(0.314)
Temperature	-0.514***	-0.603***	-0.523***	-0.543***	-0.611***
	(0.176)	(0.176)	(0.185)	(0.179)	(0.184)
WTO	0.0160	0.149	0.241**	0.0261	0.276**
	(0.0974)	(0.0978)	(0.107)	(0.0922)	(0.120)
Ln (Renewables +1)	4.013***	4.409***	3.740***	4.285***	3.901***
	(1.113)	(1.111)	(1.037)	(1.151)	(1.025)
Constant	-23.87***	-18.22***	-20.89***	-21.65***	-17.08***
	(5.472)	(5.085)	(5.228)	(5.527)	(5.200)
Pseudo R2	0.7516	0.753	0.7524	0.7518	0.7539
Observations	570	570	570	570	570

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

Overall, our findings in the first step suggest the existence of heterogeneity in the effects of our political-economic factors on bilateral trade in PNG and LNG. Specifically, we find that economic sanctions do not affect bilateral PNG trade, whereas they have a negative effect on bilateral LNG trade by reducing the trade volume by 24%. This pertains to the fact that there might be limited options for the exporter and importer to have alternatives to PNG trade, making the trading partners more inexorably intertwined. Regarding the institutional gap, we find that it has an adverse effect on the bilateral natural gas trade. Therefore, it can be considered as a fixed cost that could explain the zero trade volumes for some trading partners. In the meantime, we find that the estimate on the effect of this variable turns out to be higher on PNG trade than that on LNG trade. This is consistent with the fact that PNG is mainly traded between trading partners with a relatively high gap in their institutional quality (e.g., PNG trade between Libya and Italy; Russia and EU countries; Algeria and Spain; USA and Mexico). As for the effect of energy trade policy variables, we find that bilateral tariffs have a significant negative impact on bilateral natural gas trade. However, this impact on the LNG market is larger compared to that on the PNG market. The results also indicate that the NTMs imposed by importers are only effective in the PNG market.

In the second step of our analysis, we consider two ways to measure the effect of institutional quality on bilateral natural gas trade. The first way focuses on the simple difference between the institutional quality of the importing and exporting countries instead of the absolute difference. This measure is calculated as the difference between the value of the institutional quality of the exporter and that of the importer. As previously mentioned, the intuition behind the absolute difference is that countries with similar levels of institutional quality would tend to trade more with each other. In contrast, the simple difference reflects how better (worse) the institutional quality of the supplier compared to that of the consumer if this difference is positive (negative) (Alvarez et al., 2018). The second way to measure the effect of institutions is to include interaction effects between the level of exporter and importer's institutional quality on bilateral natural gas trade[20].

Table 6 provides the estimation results for the difference in institutions and interaction effects of their levels. Columns (1) and (6) indicate that the sign of the institutional gap is positive for the total and PNG bilateral trade, whereas it is negative and statistically insignificant for the LNG bilateral trade. This implies that higher quality of institutions in the exporting country could result in higher bilateral PNG trade volumes. In other words, better institutional quality in the exporting country might facilitate the bilateral PNG trade. Columns (2), (4), and (6) present the interaction effects between the level of exporter and importer's institutional quality (*Institutions_exporter* × *Institutions_importer*) on bilateral natural gas trade. Our results show significant positive interaction effects, suggesting that the impact of institutional quality on bilateral natural gas trade depends on the level of the respective trading partner. In particular, when one of the trading partners has high institutional quality, bilateral natural gas trade will increase if the other trading partner has a high institutional quality. For example, an importer with high institutional quality could benefit from high institutional quality in the respective exporter so that bilateral natural gas trade could increase seamlessly. Therefore, trading partners can complement each other's institutional quality effects on bilateral natural gas trade.

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[20] The variables included in the interaction terms have been cantered about their means.

Table 6: Alternative measures of institutions and natural gas trade – PPML estimator

	Total	Total	LNG	LNG	PNG	PNG
	(1)	(2)	(3)	(4)	(5)	(6)
	Trade volume	Trade volume	Trade Volume	Trade volume	Trade volume	Trade volume
Economic sanctions	-0.162	-0.165	-0.231**	-0.232**	-0.0171	-0.0228
	(0.103)	(0.103)	(0.110)	(0.108)	(0.0586)	(0.0572)
Institutional gap (exporter - importer)	0.393***		-0.160		0.464***	
	(0.126)		(0.106)		(0.0886)	
Institutions_importer		0.203		-0.379**		0.439***
		(0.173)		(0.148)		(0.134)
Institutions_exporter		-0.302		0.632***		-0.293**
		(0.197)		(0.190)		(0.136)
Institutions_exporter× Institutions_importer		0.401***		0.486***		0.304***
		(0.149)		(0.142)		(0.103)
Ln (Tariff +1)	-0.642***	-0.661***	-0.396***	-0.475***	-0.143***	-0.162***
	(0.0716)	(0.0695)	(0.116)	(0.118)	(0.0530)	(0.0511)
Ln (NTMs +1)	-0.220***	-0.206***	0.0167	0.0213	-0.0893*	-0.0547
	(0.0576)	(0.0578)	(0.0387)	(0.0373)	(0.0513)	(0.0529)
Ln (GDP_exp)	0.238	0.230	0.751***	0.819***	-0.256	-0.273
	(0.193)	(0.193)	(0.138)	(0.140)	(0.210)	(0.209)
Ln (GDP_imp)	1.569***	1.593***	2.231***	2.195***	1.563***	1.538***
	(0.261)	(0.266)	(0.216)	(0.203)	(0.209)	(0.225)
Ln (NG rents %GDP_imp)	-0.143	-0.173	1.557***	1.461***	-0.683***	-0.689***
	(0.232)	(0.234)	(0.412)	(0.388)	(0.170)	(0.168)
Ln (NG rents %GDP_exp)	0.668***	0.661***	1.227***	1.148***	0.555***	0.546***
	(0.113)	(0.111)	(0.113)	(0.109)	(0.0721)	(0.0694)
Ln (Cross ratio of exchange rate)	-0.202	-0.230	-0.402***	-0.325**	-0.164	-0.201*
	(0.143)	(0.145)	(0.143)	(0.146)	(0.114)	(0.111)
Temperature	-0.602	-0.621	-1.220**	-1.047**	-0.433*	-0.440*
	(0.381)	(0.378)	(0.541)	(0.522)	(0.230)	(0.226)
WTO	0.0954	0.0961	0.546***	0.526***	-0.00415	-0.0135
	(0.104)	(0.104)	(0.192)	(0.188)	(0.0672)	(0.0667)
Ln (Renewables+1)	0.806	0.660	-7.210***	-7.167***	0.956	0.916
	(1.242)	(1.233)	(1.413)	(1.385)	(0.938)	(0.919)
Infrastructure	5.867***	5.897***	5.319***	5.361***	4.651***	4.692***
	(0.409)	(0.409)	(0.415)	(0.415)	(1.009)	(1.011)
Constant	-53.28***	-53.94***	-85.08***	-86.57***	-37.76***	-36.91***
	(7.816)	(7.964)	(7.684)	(7.074)	(6.845)	(7.058)
Pseudo R2	0.8202	0.8205	0.7855	0.7863	0.9342	0.9344
Observations	132,348	132,348	7,199	7,199	66,174	66,174

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. The estimates in columns (1) and (2) are also obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

Apart from measuring the effect of the combined index of institutional quality, we also provide estimation results where the political stability dimension is included separately. The relevance of focusing solely on this factor becomes more evident when recent events in the gas market are observed. For example, the political instability in the aftermath of the political uprising in Libya in 2011 had a negative influence on Libya's PNG exports to Italy. Accordingly, natural gas flows via the Greenstream pipeline, which runs from Libya to Italy, were suspended in February 2011 and restarted again after eight months (Lochner and Dieckhöner, 2012). Similarly, Egypt's PNG exports to Israel were affected by the terrorist operations that targeted the Arab Gas Pipeline in the aftermath of Egypt's political instability in 2011[21].

Table 7 displays the regressions of this step. Our results reveal that the absolute difference of political stability has a negative and significant impact on bilateral PNG trade. In terms of volume impacts, if the institutional gap based on political stability increases by 1%, bilateral PNG trade decreases by 0.22%, on average. This finding implies that the political stability gap will increase the transaction costs associated with this trade. Surprisingly, the coefficient on this variable is positive and statistically significant. Moreover, Columns (2), (5), and (8) show that the coefficient on the political stability difference between the exporter and importer is negative and statistically significant. Also, the magnitude of this coefficient is larger in the PNG market than that in the LNG market. The negative sign of this coefficient means that political stability in importing countries is relatively larger than that in exporting countries. Accordingly, this finding implies that the larger the negative value of the difference in political stability between the trading partners, the larger the reduction in natural gas trade.

The third step in our analysis aims to examine the effect of trade sanctions on the natural gas trade (Table 8). As previously discussed, trade sanctions are imposed more frequently between the trading partners in the gas market relative to the other types of economic sanctions (e.g., arms and military sanctions). Table 8 shows that the coefficient on trade sanctions is negative and statistically significant for bilateral LNG trade, whereas the coefficient of this variable is economically smaller and insignificant for bilateral PNG and Russian exports. This finding means that trade sanctions have reduced bilateral LNG by about 21%, all else equal.

[21] https://www.reuters.com/article/ozabs-egypt-gas-20110205-idAFJOE71408220110205

Table 7: The effect of Political stability (PS) on bilateral natural gas trade – PPML estimator

	Total	Total	LNG	LNG	PNG	PNG
	(1)	(2)	(4)	(5)	(7)	(8)
	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume	Trade volume
Eco. Sanctions	-0.183*	-0.170*	-0.281**	-0.285**	-0.0386	-0.0441
	(0.104)	(0.102)	(0.113)	(0.114)	(0.0576)	(0.0568)
Absolute PS gap	0.0957		0.184*		-0.219*	
	(0.146)		(0.112)		(0.116)	
PS gap (exporter - importer)		-0.265**		-0.204*		-0.277**
		(0.124)		(0.105)		(0.113)
Ln (Tariff +1)	-0.631***	-0.623***	-0.333***	-0.323***	-0.106**	-0.107**
	(0.0720)	(0.0715)	(0.113)	(0.112)	(0.0521)	(0.0519)
Ln (NTMs +1)	-0.234***	-0.226***	0.0168	0.0223	-0.0857*	-0.0796
	(0.0576)	(0.0572)	(0.0381)	(0.0379)	(0.0506)	(0.0509)
Ln (GDP_exp)	0.281	0.300	0.743***	0.741***	-0.367	-0.215
	(0.195)	(0.194)	(0.139)	(0.139)	(0.227)	(0.221)
Ln (GDP_imp)	1.406***	1.394***	2.197***	2.194***	1.334***	1.305***
	(0.260)	(0.259)	(0.222)	(0.219)	(0.207)	(0.196)
Ln (NG rents %GDP_imp)	-0.0952	-0.0502	1.540***	1.588***	-0.626***	-0.595***
	(0.234)	(0.231)	(0.412)	(0.411)	(0.177)	(0.175)
Ln (NG rents %GDP_exp)	0.695***	0.686***	1.179***	1.182***	0.569***	0.583***
	(0.113)	(0.113)	(0.111)	(0.110)	(0.0743)	(0.0729)
Ln (exchange rate ratio)	-0.155	-0.152	-0.399***	-0.394***	-0.123	-0.148
	(0.148)	(0.148)	(0.143)	(0.141)	(0.118)	(0.118)
Temperature	-0.701*	-0.699*	-1.208**	-1.196**	-0.530**	-0.561**
	(0.376)	(0.376)	(0.541)	(0.538)	(0.222)	(0.225)
WTO	0.160	0.198*	0.506***	0.511***	0.0482	0.112*
	(0.104)	(0.102)	(0.192)	(0.193)	(0.0643)	(0.0585)
Ln (Renewables +1)	1.051	0.625	-7.426***	-7.431***	0.972	0.640
	(1.247)	(1.230)	(1.436)	(1.419)	(0.938)	(0.879)
Infrastructure	5.869***	5.853***	5.319***	5.324***	4.757***	4.704***
	(0.409)	(0.408)	(0.416)	(0.416)	(1.020)	(1.009)
Constant	-49.86***	-50.03***	-83.82***	-83.71***	-28.38***	-31.73***
	(7.899)	(7.855)	(7.950)	(7.953)	(6.866)	(6.988)
Pseudo R2	0.8199	0.82	0.7855	0.7856	0.9336	0.9337
Observations	130,330	130,330	7,197	7,197	65,172	65,172

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimates are obtained with year-fixed effects and pair-fixed effects. The estimates in columns (1) and (2) are also obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

The fourth step in our analysis is to test the interaction effects between economic sanctions and the institutional gap on bilateral natural gas trade. The results of this step are reported in Table 9. Columns (1), (3), and (4) indicate that this interaction term is positive and statistically significant for the total market, PNG market, and Russian exports, whereas column (2) shows that this interaction term is insignificant for the bilateral LNG trade. This finding means that a lower institutional gap decreases the negative effect of economic sanctions between the trading countries.

Table 8: The effect of trade sanctions on bilateral natural gas trade – PPML

	(1)	(2)	(3)	(4)
	Total	LNG	PNG	Russia
	Trade volume	Trade volume	Trade volume	Trade volume
Trade sanctions	-0.158	-0.236*	-0.0432	0.0159
	(0.104)	(0.135)	(0.0598)	(0.0772)
Absolute institutions gap	-0.231*	-0.179*	-0.262***	-0.324***
	(0.139)	(0.104)	(0.0979)	(0.0937)
Ln (Tariff +1)	-0.627***	-0.325***	-0.114**	-0.178**
	(0.0722)	(0.112)	(0.0540)	(0.0854)
Ln (NTMs +1)	-0.229***	0.0164	-0.0996*	-0.0268
	(0.0572)	(0.0380)	(0.0520)	(0.0901)
Ln (GDP_exp)	0.272	0.731***	-0.268	-
	(0.190)	(0.139)	(0.211)	-
Ln (GDP_imp)	1.366***	2.161***	1.261***	0.805***
	(0.261)	(0.221)	(0.210)	(0.189)
Ln (NG rents %GDP_imp)	-0.139	1.520***	-0.669***	0.0663
	(0.232)	(0.406)	(0.175)	(0.408)
Ln (NG rents %GDP_exp)	0.704***	1.219***	0.593***	-
	(0.113)	(0.110)	(0.0742)	-
Ln (Cross ratio of exchange rate)	-0.155	-0.435***	-0.122	0.732**
	(0.148)	(0.145)	(0.117)	(0.314)
Temperature	-0.688*	-1.160**	-0.537**	-0.611***
	(0.379)	(0.543)	(0.226)	(0.184)
WTO	0.137	0.532***	0.0552	0.276**
	(0.104)	(0.182)	(0.0651)	(0.120)
Ln (Renewables +1)	1.127	-7.381***	1.225	3.901***
	(1.242)	(1.415)	(0.960)	(1.025)
Infrastructure	5.889***	5.305***	4.774***	-
	(0.409)	(0.413)	(1.018)	-
Constant	-48.34***	-82.42***	-28.97***	-17.08***
	(7.888)	(7.823)	(7.012)	(5.200)
Pseudo R2	0.8198	0.7855	0.9339	0.7537
Observations	132,348	7,199	66,174	570

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. The estimates in column (1) are also obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

In the last step in our analysis, we reproduce the results obtained in the first step by two different specifications. First, we re-estimate equation (1) using the residual demand to measure the domestic market conditions of exporters and importers (Table 10). We estimate the residual demand by subtracting dry natural gas supply from dry natural gas demand. We did not include this variable in our main results because of the high potential of endogeneity. We obtain data on natural gas demand and supply from the U.S. Energy Information Administration. Second, we re-produce the estimation of the effect of our variables of interest using the OLS estimator (Tables 11). The motivation behind the OLS estimation is to compare the results we obtain by the PPML estimator with the baseline regressions applied by the previous studies.

Table 9: The effect of interaction between economic sanctions and institutional gap – PPML estimator

	(1)	(2)	(3)	(4)
	Total	LNG	PNG	Russian
	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions× Institutional gap	0.212**	-0.135	0.247***	0.263***
	(0.0989)	(0.136)	(0.0606)	(0.0732)
Economic sanctions	-0.350**	-0.0506	-0.239***	-0.193
	(0.151)	(0.229)	(0.0888)	(0.124)
Absolute Institutional gap	-0.244*	-0.181*	-0.282***	-0.397***
	(0.140)	(0.105)	(0.0990)	(0.101)
Ln (Tariff +1)	-0.627***	-0.333***	-0.103*	-0.129*
	(0.0723)	(0.113)	(0.0533)	(0.0771)
Ln (NTMs +1)	-0.220***	0.0182	-0.0682	0.0542
	(0.0574)	(0.0381)	(0.0502)	(0.0886)
Ln (GDP_exp)	0.307	0.728***	-0.162	-
	(0.191)	(0.138)	(0.215)	-
Ln (GDP_imp)	1.412***	2.167***	1.292***	0.924***
	(0.263)	(0.219)	(0.211)	(0.202)
Residual demand_importer	-0.108	1.529***	-0.670***	0.0311
	(0.234)	(0.404)	(0.173)	(0.381)
Residual demand_exporter	0.739***	1.215***	0.657***	-
	(0.114)	(0.110)	(0.0749)	-
Cross ratio of exchange rate	-0.186	-0.457***	-0.167	0.469*
	(0.148)	(0.145)	(0.115)	(0.266)
Temperature	-0.640*	-1.116**	-0.498**	-0.711***
	(0.379)	(0.543)	(0.226)	(0.203)
WTO	0.0798	0.579***	-0.0309	0.263**
	(0.102)	(0.186)	(0.0717)	(0.125)
Ln (Renewables+1)	0.870	-7.401***	0.870	3.218***
	(1.246)	(1.413)	(0.924)	(0.898)
Infrastrucutre	5.870***	5.322***	4.739***	-
	(0.409)	(0.415)	(1.017)	-
Constant	-50.68***	-82.73***	-32.78***	-19.85***
	(7.942)	(7.771)	(7.205)	(5.481)
Pseudo R2	0.8201	0.7855	0.9341	0.7559
Observations	132,348	7,199	66,174	570

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. The estimates in column (1) are also obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

Table 10 indicates that the residual demand of exporters has a negative effect on natural gas exports. Prominent evidence for this result includes the case of Egypt in 2015 and Argentina in

2008. The two countries suspended natural gas exports due to shortages in their domestic market in the respective years (EIA, 2019; 2018). In contrast, the residual demand of importers has a positive and significant effect on the natural gas trade. Overall, the estimated coefficients of our main variables obtained from this specification are similar to our baseline specification, except for the coefficients of tariffs in the PNG market and the NTMs in the LNG market.

Table 10: Measuring the domestic market of natural gas with the residual demand – PPML estimator

	(1)	(2)	(3)	(4)
	Total	LNG	PNG	Russian
	Trade volume	Trade volume	Trade volume	Trade volume
Economic sanctions	-0.0996	-0.158*	-0.0624	0.0963
	(0.0961)	(0.0924)	(0.0447)	(0.0663)
Absolute Institutional gap	-0.250*	-0.165	-0.286***	-0.378***
	(0.136)	(0.114)	(0.0905)	(0.0919)
Ln (Tariff +1)	-0.556***	-0.401***	-0.0342	0.0341
	(0.0730)	(0.120)	(0.0453)	(0.0717)
Ln (NTMs +1)	-0.215***	0.0957**	-0.100**	-0.0955
	(0.0561)	(0.0372)	(0.0404)	(0.0753)
Ln (GDP_exp)	0.0654	0.727***	-0.773***	-
	(0.198)	(0.124)	(0.197)	-
Ln (GDP_imp)	0.906***	0.0349	1.092***	0.764***
	(0.259)	(0.280)	(0.176)	(0.143)
Residual demand_exporter	-0.136***	-0.196***	-0.144***	-
	(0.0226)	(0.0314)	(0.0187)	-
Residual demand_importer	0.203**	0.712***	0.185***	0.330***
	(0.0830)	(0.102)	(0.0670)	(0.0552)
Cross ratio of exchange rate	0.112	-0.198	0.260**	0.528*
	(0.145)	(0.151)	(0.111)	(0.289)
Temperature	-0.469	0.948*	-0.133	-0.542***
	(0.393)	(0.521)	(0.255)	(0.178)
WTO	-0.0144	0.262*	-0.0235	-0.0264
	(0.0976)	(0.158)	(0.0557)	(0.128)
Ln (Renewables %+1)	1.899	-5.801***	1.309	3.214***
	(1.174)	(1.322)	(0.796)	(0.844)
Infrastructure	5.690***	5.008***	4.300***	-
	(0.418)	(0.403)	(1.019)	-
Constant	-30.64***	-29.89***	-11.62*	-17.22***
	(7.832)	(8.469)	(6.117)	(3.898)
Pseudo R2	0.8212	0.8814	0.9363	0.7621
Observations	133,388	66,694	66,694	570

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. The estimates in column (1) are obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

The results that we present in Table 11 replicate the specification of equation (1) with the OLS estimator. The following three points are noteworthy: first, the number of observations used in the OLS estimation suggests a strong difference between the PPML and OLS regressions. This implies that estimating our model using the PPML provides more degrees of freedom and more efficiency. Second, despite being different in magnitudes, the estimated coefficients obtained by the PPML and OLS estimators have similar signs and statistical significance levels, except for the coefficient of the NTMs. Third, these OLS estimations could be criticized because the log-linear specification of the gravity model does not consider the zero trade observations. The three points are important from a methodological perspective because they validate our approach to analyzing natural gas trade using the PPML estimator.

Table 11: The effect of political economy factors on bilateral LNG trade – OLS estimator

	(1)	(2)	(3)	(4)
	Total	LNG	PNG	Russian
	Ln (Trade volume)	Ln (Trade volume)	Ln (Trade volume)	Ln (Trade volume)
Economic sanctions	-0.170*	-0.590***	-0.113	0.117
	(0.0885)	(0.168)	(0.0859)	(0.0913)
Absolute Institutional gap	-0.314***	-0.120	-0.614***	-0.588***
	(0.0881)	(0.132)	(0.100)	(0.123)
Ln (Tariff +1)	-0.0110	-0.323**	-0.0962*	0.255***
	(0.0632)	(0.142)	(0.0584)	(0.0715)
Ln (NTMs +1)	0.0528	-0.00174	0.0706	0.0610
	(0.0366)	(0.0501)	(0.0691)	(0.119)
Ln (GDP_exp)	0.632***	1.131***	0.317	-
	(0.135)	(0.203)	(0.202)	-
Ln (GDP_imp)	1.097***	1.702***	0.201	0.225
	(0.173)	(0.272)	(0.199)	(0.230)
Ln (NG rents %GDP_imp)	0.000111	-0.154	-0.562***	0.281
	(0.188)	(0.362)	(0.184)	(0.345)
Ln (NG rents %GDP_exp)	0.785***	1.023***	0.544***	-
	(0.0848)	(0.148)	(0.104)	-
Cross ratio of exchange rate	-0.349***	-0.659***	-0.284***	-0.0891
	(0.0959)	(0.166)	(0.100)	(0.296)
Temperature	-0.284	-1.264*	-0.152	-0.180
	(0.277)	(0.677)	(0.248)	(0.293)
WTO	0.177*	0.383	0.00384	0.275*
	(0.0949)	(0.259)	(0.0881)	(0.151)
Ln (Renewables %+1)	0.225	-8.575***	1.518*	0.662
	(0.847)	(1.625)	(0.813)	(0.848)
Constant	-46.55***	-73.93***	-12.89**	-3.728
	(5.622)	(9.567)	(6.521)	(6.007)
R-squared	0.825	0.812	0.855	0.928
Observations	3,605	1,857	1,748	502

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. We obtain all estimates with year-fixed effects and pair-fixed effects. The estimates in column (1) are obtained with commodity fixed effects. We omit the estimates of all fixed effects for brevity but are available by request.

6. Conclusion

Using a gravity-type model, this paper explores the determinants of trade in natural gas from a political economy lens. While few studies have examined the influences of geopolitical relations on the natural gas market, limiting their analysis on the European scale, our objective is to fill this gap in the literature by analyzing how the global gas market can be affected by three political-economic factors: the existence of economic sanctions, the institutional gap between the trading partners, and the energy trade policy imposed by natural gas importers. We also contribute to the literature by distinguishing between the effect of those factors on the two commodities traded in this market, namely PNG and LNG. From a methodological perspective, we contribute to the econometric analysis of the gas market by estimating our gravity model using the PPML estimator, which considers the zero trade flows of natural gas. We find that this approach is adequate for analyzing the global natural gas market.

Overall, our findings suggest the existence of heterogeneity in the effect of our political-economic factors on bilateral trade in PNG and LNG. Thus, we first find that, on average, economic sanctions effectively impede bilateral LNG trade by reducing the trade volume by 24%, whereas we do not find such an effect on bilateral PNG trade. This heterogeneous result reinforces the conclusion that LNG is globally traded, reducing the dependence of the trading partners on each other. In contrast, PNG is regionally traded with fixed infrastructure, making the trading partners inexorably intertwined. Consequently, our analysis supports the notion that LNG trade has made the gas market more sensitive to the geopolitical tensions between the trading partners. Therefore, any geopolitical disputes between major LNG trading partners would definitely affect the natural gas market dynamics and lead to changes in the patterns for the global gas trade. Second, our findings reveal that the institutional gap between the trading partner has a significant adverse effect on bilateral natural gas trade. Therefore, the institutional gap can be considered as a fixed cost that could explain the zero trade flows for some trading partners in the gas market. We also find that the estimate on the effect of this variable on PNG trade is larger than that on LNG trade. A plausible explanation is that most of the suppliers in the PNG market are countries with relatively low levels of institutional quality, leading to a higher impact of the institutional gap on bilateral PNG trade. Moreover, we find that the way the institutional quality of exporters and importers affects PNG and LNG trade depends on the level of each other. Therefore, trading partners can complement each other's institutional quality effects on bilateral natural gas trade.

From a policy perspective, while economic factors matter for the trade in natural gas, the latter is also shaped by other political-economic factors. In this context, three main conclusions stem from this paper. First, the institutional gap has an effect on natural gas trade. Therefore, natural gas exporting countries should improve their quality of institutions to engage more in trading with more advanced economies endowed with better institutions. This could reduce the transaction costs that are associated with the natural gas trade and secure their natural gas supplies. Moreover, better institutional quality will decrease the uncertainty inherent to the interaction between the trading partners in the gas market and reap the benefits of natural gas trade. Second, improving the institutional quality will also decrease the negative impact of economic sanctions between the sanctioning and sanctioned countries, as it has been shown in the results. Third, at the energy trade policy level, it is crucial to consider non-tariff measures in energy trade negotiations. These measures still impede bilateral trade and are generally less transparent and more restrictive than classical tariffs.

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Appendix

Table A1

List of countries included in our analysis.

Natural gas exporting countries	Natural gas importing countries
Algeria, Argentina, Austria, Australia, Azerbaijan, Angola, Belgium, Bolivia, Brunei, Brazil, Canada, Cameron, Denmark, Egypt, Equatorial Guinea, France, Finland, Germany, Indonesia, Iran, Italy, India, Israel, Japan, Kazakhstan, Libya, Lithuania, Malaysia, Mexico, Mozambique, Myanmar, Netherlands, Nigeria, Norway, Oman, Papua New Guinea, Peru, Portugal, Qatar, Russia, Singapore, South Korea, Spain, Taiwan, Trinidad and Tobago, Timor-Leste, Turkey, Turkmenistan, United Kingdom, United States, Uzbekistan, United Arab Emirates, Yemen	Argentina, Belgium, Brazil, Canada, Chile, China, France, Greece, Israel, Italy, Jordan, Lithuania, Malaysia, Mexico, Netherlands, Poland, Portugal, Singapore, Spain, Sweden, Switzerland, Thailand, Turkey, UAE, U.K., USA, Armenia, Australia, Austria, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, Georgia, Germany, Ghana, Hungary, Iran, Iraq, Ireland, Kazakhstan, Kyrgyzstan, Latvia, Lebanon, Luxemburg, Moldova, Morocco, North Macedonia, Oman, Romania, Russia, Slovakia, Slovenia, South Africa, Syria, Tajikistan, Tunisia, Ukraine, Uruguay, Uzbekistan, Colombia, Dominican Republic, Egypt, India, Indonesia, Jamaica, Japan, Kuwait, Pakistan, Puerto Rico, South Korea, Taiwan.

Note: these countries are included based on the dataset obtained from Rystadt Energy.

Table A2

Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Trade volume (BCM)	0.109	1.564	0	109.02
PNG trade volume (BCM)	0.157	2.084	0	109.02
LNG trade volume (BCM)	0.061	0.74	0	34.981
Economic sanctions	0.027	0.162	0	1
Institutional gap	1.151	0.832	0	5.464
Import tariffs (simple average, %)	2.323	4.991	0	32.5
Non-Tariff Measures (AVE, %)	0.650	1.534	0	4.947
Cross exchange rate ratio	0.998	0.267	0.034	6.223
NG rents as % of GDP_exp	1.993	5.306	0	66.946
NG rents as % of GDP_imp	0.552	1.834	0	22.522
Temperature	14.192	7.953	-7.077	28.361
GDP_exp (constant 2010 US$)	9.27e+11	2.19e+12	566402.3	1.74e+13
GDP_imp (constant 2010 US$)	7.75e+11	1.98e+12	49986.07	1.74e+13
Renewables	0.113	0.141	0	0.814
WTO	0.667	0.471	0	1
Existence of pipeline	0.029	0.168	0	1
Existence of LNG facilities	0.094	0.292	0	1

Source: constructed by the authors.

Table A3

Active cases of economic sanction between trading partners in the natural gas market (2000 – 2017)

	Sanctioning country	Sanctioned country	Type of economic sanctions	Period
1	USA	Canada	Trade	2003 – 2005
2	USA	Belarus	Travel	2002 - 2003
3	USA	Belarus	Financial	2004 – 2006
4	USA	Belarus	Trade, financial, travel	2006 – 2017
5	USA	Russia	Trade, financial, travel	2014 – 2017
6	USA	Egypt	Financial, arms, military	2013 – 2015
7	USA	Egypt	Military	2017 – 2017
8	USA	France	Trade	2000 – 2017
9	USA	Greece	Trade, financial	2013 – 2017
10	USA	Taiwan	Trade, financial	2013 – 2017
11	USA	Thailand	Military	2006 – 2008
12	USA	Nigeria	Trade, financial	2013 – 2017
13	USA	Angola	Trade, financial, arms	2000 – 2003
14	USA	Moldova	Trade	2012 – 2017
15	USA	Dominican Reb.	Trade, financial	2011 – 2017
16	USA	Algeria	Arms, military	2000 - 2002
17	USA	Yemen	Financial	2012 – 2017
18	USA	Yemen	Financial, travel	2012 – 2017
19	USA	Pakistan	Financial, arms, military	2000 – 2001
20	USA	Pakistan	Military, financial	2012 – 2013
21	USA	China	Arms, military	2000 – 2017
22	USA	China	Trade, financial	2017 - 2017
23	USA	Croatia	Military	2003 – 2008
24	USA	Austria	Others	2000 – 2000
25	USA	Indonesia	Military	2000 - 2010
26	USA	Indonesia	Trade, financial	2011 – 2017
27	USA	Iran	Trade, financial, arms	2000 - 2016
28	USA	Iran	Trade, travel	2017 – 2017
29	USA	Libya	Trade, financial	2000 – 2004
30	USA	Libya	financial	2011 – 2017
31	USA	Libya	Travel	2016 – 2017
32	USA	India	Trade, financial, military	2000 – 2008
33	USA	India	Arms	2000 - 2001
34	USA	Ukraine	Trade, financial, travel	2014 – 2017
35	USA	Azerbaijan	Financial, military	2000 – 2002
36	Canada	USA	Trade	2003 – 2006
37	Canada	Belarus	Trade	2006 - 2016
38	Canada	Libya	Trade, arms, military, financial	2011 - 2017
39	Canada	Tunisia	Financial	2011 – 2017
40	Canada	Russia	Trade, financial	2014 – 2017
41	Canada	Egypt	Financial	2011 – 2016
42	Canada	Iran	Trade, arms, financial	2010 – 2017
43	Canada	Iran	Other	2012 – 2016
44	Canada	India	Trade, financial	2000 – 2008
45	Canada	Iran	Trade, financial	2016 – 2017
56	Canada	Ukraine	Trade, financial, travel, other	2014 – 2017
47	Russia	Belarus	Trade	2010 – 2010
48	Russia	Lithuania	Trade	2013 – 2014
59	Russia	Moldova	Trade	2006 – 2007
50	Russia	Moldova	Trade	2013 – 2017
51	Russia	Canada	Travel	2014 – 2017
52	Russia	Australia	Trade	2014 – 2017

	Sanctioning country	Sanctioned country	Type of economic sanctions	Period
53	Russia	USA	Trade	2014 – 2017
54	Russia	Norway	Trade	2014 – 2017
55	Russia	EU countries	Trade	2014 – 2017
56	Russia	Ukraine	Trade	2006 – 2006
57	Russia	Ukraine	Trade	2009 – 2009
58	Russia	Ukraine	Trade	2014 – 2014
59	Russia	Georgia	Trade, travel, other	2006 – 2011
60	Russia	Georgia	Trade	2009 – 2011
61	Russia	Georgia	Trade, arms	2006 – 2013
62	EU countries	Belarus	Travel	2002 - 2003
63	EU countries	Bulgaria	Financial	2008 - 2017
64	EU countries	Belarus	Financial, travel	2006 - 2011
65	EU countries	Belarus	Trade	2011 – 2016
66	EU countries	Libya	Trade, financial, travel	2011 – 2017
67	EU countries	Moldova	Travel	2003 – 2017
68	EU countries	Russia	Trade, arms, military, financial	2014 – 2017
69	EU countries	Equ. Guinea	Financial	2000 - 2000
70	EU countries	Yemen	Financial, arms, military, travel	2015 – 2017
71	EU countries	Egypt	Financial	2011 – 2017
72	EU countries	Egypt	Trade, arms	2013 – 2017
73	EU countries	Iran	Arms	2007 – 2016
74	EU countries	Iran	Travel	2011 – 2016
75	EU countries	Iran	Trade, financial	2012 - 2016
76	EU countries	Libya	Arms, travel	2000 – 2004
77	EU countries	Libya	Trade, financial, travel	2011 – 2017
78	EU countries	China	Arms, military	2000 – 2017
79	EU countries	Indonesia	Trade, arms, military	2000 – 2000
80	EU countries	China	Arms, military	2000 – 2017
81	EU countries	Austria	Others	2000 – 2000
82	EU countries	Ukraine	Trade, financial, travel, others	2014 – 2017
83	Spain	Israel	Trade, arms	2014 – 2017
84	UK	Israel	Trade, arms	2014 – 2017
85	Switzerland	Iran	Trade, financial, travel	2011 – 2016
86	Switzerland	Egypt	Financial	2011 – 2017
87	Switzerland	Russia	Trade, arms, financial	2014 – 2017
88	Georgia	Russia	Other	2008 – 2011
89	Ukraine	Russia	Trade	2014 – 2017
90	Uzbekistan	Tajikistan	Trade	2009 – 2010
91	Uzbekistan	Tajikistan	Trade	2012 – 2012
92	Uzbekistan	Kyrgyzstan	Trade	2000 – 2001
93	Uzbekistan	Kyrgyzstan	Trade	2005 – 2006
94	Uzbekistan	Kyrgyzstan	Trade	2010 – 2010
95	Uzbekistan	Kyrgyzstan	Trade	2013 – 2014
96	Azerbaijan	Armenia	Trade	2000 - 2017
97	Japan	Canada	Trade	2003 – 2006
98	Japan	Russia	Trade, financial, military, travel	2014 – 2017
99	Japan	Iran	Trade	2006 – 2016
100	Japan	USA	Trade	2003 – 2013
101	Australia	Indonesia	Trade	2011 – 2011
102	Australia	Iran	Trade, arms, financial, military, travel	2008 – 2016
103	Australia	Ukraine	Financial, travel	2014 – 2017
104	UAE	Qatar	Travel	2017 – 2017
105	Egypt	Qatar	Travel	2017 – 2017
106	China	Canada	Trade	2003 – 2016

	Sanctioning country	Sanctioned country	Type of economic sanctions	Period
107	China	Norway	Trade, travel	2010 – 2017
108	South Korea	Iran	Trade	2010 – 2012
109	South Korea	Canada	Trade	2015 – 2016
110	Mexico	Canada	Trade	2003 – 2016
111	Brazil	USA	Trade	2003 – 2016
112	Taiwan	Canada	Trade	2015 – 2016
113	Libya	Switzerland	Trade	2010 – 2011

Source: Kirilakha et al. (2021)