Journal of Industry, Competition and Trade (2024) 24:21
https://doi.org/10.1007/s10842-024-00431-8

A Game-Theoretic Analysis of the Interaction Between Embargoes, Price Caps and Tariffs in EU-Russia Gas Trade

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Received: 9 October 2023 / Revised: 19 September 2024 / Accepted: 27 September 2024 /
Published online: 22 October 2024
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Abstract

Geopolitical tensions have put the use of strategic trade policy instruments back on the agenda of policy makers. In this paper we investigate the interaction of the threat and use of three unilateral trade policy instruments: embargoes, import price caps and tariffs. In a game-theoretic framework with different scenarios and game variants, we show that the strategic use of the right combination of the respective trade policy instruments can be used to achieve more desirable outcomes for the players. In our setup, a credible threat of a tariff supports the successful implementation of an import price cap. While the results can be generalised, we show the concrete functioning of the interplay of these strategic trade policy instruments in a hypothetical game of resumption of natural gas sales from Russia to the EU. Following the application to this example, we derive policy suggestions to improve the EU's position in the specific game.

Keywords European union · Russia · Strategic interaction · Gas market · Energy policy · Game theory

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1 Introduction

Given the increasing geopolitical tensions, in the recent past, public signalling of Western trade policy is shifting from a general pro-free market stance towards a narrative focusing more on resilience and de-risking to counter perceived imbalances in the trade relations with and threats from geopolitical opponents (European Commission 2023). Current trade policy is embracing strategic trade policy instruments such as punitive tariffs and trade embargoes with the aim to achieve desirable political outcomes.[1]

These are typical political decision situations that lend themselves to game-theoretic analysis. When making such decisions, policymakers are expected to carefully weigh the advantages, disadvantages, and strategic implications of the use of different policy instruments, which renders the use of these tools "eminently susceptible to game-theoretical analysis" (Harsanyi 1965; Brams 1975, p.1).[2]

The central aim of this paper is to examine the interaction of specific trade policy instruments – embargoes, import price caps and tariffs – in a game theoretic setting.[3] We do this for the precarious case of the interaction between the EU and Russia on gas supplies. This involves analysing the conditions under which a player can achieve a more desirable outcome in an embargo game and how the player can influence the outcome of the game to its advantage. Concretely, we study the leverage effect of an additional trade policy instrument on the opponent's decision by introducing the threat of a punitive tariff into a game where a trade embargo and an import price cap are explicit policy choices. This paper thus contributes to the literature on the game-theoretic analysis of sanctions, which considers their political and economic aspects, their appropriateness and effectiveness as well as their termination (e.g., Eaton & Engers 1992, 1999; Fearon 1994; Dorussen and Mo 2001; Morgan & Bapat 2003, Kaempfer et al. 2004, and Baliga & Sjöström, 2023).

We start the analysis of the EU-Russia interaction with the hypothetical case of a resumption of gas supplies from Russia to the EU. This describes the possible strategic interaction on the EU-Russia gas market since September 2022 when Russia de facto introduced a supplier embargo on most of the EU.[4] A key aspect of our analysis is the question of whether and under which conditions the EU can successfully implement an import price cap for Russian gas if Russia has resumed supplies. Since this presupposes Russia's willingness to resume gas supplies, this question is also included in the game. From our analysis, we derive the EU's options in the game to shape the terms of supply.

We analyse some variations and extensions of the game that we consider useful in the context of EU-Russia relations. First, we assume a sequentiality of player moves as

[1] Examples are the United States' punitive tariffs on China (USTR 2023) and the European Union's trade embargo on Russia (European Council 2023a).

[2] Since its beginnings with Morgenstern & von Neumann (1944) and Nash (1951), game theory has been used to analyse politics and derive optimal policy decisions (see, e.g., Ordeshook 1986; Pahre & Papayoanou 1997; McCarty & Meirowitz 2007).

[3] The game-theoretic approach is applied in many political cases, such as politics of global warming (Ward 1996), EU bargaining processes (Schneider, Finke & Bailer 2010), oil sanctions (Javadian 2021), and further international crises (Snyder & Diesing 2015).

[4] In the beginning of September 2022, preceding the Nord Stream pipeline explosions, Russia completely stopped deliveries via the Nord Stream 1 pipeline, citing issues with a compressor station, and reduced the overall deliveries to the European Union to less than 15% of the normal level (Zachmann et. al, 2024), in fact only delivering to selected countries in the EU via alternative routes. It also did not use the remaining pipeline capacities to the full extent since.

reciprocal reactions and model a game in extensive form with observable moves (e.g., Osborne & Rubinstein 1994). Later, we integrate simultaneous player decisions into the game. Furthermore, we analyse the implementation of a credible threat in the game.[5] This is also related to the applied game theoretic solution concept of subgame perfect equilibrium (Selten 1965). The analysis is complemented by the consideration of incomplete information to capture the players' uncertainty about the opponent's preferences.

We account for the simplifications of our game by integrating different variants, extensions and uncertainties, strengthening its validity. The analysis varies the EU's and Russia's evaluations of the game outcomes and compares the corresponding solutions, where the evaluations of the outcomes are not modelled by fixed utility values (payoffs), but by individual preference orders over subsets of game outcomes. On this basis, our analysis involves a comparison of the equilibrium outcomes in different scenarios (games) resulting from different orders of preferences. It is also examined whether and how the structure of the game can be varied, e.g., by changing, adding, or omitting policy decision options.

Our game-theoretic framework enables the design, analysis and comparison of different policy scenarios determined by different assumptions about players' preferences over the outcomes. It could also support the EU in redesigning the game to achieve the best possible outcomes in a potential political decision-making situation.

2 Political Background

Russia's military invasion of Ukraine in February 2022 was a watershed moment for the political order in Europe and has led to a reassessment of the EU's energy policy (European Commission 2022a). While the abundant availability of Russian pipeline gas had kept EU natural gas prices low in recent decades, the crisis highlighted the EU's dependence on Russia's reliability as a gas supplier. Following the military invasion and the imposition of various sanction packages against Russia by the EU (which, notably, did not include sanctions on gas), Russia responded by drastically reducing or cutting gas supplies to various EU countries.[6] The market reaction resulted in gas prices at times reaching fifteen times the long-term average.[7] After reinforcing supply cuts and flaring surplus gas, Russian gas supplies to the main EU markets almost ceased in mid-September 2022 (Financial Times 2022a). On 26 September 2022, the destruction of three of the four Nord Stream pipelines largely ended EU-Russia interaction in the EU gas market (CNN 2022), despite Russia's continued physical ability to deliver through remaining routes. Russia claims that its

[5] Threats and their credibility play an important role in strategic interactions (e.g., Brams 2000; Bolt & Houba 2005) and are a typical game-theoretic topic (e.g., Luce & Raiffa, 1989). The issue of credible threats in the context of sanctions is also addressed, e.g., by Krustev (2010) and Walentek et al. (2021).

[6] Gazprom completely ceased voluntary spot market deliveries in October 2021 after already having supplied significantly less than usual during summer 2021. After the invasion, Russia also started to cut supplies to long-term contract holding entities on 27 April 2022 with cuts to Poland and Bulgaria, followed by cuts to the Netherlands, Greece, Denmark, and Finland as well as reductions to Germany, Italy, France, the Czech Republic, Slovakia, and Austria later in spring and early summer 2022 (McWilliams & Zachmann 2022).

[7] The historical average TTF gas price was 20 EUR/MWh in 2010–2019, while it rose to over 300 EUR/MWh in August 2022 (European Commission 2022b). Even after a mild winter 2022/2023 and gas consumption reductions of 19% (European Council 2023b), gas futures prices in the EU have stabilized around 50 EUR/MWh (Intercontinental Exchange 2023) due to the higher prices of LNG, which has come to replace most Russian pipeline gas on the EU market.

supplier embargo to the main EU markets will not be lifted until sanctions against Russia are eased (Financial Times 2022b). On 19 December 2022, the EU consented to a price cap mechanism for natural gas in the EU (Reuters 2022a), albeit at a high level of 180 Euro/MWh which is unlikely to be binding under plausible circumstances and hence can only be seen as a measure aiming at limiting extreme price peaks. As of spring 2024, Ukraine is weighing the possibility of not prolonging the gas transit agreement with Russia, which expires on 1 January 2025 (Sabadus 2024; European Commission 2024). This would further reduce gas deliveries of Russia into Europe.

This situation provides a real-world example to examine the underlying rationale of the players in a reciprocal embargo game, where they have the option of lifting or reintroducing the embargo and the importer can impose import price caps or tariffs.

There is a rapidly growing literature studying the design and potential effects of sanctions in this context. Some literature focuses on the economic costs and appropriate conditions for imposing embargos (Bachmann et al. 2022; Sturm 2022). While some scholars and policymakers have pointed to tariffs as the preferred strategic trade policy instrument in this context (e.g., Gros 2022; Hausmann et al. 2022, 2024; Chaney et al. 2022), which make sense in the case of oil (Sturm et al., 2022), others recommend an import price cap (e.g., Weder di Mauro & Martin 2022; European Council 2022) and show such a price cap to be pareto-dominating for the given market structure (Ehrhart et al. 2023). The key difference between the oil and the gas market with respect to the adequate trade policy instrument is Russia's market power in the gas market. At the same time, given the existing pipeline infrastructure, the EU is currently the only potential foreign buyer of Russian gas from the Western Siberian gas fields, but has in the past not chosen to exercise its resulting market power in the form of a monopsony. Our analysis applied to this real-world case allows to examine the interaction between and strategic sequencing of all three trade policy instruments discussed – embargoes, price caps and tariffs.

3 The EU-Russia Gas Market Game

The strategic interaction between the EU and Russia in the gas market is modelled in a non-cooperative sequential two-player game with mixed motives (non-zero-sum game). It is assumed that players have a set of given policy options (actions), consistent preferences, and act rationally to maximise their utility, and that their decisions are observable. These assumptions are common knowledge. Individual preferences encompass multiple dimensions, such as one's own economic welfare, the destruction of the economic welfare of others, and short- and long-term political considerations. By including others' welfare, sanctions can be evaluated by one's own benefits through the disadvantages (costs) of the other player one wishes to harm.

3.1 Description of the Basic Game

The basic game is represented in Fig. 1. The circles EU_1 and EU_2 denote the decision nodes of the EU, and RU_1 and RU_2 those of Russia. The game outcomes are denoted by o_j, $j = 1, 2, \ldots, 5$. The individual preference relations of the players $i \in \{\text{EU, Russia}\}$ are represented by individual utility functions u_i such that $u_i(o_j) \geq u_i(o_k)$ if player i weakly prefers o_j to o_k (e.g., Osborne & Rubinstein 1994, Ch. 2). The individual utilities are

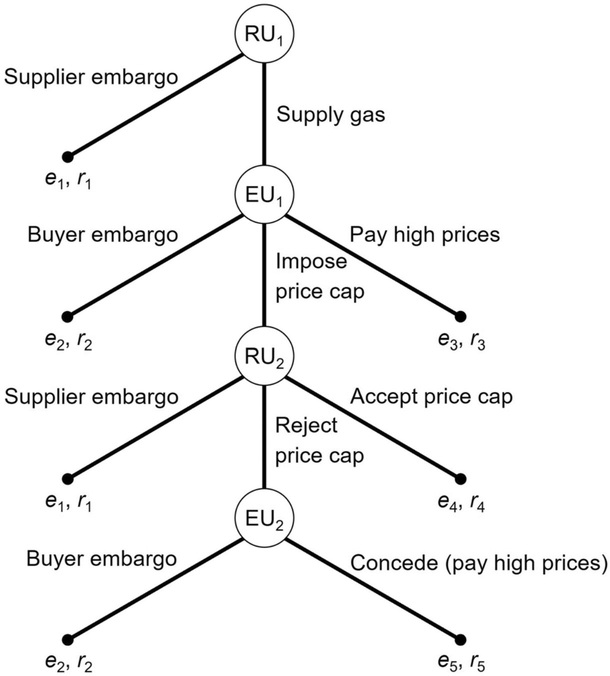


Fig. 1 Game tree of the basic game

ordinal and not intersubjectively comparable. Let $e_j = u_{\mathrm{EU}}(o_j)$ and $r_j = u_{\mathrm{Russia}}(o_j)$. For the sake of clarity, only the utility values e_j and r_j for the EU and Russia are shown in Fig. 1.

The game in Fig. 1 assumes a certain sequence of alternate moves, which is modified below. The game starts in RU_1, where Russia has two options: not to supply gas (supplier embargo), resulting in e_1 for the EU and r_1 for Russia, or to be willing to supply gas. The latter leads to EU_1, where the EU has three options: not to import Russian gas (buyer embargo) leading to e_2 and r_2, to import Russian gas and pay high prices leading to e_3 and r_3, or to import Russian gas, but only on condition that it pays no more than a maximum price, i.e., the EU imposes a price cap. This leads to RU_2, where Russia then has three options: supplier embargo leading to e_1 and r_1, to comply with the EU price cap leading to e_4 and r_4, or to reject the price cap and to continue to charge high prices leading to EU_2, where the EU has two options: either to stand firm and decide on a buyer embargo leading to e_2 and r_2 or to concede and to pay high prices leading to e_5 and r_5.

The assumption of the first move by Russia is due to the underlying political situation in which Russia, as described above, greatly reduced its gas supplies to the EU before the EU acted. We will vary this assumption in two ways, with the EU deciding first (Section 4.2) and the EU and Russia deciding simultaneously at the beginning of the game (Section 4.3).

3.2 Ranking of Outcomes

In the basic game in Fig. 1, preference orders are established separately for both the EU and Russia for the embargo cases and the gas trade cases.

First, we examine for which subsets of outcomes one can assume fixed rankings. This should be true for the embargo cases, where an active embargo is better for both the EU and Russia than a passive embargo, which can also be interpreted as a first-mover advantage[8]:

$$e_2 > e_1, \tag{1}$$

$$r_1 > r_2. \tag{2}$$

In the trade cases, the best outcome for the EU is assumed to be Russia accepting the price cap, followed by the case where the EU accepts high prices immediately, which is again better for the EU than accepting high prices after a price cap has not been enforced, as this could be interpreted as weakness or a loss of face. For Russia, the order is reversed:

$$e_4 > e_3 > e_5, \tag{3}$$

$$r_5 > r_3 > r_4. \tag{4}$$

While we take the four orders (1) to (4) as given, this does not apply to their relative positions, i.e., how e_1 and e_2 compare to e_3, e_4 and e_5, and r_1 and r_2 compare to r_3, r_4 and $r_{5.}$ If Russia sees its benefits dwindling from the continuation of an embargo and the EU is better able to cope with an embargo (for example, through heavy investment in LNG capacities by many EU members and exclusion Russia from delivery), Russia's utilities r_1 and r_2 will decrease relative to r_3, r_4 and r_5, while the EU's utilities e_1 and e_2 will increase relative to e_3, e_4 and e_5. However, if Russia can ship its energy supplies to third countries, Russia's utilities r_1 and r_2 will increase relative to r_3, r_4 and r_5, and the EU's utilities e_1 and e_2 will decrease relative to e_3, e_4 and e_5. To capture these differences, different scenarios are analysed.

3.3 Results

For each of the scenarios, which differ in the placement of e_2 in the EU's utility order and of r_1 in Russia's utility order, the subgame perfect equilibrium is determined.[9] The interpretation of the scenarios and the derivation of the results can be found in the Appendix.

Scenario 1: $e_2 > e_4$ or $r_1 > r_3$
SPE → Supplier embargo with e_1 and r_1
Scenario 2: $e_4 > e_2 > e_3$ and $r_3 > r_1 > r_4$
SPE → Supplier embargo with e_1 and r_1
Scenario 3: $e_4 > e_2 > e_5$ and $r_4 > r_1$
SPE → Russia accepts EU's price cap with e_4 and r_4
Scenario 4: $e_3 > e_2 > e_5$ and $r_3 > r_1 > r_4$

[8] Since we consider it more relevant who imposes the embargo and less relevant when the embargo is imposed in the course of the game, we assume for simplicity that the latter plays no role in the EU's and Russia's evaluation.

[9] A strategy profile is a SPE if it represents a Nash equilibrium of every subgame of the original game (Selten 1965). The SPE solves the rationality problems that can arise with the Nash equilibrium, such as credible threats. The SPEs are determined by backward induction (e.g., Fudenberg & Tirole, 1991). Due to the assumptions (1) and (2), only the positions of e_2 and r_1 in the respective utility order are relevant for the SPE, while the positions of e_1 and r_2 do not matter.

SPE → EU pays high prices with e_3 and r_3
Scenario 5: $e_5 > e_2$ and $r_3 > r_1$
SPE → EU pays high prices with e_3 and r_3

Scenario 1 with $e_2 > e_4$ and/or $r_1 > r_3$ results in a supplier embargo. The first condition means that a buyer embargo is better than the best non-embargo outcome for the EU, namely, introducing a price cap. In this case, the EU could unilaterally improve by ceasing to buy gas from Russia. Assuming common knowledge, Russia will predict this correctly. The latter condition means that Russia prefers the supplier embargo to the case where the EU immediately accepts high prices. Therefore, Russia will impose a supplier embargo.

In *Scenario 2*, the EU prefers a buyer embargo to paying high prices at EU_1 ($e_2 > e_3$), and Russia rather imposes a supplier embargo than accepting a price cap at RU_2 ($r_1 > r_4$). Thus, the SPE implies an embargo outcome.

Scenario 3 is based on the plausible assumption that the EU values Russian compliance with the EU price cap more than a supplier embargo ($e_4 > e_2$) and prefers to stand firm after a Russian rejection of the price cap ($e_2 > e_5$). If the threat of a supplier embargo in the event of a price cap, as announced by Russia (Reuters 2022b), is not credible ($r_4 > r_1$), the SPE would lead to Russia's compliance with the EU price cap. The assumption $e_4 > e_2$ in scenarios 2 and 3 is supported by the fact that the EU agreed on a price cap mechanism for natural gas on 19 December 2022, i.e., the EU prefers a price cap to a buyer embargo.

The SPE in *Scenario 4* leads to a high price situation, as both the EU and Russia value the high price situation more than an active embargo ($e_3 > e_2$, $r_3 > r_1$), and Russia is better off with the supplier embargo than when complying with the EU price cap ($r_1 > r_4$). Here, it would be not rational for the EU to threaten a price cap, although it is credible.

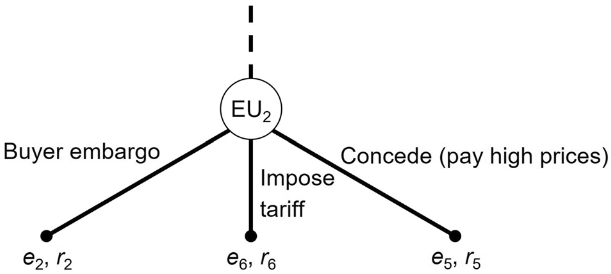
In *Scenario 5***,** the EU cannot credibly commit to standing firm after a Russian rejection of the price cap ($e_5 > e_2$). Since Russia is worse off with the supplier embargo than selling gas at high prices ($r_3 > r_1$), the SPE leads to the high price situation.

This means that by shifting the partial preference orders, different SPE outcomes are possible – a supplier embargo, paying higher prices, and acceptance of a price cap. In *Scenario 3*, it is optimal for Russia to resume gas supplies and even comply with an EU-imposed price cap. Four possible EU policies can support this.

i. The EU could make the continuation of the supplier embargo costly for Russia, i.e., lower r_1 in relation to $r_3 – r_5$. For example, the EU can threaten or implement additional economic sanctions, convince third countries to join an embargo / the sanctions, or implement other political measures to change the relative payoffs for Russia.
ii. The EU could make a Russian gas embargo more bearable for itself, i.e., increase e_1 and e_2 in relation to $e_3 – e_5$. Measures that alleviate economic impacts and social hardship could help limit the damage that a Russian gas embargo has on the EU.[10]
iii. The EU could make its own backpedalling from a price cap as difficult and unattractive as possible, i.e., lower e_5 in relation to e_1 and e_2. This could be achieved by credible political signalling to both the EU audience and Russia that once it has announced the price cap, the EU will not waver ('locking in policy choices').

[10] These include efforts to replace Russian with non-Russian gas, construction of LNG import terminals, accelerating the transition to renewables, as well as energy saving measures. The REpowerEU package of the EU (European Commission 2022a) as well as Germany's efforts to increase LNG import capacity (Deutscher Bundestag 2022) are examples of such policies.

Fig. 2 Extended game tree



iv. The EU could make a price cap acceptable to Russia, i.e., make r_4 not too unattractive by introducing a reasonably price cap that covers the Russian extraction costs and leaves a profit margin.

This analysis also illustrates the limits of sanctions in the context of the game shown in Fig. 1. Since Russia can secure r_1 for itself through a supplier embargo, this is the lowest level to which the EU can push Russia. The EU can therefore try to make this as painful as possible for Russia and, in conjunction, try to convince Russia to accept a price cap calibrated so that r_4 is slightly above r_1, which is more attractive for the EU, as described in *Scenario* 3.

4 Extension and Variations of the Game

This section presents some extensions and variations of the game. The changes in Sections 4.2 and 4.3 in particular are also intended to check the robustness of our results.

4.1 Extending the Game by a Credible Threat

In the basic game, the EU's best non-embargo outcome from a price cap can only be achieved in *Scenario 3*. We now examine whether this can be expanded if the game is extended by threatening a tariff on Russian gas imports at decision node EU_2 (Fig. 2), leading to utilities e_6 and r_6. According to Ehrhart et al. (2023), both a tariff and a price cap can be designed to favour the EU and disadvantage Russia, and for any tariff there exists a price cap that can keep Russia's welfare/costs at the same level while the EU's welfare is higher than with a tariff.[11] Therefore, the EU should design the tariff and the price cap in such a way that it is better for the EU to impose a price cap than to impose tariff, which in turn is better than to pay high prices. For Russia, the situation with high prices is better than accepting a price cap, which is better than the tariff. That is, $e_4 > e_6 > e_3 > e_5$ and $r_5 > r_3 > r_4 > r_6$. In this way, the tariff option can be used as a credible threat by the EU to enforce the price cap.[12]

[11] Given that the EU's objective is not only to maximize its own welfare but also to impose a cost on Russia, the price cap can be an appropriate policy tool that dominates the tariff.

[12] Thus, the conditions for a successful threat are fulfilled, i.e., the player knows the game well and have the "power of threat", i.e. the opponents must perceive the threat as credible (Brams 2000).

When adding the tariff option to the basic game, the SPE outcome remains the same in scenarios 1–4, but not in *Scenario 5*, which is therefore split into *Scenario 5a* and *Scenario 5b*. The derivation of the SPE is shown in the Appendix.

Scenario 5a: $e_5 > e_2$ and $r_3 > r_1 > r_4$
SPE → EU pays high prices with e_3 and r_3
Scenario 5b: $e_5 > e_2$ and $r_4 > r_1$
SPE → Russia accepts EU's price cap with e_4 and r_4

Unlike the basic game, the order of r_1 and r_4 now matters. If Russia values the supplier embargo more than accepting the price cap (*Scenario 5a* with $r_1 > r_4$), the SPE induces the EU to pay high prices, as in *Scenario 5* in the basic game. Conversely, if $r_4 > r_1$ (*Scenario 5b*), the SPE leads Russia to accept the price cap. Compared to the basic game, the condition $r_4 > r_1$ changes the SPE outcome from paying high prices to accepting the price cap, despite concession being better than buyer embargo ($e_5 > e_2$). That is, with the tariff extension, the conditions for achieving the best EU outcome are easier to meet because $e_2 > e_5$ is no longer necessary to reach the price cap. In conclusion, the EU could support its policy measure (iv) to impose a price cap by credibly threatening a tariff as an alternative policy option that would make Russia worse off than the price cap.[13]

The threat of a tariff can therefore help the EU to achieve a better solution than the supplier embargo while hurting Russia. As this extension of the game is advantageous for the EU, it will be retained in the following.

4.2 EU to Decide First

In the game in Fig. 1, Russia has a first-mover advantage in imposing the embargo. We now analyse what changes if the EU has this advantage. We therefore assume that Russia will supply gas and that the EU can decides first. This is implemented in the game in Fig. 1 by removing the decision node RU_1 and starting the game in EU_1. Thus, the first-mover advantage of imposing the embargo switches from Russia to the EU. The SPE of the game are as follows (for the derivation see Appendix). Compared to the game in the Figs. 1 and 2, the SPE outcome in the scenarios 3 – 5, including 5a and 5b, does not change. This is because the first-mover advantage does not affect the SPE of these scenarios, as the outcomes do not include an embargo. The SPE of *Scenario 2* changes in that the embargo is now imposed by the EU and not by Russia, resulting in e_2 and r_2 instead of e_1 and r_1. This is where the first-mover advantage that the EU now has comes into play. *Scenario 1* is split into *Scenario 1a* and *Scenario 1b*.

Scenario 1a: $e_3 > e_2$ and $r_1 > r_3$
SPE → EU pays high prices with e_3 and r_3

[13] Moreover, the imposition of a tariff in the extended game differs from the other outcomes in that there may be relevant follow-up actions by Russia, such as a supplier embargo. However, this is not considered relevant to the solution of the game, as it does not change the equilibrium in any scenario. If Russia were to choose supplier embargo in response to an EU-imposed tariff, it would have already chosen the supplier embargo action at decision node RU_2. Similar to the high price situation following the EU's failure to impose a price cap (resulting in utilities e_5 and r_5), the imposition of the tariff is not a possible outcome in a SPE. Nevertheless, this does not mean the tariff option is not relevant to the solution of the game, because it could change the equilibrium in some scenarios: The tariff option allows the EU to make a credible threat and therefore has a better chance of achieving the best EU outcome.

Scenario 1b: $e_2 > e_4$ or ($r_1 > r_3$ and $e_2 > e_3$)
SPE → Buyer embargo with e_2 and r_2

In *Scenario 1a* the EU prefers paying high prices to a buyer embargo and thus to a supplier embargo ($e_3 > e_2 > e_1$), thus benefiting from the first-mover advantage.

4.3 EU and Russia to Decide Simultaneously at the Beginning of the Game

Now we vary the game and assume that Russia and the EU make their first decisions in RU_1 and EU_1 at the same time, which is also a conceivable variation. That is, they play a simultaneous game at the nodes RU_1 and EU_1, which is described by a normal form game represented by the following payoff matrix (Table 1).[14]

If both the EU and Russia choose embargo simultaneously, the outcome of the game is a bilateral embargo, which is not possible in the sequential game. In this case, the utilities are e_B and r_B, assumed to be $e_1 < e_B < e_2$ and $r_2 < r_B < r_1$. This means that for a player the bilateral embargo is worse than the player's unilateral embargo, but better than the unilateral embargo set by the other player. If Russia continues to supply gas and the EU pays high prices, the utilities are e_3 and r_3. If the EU imposes a price cap, the outcome depends on the further movements of the EU and Russia at nodes RU_2 and EU_2. Thus e_X and r_X are used to denote the equilibrium utilities of the subgame starting from RU_2 depending on the utility orders.

Utilities e_X and r_X are determined for each *Scenario* 1 – 4, 5a and 5b via the respective SPE in the subgame from the node EU_1 in the game in Fig. 1. The derivation of the results can be found in the Appendix. In each scenario there exists a Nash equilibrium (NE) of the bilateral embargo. In addition, the non-embargo SPE remains in scenarios 3, 4, 5a and 5b, resulting in two NE in these scenarios, both of which are SPE. Thus, the initial order of the moves does not influence the existence of the non-embargo equilibria. However, the existence of two NE raises the question of equilibrium selection. Prominent selection criteria are the payoff (Pareto) and risk criteria.[15]

In all scenarios with two NE, the non-embargo NE is payoff dominant over the bilateral embargo NE. For the sensitive political situation considered here, we propose the application of the maximin principle as risk criterion, which represents the strictest form of risk avoidance. This criterion also has the advantage that it can be applied to ordinal utilities, as required here. According to the maximin principle, a player prefers the NE where miscoordination, in the form of the other players choosing any strategy, causes the least damage to the player. In mathematical terms, this means that player i chooses strategy s_i^* from the player's set of NE strategies S_i^* for which $\max_{s_i^* \in S_i^*} \min_{s_{-i} \in S_{-i}} u(s_i^*, s_{-i})$ holds, i.e., for all strategies s_{-i} of i's opponents, denoted by *-i*, from the opponents' set of all strategies S_{-i}. Applied to the game in Table 1 as for scenarios 3, 4, 5a and 5b with two NE, the embargo NE dominates

[14] Equivalently, the game can be represented as an extensive form as in Fig. 1 with imperfect information by extending the decision node EU_1 to a two-element information set containing both Russia's execution of the supplier embargo and the gas supply, i.e., the EU cannot observe Russia's decision in RU_1.

[15] A NE is (weakly) payoff dominant over another NE if it is (weakly) Pareto superior, i.e., the utility of all players is (weakly) higher. The concept of risk dominance is first proposed by Harsanyi and Selten (1988) for a 2x2 normal form game, which is extended by Carlsson & van Damme (1989), Young (1993), Staub (1995) and Peski (2010).

the non-embargo NE in terms of risk according to the maximin principle.[16] For example, in scenarios 4 and 5a, in addition to the embargo NE with the utilities e_B and r_B, the strategy combination "Pay high prices" for the EU and "Supply gas" for RU with $e_X = e_3$ and $r_X = r_3$ forms the second NE. Because of $e_3 > e_B$ and $r_3 > r_B$, the second NE payoff dominates the first NE. However, $e_2 > e_1$ and $r_1 > r_2$ imply that the first NE dominates the second NE in terms of risk according to the maximin principle. This means that from a risk avoidance perspective, the embargo NE is the better one, although the second NE of gas supply at high prices is better for both players.

The risk dominance property of the embargo NE can also serve to capture the current situation between the EU and Russia, which can be described as a bilateral embargo.

4.4 Modelling of Uncertainty

In the following, complete information is no longer assumed, i.e., a player is uncertain about the other player's preferences. If a player misjudges the other player's preferences and decides on the basis of this misjudgement, the game may end to the player's disadvantage.[17] In games with incomplete information, players' uncertainties are captured by probability distributions.[18] To compare the expected utilities of different options using probability distributions, we assume in this section that the utilities are cardinal.

In the extended and variant games, when the EU is uncertain about Russia's preferences, the outcomes that differ from the equilibria in the complete information game are always worse for the EU, while in some cases in Russia's favour. In each of the uncertain cases, the EU can influence Russia's preference order in favour of the EU through the level of the price cap (and, in one case, through the level of the tariff). The higher the price cap, the higher the probability that Russia will accept the price cap, leading to the best outcome for the EU.

Similarly, when Russia is uncertain about the EU's preferences, the outcomes that differ from the equilibria in the complete information game always worse for Russia, while in some cases it is better for the EU, namely when the complete information equilibrium is supplier or bilateral embargo, but it deviates towards buyer embargo under incomplete information. As long as the EU's best possible outcome is not the buyer embargo (as justified above, in reality it should be $e_4 > e_2$), the EU has an incentive to promote the best possible outcome, namely Russia accepting the price cap imposed by the EU. To ensure this, the EU can benefit from revealing its own preferences and

[16] The meaningful application of the maximin criterion and other criteria that use payoffs other than the equilibrium payoffs requires that the application of the criterion selects an equilibrium and does not lead to a non-equilibrium outcome, which is fulfilled in the game here. This requirement is one of the reasons why Harsanyi & Selten (1988) restricted the definition of risk dominance to 2x2 normal form games.

[17] A real-life example of a failed deal was Carter's approach during the Iran hostage crisis, where U.S. President Carter seemed to misread Iran's preferences regarding the outcome, and his threat did not work (Brams 2000).

[18] Games with incomplete information can be modelled and analysed (under certain quite general conditions) as games with imperfect information, where a player's type (i.e., utility order) is initially determined by a random move that cannot be observed by the other players (Fudenberg & Tirole, 1991). The solution concepts for the extensive form games considered here, with incomplete information and observable player moves, are the sequential equilibrium and the perfect Bayesian equilibrium, both of which allow players' risk attitudes to be taken into account (e.g., Osborne & Rubinstein 1994).

Table 1 Payoff matrix of the simultaneous game

EU \ RU	Supplier embargo	Supply gas
Buyer embargo	e_B, r_B	e_2, r_2
Pay high prices	e_1, r_1	e_3, r_3
Impose price cap	e_1, r_1	e_X, r_X

influencing Russia's preference order in favour of the EU through the level of the price cap as well as tariff.

The derivation of the results can be found in the appendix. Consider, for example the extended game and assume that the EU only knows its own preferences but is uncertain about the position of r_1 in Russia's preference, while Russia knows both preferences. If Russia imposes a supplier embargo, the game is over. If Russia chooses to supply gas, meaning $r_3 > r_1$, the EU will impose a price cap if $e_2 > e_3$. In this case, the EU's initial beliefs about Russia's preferences do not matter, i.e., the EU does not have to take uncertainty into account in its decision. Consequently, the outcome corresponds to the equilibrium in the complete information game. However, if $e_3 > e_2$ (as in *Scenario 4, 5a, 5b* or in a subcase of *Scenario 3*), the EU's decision depends on whether $r_4 > r_1$ or $r_3 > r_1 > r_4$. At EU_1, the EU's decision is based on the expected utility of the rest of the game. Let p denote the probability of $r_4 > r_1$ and $1 - p$ the probability of $r_3 > r_1 > r_4$. If the EU decides to impose a buyer embargo, the game ends in o_2, if it decides to pay high prices in o_3, and if it imposes a price cap in o_4 with probability p and in o_1 with probability $1 - p$. The EU evaluates the outcomes o_j by means of an individual utility function $e_j = u_{EU}(o_j)$ which, in the form of a von Neumann-Morgenstern function, allows the modelling of risk attitude (Morgenstern & von Neumann, 1944). Since $e_3 > e_2$, the EU compares e_3 of paying high prices with the expected utility $pe_4 + (1 - p)e_1$ of imposing a price cap. The EU will pay high prices if $e_3 \geq pe_4 + (1 - p)e_1$ and will impose a price cap if $e_3 < pe_4 + (1 - p)e_1$. Note that the EU can influence p by the level of the price cap in its favour: The higher the price cap is, the higher is p, the higher is the probability that Russia will accept it, and the lower is the resulting EU welfare. The equilibrium outcome in the complete information game is o_4 if $r_4 > r_1$ and o_3 if $r_3 > r_1 > r_4$. This means that under incomplete information, the complete information equilibrium outcome o_4 may deviate to o_3 if the EU decides to pay high prices, or o_3 may deviate to o_1 if the EU imposes a price cap. Both deviations are worse for the EU compared to the equilibrium outcome in the complete information game ($e_4 > e_3 > e_1$), while Russia benefits from the first deviation ($r_3 > r_1 > r_4$).

5 Conclusion and Policy Implications

Recent international political conflicts have led to increased use of strategic trade policy instruments. Modelling a non-cooperative game, we examine specific strategic trade policy instruments: embargoes, import price caps and tariffs. We show how these strategic trade policy instruments interact in a hypothetical game of resumption of natural gas sales from Russia to the EU.

Several scenarios are analysed and compared, varying in the preference orders of the EU and Russia on the possible outcomes. It is shown that a possible resumption of Russian gas supplies under an import price cap is possible in a subgame perfect equilibrium if (i) a continued gas embargo is more costly for Russia than the status quo, (ii) a Russian gas embargo is bearable for the EU, (iii) the EU is able to credibly commit to stand firm even if Russia rejects the price cap, and (iv) the conditions of the price cap are still acceptable to Russia. In particular, we show that the threat of an EU tariff can increase the likelihood that Russia will agree to a price cap.

The analysis is extended by changing the starting point of the strategic interaction, through including simultaneous decisions. Since these variations have no impact on the existence of the non-embargo equilibria in the extended game and thus on the recommended EU policies, this speaks in favour of the robustness of our results. In addition, we model the players' uncertainty about the opponent's preferences in a game with incomplete information and observable player moves, which does not affect our policy recommendations above.

In the model with simultaneous decisions, the risk dominance criterion selects the bilateral embargo equilibrium, although a non-embargo equilibrium is better for both players, but riskier. This result can help to capture the current situation between the EU and Russia, which can be described as a bilateral embargo.

While the derived conditions are obviously not an automatic recipe for the successful implementation of an import price cap, this analysis can contribute to structuring the debate in the event of a potential resumption of gas trade between the EU and Russia, whenever this may happen.

Furthermore, it can inform policymaking on similar issues, such as the interaction of specific trade policy instruments more generally. We show that the strategic use of the right combination of trade policy instruments can be used to achieve more desirable outcomes. This underlines a player can shape the game in its favour, e.g., by changing, adding, or excluding trade policy options or changing the opponent's value for an outcome. It should also be examined whether and how a credible threat can be successfully implemented. These are lessons for international policy makers that more generally can be drawn from our modelling setup.

When using game-theoretic models, it is important to acknowledge the simplification of reality. This is especially true for assumptions about the opponents' evaluations of the game outcomes. Uncertainty can be addressed by incorporating this into the game or by analysing different scenarios, as we have done.

Our game-theoretic analysis of the EU-Russia gas game is subject to several additional limitations. First, although we model different game variants and consider different scenarios, the structures of the games are not uncontroversial. While we have tried to map the strategic interaction that was (to some extent) common knowledge, the evolution of the situation may change the structure of the game. Second, the game theory model focuses only on the two main actors, whereas other actors may be involved in the game, even if they only influence the preference orders and strategies of the main actors. This requires an extended analysis. Third, our approach uses ordinal preferences and thus provides qualitative results. For policy making, it is often necessary to quantify the utility and impact of policies.

Appendix

A.1 Determination of the Subgame Perfect Equilibria (SPEs) in the Basic Game

The subgame perfect equilibria (SPEs) of the game are derived by backward induction. The orders (1) – (4) are given.

Starting with the subgame from the decision node EU_2, the decision of the EU in EU_2 depends on the ratio of e_2 and e_5. If $e_2 > e_5$, the EU will impose a buyer embargo. If $e_5 > e_2$, the EU will concede.

In RU_2, Russia takes the EU's decision in EU_2 into account and compares r_1, r_4 and its expected outcome in the subgame from EU_2:

- If $e_2 > e_5$, Russia compares r_1, r_4 and r_2. Since $r_1 > r_2$, Russia will not reject the price cap. If $r_1 > r_4$, Russia will impose the supplier embargo. If $r_4 > r_1$, Russia will accept the price cap.
- If $e_5 > e_2$, Russia compares r_1, r_4, and r_5. Since $r_5 > r_4$, Russia will not accept a price cap. If $r_1 > r_5$, Russia will impose the supplier embargo. If $r_5 > r_1$, Russia will reject the price cap.

Consequently, the EU's decision in EU_1 is considered a function of the previously derived decisions in the subgames starting in RU_2 and EU_2. Thus, the EU decides by comparing the expected outcome in the subgame from RU_2 with e_2 and e_3.

- If $e_2 > e_5$ and $r_1 > r_4$, the EU compares e_1, e_2 and e_3. Since $e_2 > e_1$, the EU will not impose a price cap. If $e_2 > e_3$, the EU will impose the buyer embargo. If $e_3 > e_2$, the EU will pay high prices.
- If $e_2 > e_5$ and $r_4 > r_1$, the EU compares e_2, e_3 and e_4. Since $e_4 > e_3$, the EU will not pay high prices. If $e_2 > e_4$, the EU will impose the buyer embargo. If $e_4 > e_2$, the EU will impose a price cap.
- If $e_5 > e_2$ and $r_1 > r_5$, the EU compares e_1, e_2 and e_3. Since $e_3 > e_5$ and $e_2 > e_1$, the EU will pay high prices.
- If $e_5 > e_2$ and $r_5 > r_1$, the EU compares e_2, e_3 and e_5. Since $e_3 > e_5$, the EU will pay high prices.

Finally, in RU_1, Russia decides by comparing the expected outcome in the subgame from EU_1 with r_1 whether to impose the supplier embargo or supply the gas.

Table 2 SPE outcome in the basic game under different utility orders

outcome (utilities)	$r_5 > r_3 > r_4 > r_1$	$r_5 > r_3 > r_1 > r_4$	$r_5 > r_1 > r_3 > r_4$	$r_1 > r_5 > r_3 > r_4$
$e_4 > e_3 > e_5 > e_2$	pay high prices (e_3 and r_3)	pay high prices (e_3 and r_3)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_4 > e_3 > e_2 > e_5$	accept price cap (e_4 and r_4)	pay high prices (e_3 and r_3)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_4 > e_2 > e_3 > e_5$	accept price cap (e_4 and r_4)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_2 > e_4 > e_3 > e_5$	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)

- If $e_2 > e_3$ and $r_1 > r_4$ or $e_2 > e_4$ and $r_4 > r_1$, Russia expects that the EU will choose the buyer embargo in EU_1 Since $r_1 > r_2$, Russia will impose the supplier embargo.
- If $e_3 > e_2 > e_5$ and $r_1 > r_4$ or $e_5 > e_2$ and $r_5 > r_1$, the EU is expected to pay high prices in EU_1. Thus, Russia compares r_1 and r_3 for its decision. If $r_1 > r_3$, Russia will impose the supplier embargo. If $r_3 > r_1$, Russia will supply gas.
- If $e_4 > e_2 > e_5$ and $r_4 > r_1$, the EU is expected to impose a price cap. Since Russia prefers a price cap to a supplier embargo ($r_4 > r_1$), Russia will supply gas.
- If $e_5 > e_2$ and $r_1 > r_5$, the EU is expected to pay high prices. Since Russia prefers a supplier embargo to high prices ($r_1 > r_5 > r_3$), Russia will impose the supplier embargo.

The above considerations are summarized in the following table (Table 2).

The SPE and its outcome for each of the five scenarios can now be determined:

- *Scenario 1*: $e_2 > e_4$ and/or $r_1 > r_3$. SPE leads to the supplier embargo with utilities e_1 and r_1.
- *Scenario 2*: $e_4 > e_2 > e_3$ and $r_3 > r_1 > r_4$. SPE leads to supplier embargo with utilities e_1 and r_1.
- *Scenario 3*: $e_4 > e_2 > e_5$ and $r_4 > r_1$. SPE induces Russia to accept the EU's price cap with utilities e_4 and r_4.
- *Scenario 4*: $e_3 > e_2 > e_5$ and $r_3 > r_1 > r_4$. SPE induces the EU to pay high prices with utilities e_3 and r_3.
- *Scenario 5*: $e_5 > e_2$ and $r_3 > r_1$. SPE induces the EU to pay high prices with utilities e_3 and r_3.

A.2 Determination of the SPEs in the Extended Game

The SPEs of the extended game are determined by backward induction: Starting with the subgame from EU_2, the EU compares e_2, e_5, and e_6. Since $e_6 > e_5$, the EU will not concede. If $e_2 > e_6$, the EU will impose the buyer embargo. If $e_6 > e_2$, the EU will impose a tariff.

In RU_2, Russia compares r_1 and r_4 with its expected outcome in the subgame from EU_2. Since $r_1 > r_2$ and $r_4 > r_6$, independent of the expected outcome in EU_2, Russia will not reject a price cap. If $r_1 > r_4$, Russia will impose the supplier embargo. If $r_4 > r_1$, Russia will accept a price cap.

Subsequently, the EU's decision in EU_1 is decided by comparing the expected outcome in the subgame from RU_2 with e_2 and e_3.

- If $r_1 > r_4$, the EU compares e_1, e_2 and e_3. Since $e_2 > e_1$, the EU will not impose a price cap. If $e_2 > e_3$, the EU will impose the buyer embargo. If $e_3 > e_2$, the EU will pay high prices.
- If $r_4 > r_1$, the EU compares e_2, e_3 and e_4. Since $e_4 > e_3$, the EU will not pay high prices. If $e_2 > e_4$, the EU will impose the buyer embargo. If $e_4 > e_2$, the EU will impose a price cap.

Finally, Russia's decision in node RU_1 compares r_1 with its expected outcome in the subgame from EU_2.

- If $r_1 > r_4$ and $e_2 > e_3$ or $r_4 > r_1$ and $e_2 > e_4$, the EU is expected to impose the buyer embargo in EU_1. Thus, Russia compares r_1 with r_2 and will impose the supplier embargo.
- If $r_1 > r_4$ and $e_3 > e_2$, the EU is expected to pay high prices. Thus, Russia compares r_1 with r_3. If $r_1 > r_3$, Russia will impose the supplier embargo. If $r_3 > r_1$, Russia will supply gas.
- If $r_4 > r_1$ and $e_4 > e_2$, the EU is expected to impose a price cap in EU_1. Since Russia prefers the acceptance of a price cap to a supplier embargo ($r_4 > r_1$), it will supply gas.

For the sake of clarity, only the relevant utility orders are listed in Table 3.

The SPE and its outcome for each of the scenarios of the extended game are as follows:

- *Scenario 1–4*: the SPEs and their outcomes are the same as in the basic game.

Table 3 SPE outcome in the extended game under different utility orders

outcome (utilities)	$r_6 > r_1$	$r_4 > r_1 > r_6$	$r_3 > r_1 > r_4$	$r_5 > r_1 > r_3$	$r_1 > r_5$
$e_5 > e_2$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	pay high prices (e_3 and r_3)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_3 > e_2 > e_5$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	pay high prices (e_3 and r_3)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_6 > e_2 > e_3$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_4 > e_2 > e_6$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)
$e_2 > e_4$	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)	supplier embargo (e_1 and r_1)

Table 4 SPE outcome in the game where the EU decides first under different utility orders

outcome (utilities)	$r_6 > r_1$	$r_4 > r_1 > r_6$	$r_3 > r_1 > r_4$	$r_5 > r_1 > r_3$	$r_1 > r_5$
$e_5 > e_2$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	pay high prices (e_3 and r_3)	pay high prices (e_3 and r_3)	pay high prices (e_3 and r_3)
$e_3 > e_2 > e_5$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	pay high prices (e_3 and r_3)	pay high prices (e_3 and r_3)	pay high prices (e_3 and r_3)
$e_6 > e_2 > e_3$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)
$e_4 > e_2 > e_6$	accept price cap (e_4 and r_4)	accept price cap (e_4 and r_4)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)
$e_2 > e_4$	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)	buyer embargo (e_2 and r_2)

- *Scenario 5a*: $e_5 > e_2$ and $r_3 > r_1 > r_4$. SPE induces the EU to pay high prices with utilities e_3 and r_3.
- *Scenario 5b*: $e_5 > e_2$ and $r_4 > r_1$. SPE induces Russia to accept EU's price cap with utilities e_4 and r_4.

A.3 Determination of the SPEs in the Game Where the EU Decides First

If the EU decides first, the SPEs are determined by backward induction under all possible utility orders, which are summarised in the table below (Table 4).

The SPE and its outcome for each of the scenarios of the extended game are as follows:

- *Scenario 1a*: $e_3 > e_2$ and $r_1 > r_3$. SPE induces the EU to pay high prices with utilities e_3 and r_3.
- *Scenario 1b*: $e_2 > e_4$ and/or ($r_1 > r_3$ and $e_2 > e_3$). SPE leads to buyer embargo with utilities e_2 and r_2.
- *Scenario 2*: $e_4 > e_2 > e_3$ and $r_3 > r_1 > r_4$. SPE leads to buyer embargo with utilities e_2 and r_2.
- *Scenario 3–4, 5a and 5b*: the SPE and its outcome of each of these scenarios are the same as in the extended game.

A.4 Determination of the Nash equilibria (NE) in the simultaneous game

In order to determine the Nash equilibria (NE) for the simultaneous game, the payoffs e_X and r_X are first determined under different utility orders (Table 5).

Table 5 Equilibrium payoffs of the subgame from RU_2 under different utility orders

e_X, r_X	$r_6 > r_1$	$r_4 > r_1 > r_6$	$r_3 > r_1 > r_4$	$r_5 > r_1 > r_3$	$r_1 > r_5$
$e_5 > e_2$	e_4, r_4	e_4, r_4	e_1, r_1	e_1, r_1	e_1, r_1
$e_3 > e_2 > e_5$	e_4, r_4	e_4, r_4	e_1, r_1	e_1, r_1	e_1, r_1
$e_6 > e_2 > e_3$	e_4, r_4	e_4, r_4	e_1, r_1	e_1, r_1	e_1, r_1
$e_4 > e_2 > e_6$	e_4, r_4	e_4, r_4	e_1, r_1	e_1, r_1	e_1, r_1
$e_2 > e_4$	e_4, r_4	e_4, r_4	e_1, r_1	e_1, r_1	e_1, r_1

Table 6 NE outcome in the simultaneous game under different utility orders

outcome (utilities)	$r_6 > r_1$	$r_4 > r_1 > r_6$	$r_3 > r_1 > r_4$	$r_5 > r_1 > r_3$	$r_1 > r_5$
$e_5 > e_2$	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	pay high prices (e_3 and r_3) bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)
$e_3 > e_2 > e_5$	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	pay high prices (e_3 and r_3) bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)
$e_6 > e_2 > e_3$	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)
$e_4 > e_2 > e_6$	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	accept price cap (e_4 and r_4) bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)
$e_2 > e_4$	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)	bilateral embargo (e_B and r_B)

Subsequently, the NE in the game in normal form are determined under different utility orders, whose outcome are given in the following table (Table 6).

The NE and their outcome for each of the scenarios of the extended game are as follows:

- *Scenario 1–2:* NE leads to bilateral embargo with e_B and r_B.
- *Scenario 3 and 5b:*
  - One NE induces Russia to accept EU's price cap with e_4 and r_4 (payoff dominant).
  - The other NE leads to bilateral embargo with e_B and r_B.
- *Scenario 4 and 5a* (as well as *Scenario 5* in the non-extended game):
  - One NE induces the EU to pay high prices with e_3 and r_3 (payoff dominant).
  - The other NE leads to bilateral embargo with e_B and r_B.

A.5 Modelling of Uncertainty

Extended Game

Consider the extended game and assume that Russia only knows its own preferences but is uncertain about the position of e_2 in the EU's preference, while the EU knows both preferences. If $r_1 > r_3$, Russia imposes a supplier embargo, the game is over. If $r_3 > r_1 > r_4$ (as in *Scenario 2, 4*, *5a* or in a subcase in *Scenario 1*), Russia's decision depends on whether $e_3 > e_2$ or $e_2 > e_3$. Let q denote the probability of $e_3 > e_2$ and $1 - q$ the probability of $e_2 > e_3$. If Russia decides to impose a supplier embargo, the game ends in o_1, if it decides to supply gas in o_3 with probability q and in o_2 with probability $1 - q$. Thus, Russia compares r_1 of a supplier embargo with the expected utility $q\ r_3 + (1 - q)r_2$ of supplying gas. Russia will impose a supplier embargo if $r_1 \geq q\ r_3 + (1 - q)r_2$ and will supply gas if $r_1 < q\ r_3 + (1 - q)r_2$. The equilibrium outcome in the complete information game is o_3 if $e_3 > e_2$ and o_1 if $e_2 > e_3$. That is, under incomplete information, the complete information equilibrium outcome o_3 may deviate to o_1 if Russia decides to impose a supplier embargo, or o_1 may deviate to o_2 if Russia decides to supply gas. Both deviations are worse for Russia compared to the equilibrium outcome in the complete information game ($r_3 > r_1 > r_2$), while the EU benefits from the second deviation ($e_2 > e_1$). At RU$_1$, if $r_4 > r_1$, r_4 (as in *Scenario 3, 5b* or in two subcases in *Scenario 1*), the Russia's decision depends on whether $e_4 > e_2$ or $e_2 > e_4$. Let q' denote the probability of $e_4 > e_2$ and $1 - q'$ the probability of $e_2 > e_4$. If Russia decides to impose a supplier embargo, the game ends in o_1, if it decides to supply gas in o_4 with probability q' and in o_2 with probability $1 - q'$. Thus, Russia compares r_1 of a supplier embargo with the expected utility $q'\ r_4 + (1 - q')r_2$ of supplying gas. Russia will impose a supplier embargo if $r_1 \geq q'\ r_4 + (1 - q')r_2$ and will supply gas if $r_1 < q'\ r_4 + (1 - q)r_2$. The equilibrium outcome in the complete information game is o_4 if $e_4 > e_2$ and o_1 if $e_2 > e_4$. Under incomplete information, the complete information equilibrium outcome o_4 may deviate to o_1 if Russia decides to impose a supplier embargo, or o_1 may deviate to o_2 if Russia decides to supply gas. Both deviations are worse for Russia compared to the equilibrium outcome in the complete information game ($r_4 > r_1 > r_2$), while the EU benefits from the second deviation ($e_2 > e_1$). In the following subgame, Russia does not have to take uncertainty into account in its decision.

EU to Decide First

Consider the game where the EU moves first and assume that the EU only knows its own preferences but is uncertain about the position of r_1 in Russia's preference, while Russia knows both preferences. If $e_2 > e_4$, the EU imposes a buyer embargo, the game is over. Otherwise, the EU's decision depends on whether $r_4 > r_1$ or $r_1 > r_4$. Let p' denote the probability of $r_4 > r_1$ and $1 - p'$ the probability of $r_1 > r_4$. If $e_4 > e_2 > e_3$ and the EU decides to impose a buyer embargo, the game ends in o_2, if it decides to impose a price cap in o_4 with probability p' and in o_1 with probability $1 - p'$, if it decides to pay high prices in o_3 with probability p' and in o_1 with probability $1 - p'$. Since $e_4 > e_3$, the EU will impose a buyer embargo if $e_2 \geq p'e_4 + (1 - p')e_1$ and will impose a price cap if $e_2 < p'e_4 + (1 - p')e_1$. The equilibrium outcome in the complete information game is o_4 if $r_4 > r_1$ and o_2 if $r_1 > r_4$. That is, under incomplete information, the complete information equilibrium outcome o_4 may deviate to o_2 if the EU decides to impose a buyer embargo, or o_2 may deviate to o_1 if the EU decides to impose a price cap. Both deviations are worse for the EU compared to the equilibrium outcome in the complete information game ($e_4 > e_2 > e_1$), while Russia benefits from the second deviation ($r_1 > r_2$). If $e_3 > e_2$ and the EU decides to impose a buyer embargo, the game ends in o_2, if it decides to pay high prices in o_3, and if it imposes a price cap in o_4 with probability p' and in o_1 with probability $1 - p'$. Since $e_3 > e_2$, the EU will pay high prices if $e_3 \geq p'e_4 + (1 - p')e_1$ and will impose a price cap if $e_3 < p'e_4 + (1 - p')e_1$. Note that the EU can influence p' by the level of the price cap, the higher the price cap is, the higher is p', the higher is the probability that Russia will accept it. The equilibrium outcome in the complete information game is o_4 if $r_4 > r_1$ and o_3 if $r_1 > r_4$. Under incomplete information, the complete information equilibrium outcome o_4 may deviate to o_3 if the EU decides to pay high prices, or o_3 may deviate to o_1 if the EU decides to impose a price cap. Both deviations are worse for the EU compared to the equilibrium outcome in the complete information game ($e_4 > e_3 > e_1$), while Russia benefits from the first and if $r_1 > r_3$ also from the second deviation ($r_3 > r_4$). In this game, Russia's initial beliefs about the EU's preferences do not matter, i.e., Russia does not have to take uncertainty into account in its decision.

EU and Russia to Decide Simultaneously at the Beginning of the Game

Assume that if two NE exist, the bidders will coordinate to the risk dominant one. Then the game always ends in bilateral embargo.

Assume that if two NE exist, the bidders will coordinate to the Pareto-dominant one. Consider the game with simultaneous movement at the beginning and assume that the EU only knows its own preferences but is uncertain about the position of r_1 in Russia's preference, while Russia knows both preferences. If $e_2 > e_4$, the EU imposes an embargo, the game ends with a bilateral embargo. Otherwise, the EU's decision depends on its beliefs about Russia's preferences. Let p_1 denote the probability of $r_4 > r_1$, p_2 the probability of $r_3 > r_1 > r_4$, and $1 - p_1 - p_2$ the probability of $r_1 > r_3$. In case $e_4 > e_2 > e_3$, if the EU decides to impose an embargo, the game ends in a buyer embargo with probability p_1 and in a bilateral embargo with probability $1 - p_1$, if the EU decides to impose a price cap in Russia accepting the price cap by Russia with probability p_1 and in a supplier embargo with probability $1 - p_1$, if the EU decides to pay high prices in high prices with probability p_1 and in a supplier embargo with probability $1 - p_1$. Since $e_4 > e_3$, the EU will prefer imposing a price cap than paying high prices. Thus, the EU will impose an embargo if $p_1 e_2 + (1 - p_1)e_B \geq p_1 e_4 + (1 - p_1)e_1$ and will impose a price cap if $p_1 e_2 + (1 - p_1)e_B < p_1 e_4 + (1 - p_1)e_1$. The equilibrium outcome in the complete information game is Russia accepting the price cap if $r_4 > r_1$ and bilateral embargo if $r_1 > r_4$. Under incomplete information, the complete information equilibrium outcome Russia accepting the price cap may deviate to a buyer embargo if the EU decides to impose an embargo, or the bilateral embargo may deviate to a supplier embargo if the EU decides to impose a price cap. Both deviations are worse for the EU compared to the equilibrium outcome in the complete information game ($e_4 > e_2 > e_B > e_1$), while Russia benefits from the second deviation ($r_1 > r_B$). In case $e_3 > e_2$, if the EU decides to impose an embargo, the game ends in a buyer embargo with probability $p_1 + p_2$ and in a bilateral embargo with probability $1 - p_1 - p_2$, if the EU decides to impose a price cap in Russia accepting the price cap with probability p_1 and in a supplier embargo with probability 1- p_1, if the EU decides to pay high prices in high prices with probability p_1+p_2 and in a supplier embargo with probability $1-p_1-p_2$. Thus, the EU compares the expected utilities of $(p_1+p_2)e_2+(1-p_1-p_2)e_B$, $p_1e_4+(1-p_1)e_1$, and $(p_1+p_2)\ e_3+(1-p_1-p_2)\ e_1$ and decides to the policy option with the highest expected utilities. Note that the EU can influence p_1 by the level of the price cap, the higher the price cap is, the higher is p_1, the higher is the probability that Russia will supply gas and accept the price cap. The equilibrium outcome in the complete information game is Russia accepting the price cap if $r_4>r_1$, high prices if $r_3>r_1>r_4$, and bilateral embargo if $r_1>r_3$. Under incomplete information, the complete information equilibrium outcomes Russia accepting the price cap and high prices may deviate to a buyer embargo if the EU decides to impose an embargo, or high prices and the bilateral embargo may deviate to a supplier embargo if the EU decides to impose a price cap, or Russia accepting the price cap may deviate to high prices and the bilateral embargo may deviate to a supplier embargo if the EU decides to pay high prices. All deviations are worse for the EU compared to the equilibrium outcome in the complete information game ($e_4>e_3>e_2>e_B>e_1$), while Russia benefits from some of these deviations ($r_3>r_4$, $r_1>r_B$).

Consider the game with simultaneous movement at the beginning and assume that Russia only knows its own preferences but is uncertain about the position of e_2 in the EU's preference, while the EU knows both preferences. If $r_3>r_1$, Russia imposes an embargo, the game ends with a bilateral embargo. Otherwise, Russia's decision depends on its beliefs about the EU's preferences. Let q_1 denote the probability of $e_3>e_2$, q_2 the probability of $e_4>e_2>e_3$, and $1-q_1-q_2$ the probability of $e_2>e_4$. In case $r_3>r_1>r_4$, if Russia decides to impose an embargo, the game ends in a supplier embargo with probability p_1 and in a bilateral embargo with probability $1-p_1$, if Russia decides to supply gas in high prices with probability p_1 and in a buyer embargo with probability $1-p_1$. Thus, Russia will impose an embargo if $p_1r_1+(1-p_1)r_B \geq p_1r_3+(1-p_1)r_2$ and will impose a price cap if $p_1r_1+(1-p_1)r_B<p_1r_3+(1-p_1)r_2$. The equilibrium outcome in the complete information game is high prices if $e_3>e_2$ and bilateral embargo if $e_2>e_3$. Under incomplete information, the complete information equilibrium outcome high prices may deviate to a supplier embargo if Russia decides to impose a supplier embargo, or the bilateral embargo may deviate to the buyer embargo if Russia decides to supply gas. Both deviations are worse for Russia compared to the equilibrium outcome in the complete information game ($r_3>r_1>r_B>r_2$), while the EU benefits from the second deviation ($e_2>e_B$). In case $r_4>r_1$, if Russia decides to impose an embargo, the game ends in a supplier embargo with probability p_1+p_2 and in a bilateral embargo with probability $1-p_1-p_2$, if Russia decides to supply gas in Russia accepting the price cap with probability p_1+p_2 and in a buyer embargo with probability $1\ p_1-p_2$. Thus, Russia will impose an embargo if $(p_1+p_2)r_1+(1-p_1-p_2)r_B \geq (p_1+p_2)r_4+(1-p_1-p_2)\ r_2$ and will supply gas if $(p_1+p_2)r_1+(1-p_1-p_2)r_B<(p_1+p_2)r_4+(1-p_1-p_2)r_2$. The equilibrium outcome in the complete information game is Russia accepting the price cap if $e_4>e_2$ and bilateral embargo if $e_2>e_4$. Under incomplete information, the complete information equilibrium outcome Russia accepting the price cap may deviate to a supplier embargo if Russia decides to impose a supplier embargo, or the bilateral embargo may deviate to the buyer embargo if Russia decides to supply gas. Both deviations are worse for Russia compared to the equilibrium outcome in the complete information game ($r_4>r_1>r_B>r_2$), while the EU benefits from the second deviation ($e_2>e_B$).

Author Contribution Karl-Martin Ehrhart: Conceptualization, Formal analysis, Writing. Ingmar Schlecht: Conceptualization, Writing. Jan Schmitz: Conceptualization, Writing. Runxi Wang: Conceptualization, Formal analysis, Writing.

Funding Open Access funding enabled and organized by Projekt DEAL. Ingmar Schlecht's work on this paper was sponsored by the Swiss Federal Office of Energy's "SWEET" programme as part of the PATH-FNDR project under Grant Number SI/502259. This funding source was not involved in the conduct of the research or preparation of the article.

Data Availability N/A.

Declarations

The authors acknowledge feedback from Lion Hirth on an earlier draft of the paper.
The ideas and views expressed in this paper are those of its authors. The findings, interpretations, and conclusions expressed here cannot be taken to reflect the views of the European Commission.

Ethical Approval N/A

Informed Consent N/A

Conflict of Interest The authors declare no conflict of interest.

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References

Bachmann R, Baqaee D, Bayer C, Kuhn M, Löschel A, Moll B, Peichl A, Pittel K, Schularick M (2022) What if? The Economic Effects for Germany of a Stop of Energy Imports from Russia, ECONtribute Policy Brief, No. 028

Baliga S, Sjöström T (2023) Optimal compellence (No. 2023–02). Working Paper. Available at: https://www.econstor.eu/bitstream/10419/283995/1/2023-02.pdf. Accessed 4 Oct 2024

Bolt W, Houba H (2005) Credible threats in negotiations: A game-theoretic approach, vol 32. Springer Science & Business Media

Brams SJ (1975) Game theory and politics. The Free Press

Brams SJ (2000) Game theory: Pitfalls and opportunities in applying it to international relations. Int Stud Perspect 1(3):221–232

Bundestag D (2022) Beschleunigung des Einsatzes von Flüssiggas beschlossen. Press release. Available at: https://www.bundestag.de/dokumente/textarchiv/2022/kw20-de-lng-beschleunigungsgesetz-894668. Accessed 4 Oct 2024

Carlsson H, van DAMME EE, (1989) Global payoff uncertainty and risk dominance. Econometrica 61(5):989–1018

Chaney E, Gollier C, Philippon T, Portes R (2022) Economics and politics of measures to stop financing Russian aggression against Ukraine. VoxEU. Available at: https://cepr.org/voxeu/columns/economics-and-politics-measures-stop-financing-russian-aggression-against-ukraine. Accessed 4 Oct 2024

CNN (2022) Mystery leaks hit Russian undersea gas pipelines to Europe. Available at: https://edition.cnn.com/2022/09/27/energy/nord-stream-pipeline-leaks/index.html. Accessed 4 Oct 2024

Dorussen H, Mo J (2001) Ending economic sanctions audience costs and rent- seeking as commitment strategies. J Conflict Resolut 45(4):395–426

Eaton J, Engers M (1992) Sanctions. J Polit Econ 100(5):899–928

Eaton J, Engers M (1999) Sanctions: Some simple analytics. Am Econ Rev 89(2):409–414

Ehrhart K-M, Schlecht I, Schmitz J, Wang R (2023) Comparison of price caps and tariffs to counter a foreign monopoly. Econ Lett 227:111128

European Commission (2022a) REPowerEU: A plan to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131. Accessed 4 Oct 2024

European Commission (2022b) Quarterly report on European gas markets. Market Observatory for Energy, DG Energy. Volume 15, issue 2, covering second quarter of 2022. Available at: https://commission.europa.eu/system/files/2022-10/quarterly_report_on_european_gas_markets_q2_2022_final_0.pdf. Accessed 4 Oct 2024

European Commission (2023) An EU approach to enhance economic security. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_23_3358. Accessed 4 Oct 2024

European Commission (2024) Readout of the meeting between Commissioner Kadri Simson and Ukraine's Minister of Energy German Galushchenko. 6 May 2024, Kyiv. Available at: https://ec.europa.eu/commission/presscorner/detail/en/STATEMENT_24_2467. Accessed 4 Oct 2024

European Council (2022) Conclusions of the European Council meeting 23 and 24 June 2022. Available at: https://www.consilium.europa.eu/media/57442/2022-06-2324-euco-conclusions-en.pdf. Accessed 4 Oct 2024

European Council (2023a) EU sanctions against Russia explained. Available at: https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/. Accessed 4 Oct 2024

European Council (2023b) Gas demand reduction in the EU. Available at: https://www.consilium.europa.eu/en/infographics/gas-demand-reduction-in-the-eu/. Accessed 4 Oct 2024

Fearon JD (1994) Domestic political audiences and the escalation of international disputes. Am Political Sci Rev 88(3):577–592

Financial Times (2022a) Russia indefinitely suspends Nord Stream gas pipeline to Europe. Available at: https://www.ft.com/content/5867c175-df16-4c8b-9b7a-a868a19d0138. Accessed 4 Oct 2024

Financial Times (2022b) Russia switches off Europe's main gas pipeline until sanctions are lifted. Available at: https://www.ft.com/content/2624cc0f-57b9-4142-8bc1-4141833a73dd. Accessed 4 Oct 2024

Fudenberg D, Tirole J (1991) Game theory. MIT press

Gros D (2022) Optimal tariff versus optimal sanction: The case of European gas imports from Russia. European University Institute. Policy Brief. Issue 2022/19, March 2022. Available at: https://doi.org/10.2870/966335

Harsanyi JC (1965) Game theory and the analysis of international conflicts. Aust J Polit Hist 11(3):292–304

Harsanyi JC, Selten R (1988) A general theory of equilibrium selection in games, vol 1. MIT Press Books

Hausmann R, Łoskot-Strachota A, Ockenfels A, Schetter U, Tagliapietra S, Wolff G, ^#^#^# G (2022) How to weaken Russian oil and gas strength. Sci Lett 376:6592

Hausmann R, Schetter U, Yildirim MA (2024) On the design of effective sanctions: The case of bans on exports to Russia. Economic Policy 39(117):109–153

Intercontinental Exchange (2023) Dutch TTF Natural Gas Futures. Available at: https://www.theice.com/products/27996665/Dutch-TTF-Gas-Futures/data. Accessed 4 Oct 2024

Javadian A (2021) A credible threat against oil sanctions for Iran. Int J Nonlinear Anal Appl 12(1):175–178

Kaempfer WH, Lowenberg AD, Mertens W (2004) International economic sanctions against a dictator. Econ Polit 16(1):29–51

Krustev VL (2010) Strategic demands, credible threats, and economic coercion outcomes. Int Stud Quart 54(1):147–174

Luce RD, Raiffa H (1989) Games and decisions: Introduction and critical survey. Courier Corporation

McCarty N, Meirowitz A (2007) Political game theory: an introduction. Cambridge University Press

McWilliams B, Zachmann G (2022) European Union demand reduction needs to cope with Russian gas cuts. Bruegel Blog. Available at: https://www.bruegel.org/2022/07/european-union-demand-reduction-needs-to-cope-with-russian-gas-cuts/. Accessed 4 Oct 2024

Morgan TC, Bapat NA (2003) Imposing sanctions: States, firms, and economic coercion. Int Stud Rev 5(4):65–79

Morgenstern O, von Neumann J (1944) Theory of Games and Economic Behavior. Princeton University Press

Nash J Jr (1951) Non-cooperative games. Ann Math 54(2):286–295

Ordeshook PC (1986) Game Theory and Political Theory. Cambridge Books

Osborne MJ, Rubinstein A (1994) A course in game theory. MIT press

Pahre R, Papayoanou PA (1997) Using game theory to link domestic and international politics. J Conflict Resolut 41(1):4–11

Peski M (2010) Generalized risk-dominance and asymmetric dynamics. J Econ Theory 145(1):216–248

Reuters (2022a) EU countries agree gas price cap to contain energy crisis. Available at: https://www.reuters.com/business/energy/eu-countries-make-final-push-gas-price-cap-deal-this-year-2022-12-19/. Accessed 4 Oct 2024

Reuters (2022b) Russia warns the West: energy price cap will be your undoing. Available at: https://www.reuters.com/business/energy/russias-top-lawmaker-wests-energy-price-cap-will-fail-price-will-rise-2022-09-09/. Accessed 4 Oct 2024

Sabadus A (2024) ICIS explains: What will happen after Ukraine's gas transit contract expires? Available at: https://www.icis.com/explore/resources/news/2024/03/18/10981563/icis-explains-what-will-happen-after-ukraine-s-gas-transit-contract-expires/. Accessed 4 Oct 2024

Schneider G, Finke D, Bailer S (2010) Bargaining power in the European Union: An evaluation of competing game-theoretic models. Political Stud 58(1):85–103

Selten R (1965) Spieltheoretische Behandlung eines Oligopolmodells mit Nachfrageträgheit. Zeitschrift Für Die Gesamte Staatswissenschaft 121(301–324):667–689

Snyder GH, Diesing P (2015) Conflict among nations: Bargaining, decision making, and system structure in international crises. Princeton University Press

Straub PG (1995) Risk dominance and coordination failures in static games. Q Rev Econ Finance 35(4):339–363

Sturm J (2022) A theory of economic sanctions as terms of trade manipulation. Working paper

Sturm J, Menzel K, Schmitz J (2022) The simple economics of optimal sanctions the case of Russia oil. Working paper

USTR (2023) Office of the United States trade representative: China section 301-tariff actions and exclusion process. Available at: https://ustr.gov/issue-areas/enforcement/section-301-investigations/tariff-actions. Accessed 4 Oct 2024

Walentek D, Broere J, Cinelli M, Dekker MM, Haslbeck JMB (2021) Success of economic sanctions threats: coercion, information and commitment. Empir Theor Res Int Relat 47(3):417–448. https://doi.org/10.1080/03050629.2021.1860034

Ward H (1996) Game theory and the politics of global warming: The state of play and beyond. Political Stud 44(5):850–871

Weder di Mauro B, Martin P (2022) Winter is coming: Energy policy towards Russia. Centre for Economic Policy Research. Retrieved June 6, 2024. Available at: https://cepr.org/voxeu/columns/winter-coming-energy-policy-towards-russia

Young HP (1993) The evolution of conventions. Econometrica: J Econ Soc 61(1):57–84

Zachmann G, McWilliams B, Keliauskaitė U, Sgaravatti G (2024) Dataset: European natural gas imports. Bruegel. Available at: https://www.bruegel.org/dataset/european-natural-gas-imports. Accessed 4 Oct 2024

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