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RESEARCH PAPER

Strategic Analysis of Russia -European Union Gas Relations: An Evolutionary Game Theory Approach

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Abstract

The Russia–European Union relationship affects their energy ties, specifically in the natural gas trade. The changes in their gas relations, from the energy dialogue in October 2000 to recent gas interruptions and the REPowerEU plan in 2022, show a shift from neoliberal toward realist–geopolitical relations. Employing evolutionary game theory, this study has analyzed the evolution of gas trade strategies within the framework of the political relations of these two players. The study examines strategic equilibrium in energy relationships to determine whether realism will persist or shift toward liberal energy equilibrium. During the assessment of Russia–EU energy, three strategies were identified. Their first strategy is based on liberal cooperation (EU and CO), the second shows economic cooperation but with an element of security competition (RC and ER), and the last involves mutual avoidance (CH and ES). We define a 3×3 game with symmetrical payoffs in two liquefied natural gas market scenarios: current status and the possibility of further expansion. Initial game results show a mixed equilibrium, which is unstable and can change in the long run. The second game's outcome (second scenario) shows a pure equilibrium in mutual cooperation that is also unstable and short-term. Based on the outcomes of these two games, Russia and the European Union cannot always rely on mutual cooperation in gas trade, so government agencies, security issues, and realistic approaches will continue to play a role in their gas policy decisions, with varying degrees of impact.

Keywords: EU–Russia relations, evolutionary game theory, evolutionarily stable strategies, gas trading, international relations.
JEL Classification: C73, F53, F59, Q49.

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Introduction

The Soviet oil and gas exports to Europe gained an important strategic role in this market by the start of the oil crisis in the 1970s. Since most of the Soviet oil and gas extraction facilities and reserves were located in Russia, it inherited the role of the main supplier of European gas after the collapse of the Soviet Union and continued to export oil and gas to Europe and European Union (EU) member states (Siddi, 2017). However, the geology of these two regions and the distribution of fossil energy between Russia and the EU has been in such a way that geopolitical turmoil has always affected the parties, energy prices, and energy relations. Therefore, oil and gas trade has inevitably been a key feature of EU–Russia political-economic relations.

Political-economic relations between them from the late 1990s to the mid-2000s were associated with collaboration, and their energy and gas transactions at this time can be explained in the form of a liberal approach. During this period, the East's doors opened to the EU, and Russia and the Union had a relatively close agreement on their mutual economic relations and European energy order (Wigell and Vihma, 2016; Siddi, 2017). However, there was an asymmetrical international relationship between Russia and the EU. The latter held dominance, set priorities, and encouraged countries to adopt a Euro-centric capitalist economy (Figus, 2020). During this time, energy exports helped alleviate the Russian economic crisis. High energy prices and the utilization of the economic capacity of Western countries also contributed to improving Russia's economy. Russia experienced a significant economic rebound, stabilized its domestic policy, and increased its international position, becoming a solid and independent voice in international issues (Rumer, 2016). It could be argued that Russian-European relations during this time were explicable within the scope of the neoliberal paradigm, as defined by Keohane and Nye (1977).

With the increase in power, the rise of Putin, the president of Russia, and the revival and strengthening of Russia's international position, Moscow's behavior in the EU gas market underwent a gradual transformation. Throughout this process, Moscow's actions were guided by a combination of political objectives and business considerations. Finally, the 2004 Orange Revolution in Ukraine changed this liberal collaboration scenario (Trenin et al., 2013; Yafimava, 2015). Ukraine's foreign policy stance, which supported the North Atlantic Treaty Organization (NATO) and the EU, was seen as a threat to Russia's strategic interests, such as strengthening its position against the West and EU and NATO efforts to integrate and expand near the Russian borders,

Western security order, and Russia's ontology. As a result, the geopolitical landscape in this region underwent a significant and strenuous change (Figus, 2020; Yafimava, 2015; Casier, 2018). Therefore, to change these conditions to expand its sphere of influence, Russia pursued a realistic approach considering its geoeconomic and geopolitical goals in the energy sector (Siddi, 2017; Wigell and Vihma, 2016), and the dismissal of Yanukovych and the change of the Ukrainian government in 2013 strengthened the adoption of negative compulsory power strategies by Russia (Casier, 2018).

The EU's interaction with Russia was mainly guided by a liberal approach. However, the gas disputes between Russia and Ukraine in 2006 and 2009 served as a warning that Russia's impact on the EU is not limited to military security but also extends to energy security. Consequently, the strategy and definition of energy security for Europe also underwent reforms that were closely related to the changes in political and economic issues in the region (Mankoff, 2009; Umbach, 2010). The EU shifted from a liberal to a realistic and geopolitical approach to foreign policy on energy. Russia and the EU seemed to avoid each other in energy interdependence, and the Crimean crisis in March 2014 accelerated it. This tendency of mutual avoidance means a high level of political distrust, which has had a long-term impact on the gas market.

The EU's change in its approach toward Russia and the resulting challenges, such as Gazprom's difficulty in accessing the European market and the sanctions imposed by the EU and the West against Moscow, forced Russia to seek new export partners and alternative gas markets (Massalin, 2021). Although the EU was a crucial economic partner for Russia, the latter chose to strengthen its ties with China and other emerging powers. Russia's energy relations with China highlighted the significance of the energy threat to Europe if it did not comply with Russia's geopolitical strategies. Amid growing tensions with Western Europe and the West over the Crimean crisis, Russia had to demonstrate that it had other centers of geopolitical power to rely on. Russia also made it clear that if the EU does not want its energy, it can sell it to China (Figus, 2020).

With all these ups and downs, according to BP (2022), Russia was the largest gas exporter to the EU, and the EU was the most profitable market for Russia until 2021. The 2022 Russia-Ukraine war has changed the global energy landscape, particularly the gas market, and has intensified discussions about geopolitical realism in Russia's energy relations with the EU and has led to evolving complex political programs for the EU. Energy supply stability has always been a major concern for the EU (Carfora et al., 2022), but the crisis has

heightened the unity among EU members against Russia's policies, making energy security a top priority. The EU is trying to reduce its dependence on Russian natural gas imports as a major geopolitical risk factor and has turned to US and Qatari LNG and alternative clean energies.

So, from 2006 onwards, the relations between the two regions have shifted towards realism patterns (mostly neorealism and geopolitical realism approaches). During this period, the developments in the relations between these two regions have been dominated by geopolitical and security competition in the field of energy that was surpassing economic cooperation. Both actors have constantly redefined their strategies by considering their regional position, relations with America, and the emerging power of China. In this context, Romanova (2023) examines EU-Russia energy cooperation, highlighting the roles of neoliberalism and geopolitics-realism in their energy relations, specifically focusing on the EU's security-geopolitical efforts regarding energy and the direct effect of Russia's actions on them. Additionally, Siddi (2017) analyzes the historical evolution of these two actors' actions and strategic gas relations, emphasizing the transition from liberal approaches to geopolitical realism in energy.

Most traditional theories and energy market models are designed for mature markets based on consistent historical data and the equilibrium principle. However, this is certainly not the case in most markets where history is still being made, and the rules of the game are not yet clearly stated (or understood). Also, the classical theory fails to represent the essence of human nature – the capacity for learning through experience (Pinto and Szczupak, 2003). Relations between Russia and the EU about the natural gas sector are still under a dynamic evolutionary process, and historical events are occurring.

The evolutionary game consists of several simultaneous strategic interactions, each of which is expressed as a game with a normal form or extended form, similar to classic games. However, evolutionary games do not rely on the static equilibrium analysis and strict rationality assumptions of classical games, and this focuses on the dynamics of strategy change, allowing for the modeling of learning and selection processes (Hodgson and Huang, 2012). Therefore, this research analyzes the strategic EU-Russia gas relations in the framework of international relations using evolutionary game theory and explores the equilibrium and evolutionarily stable strategies (ESS) despite the mutation and turn of the gas strategies of Russia and the EU toward a geopolitical realism approach. Specifically, it aims to answer the question, "Will the current realistic

approach remain in the energy relations of these two players, or will it move again toward a liberal energy equilibrium?"

Research on energy relations affected by political relations between the EU and Russia using game theory has often been in the form of theoretical analysis or based on classic games. For example, Richman and Ayyılmaz (2019) investigated the feasibility of replacing Russian gas with US LNG in the EU market. Also, they analyzed Russia's capacity to politicize the European energy market with the help of classical game theory. They found that even the existence of a large and dynamic international energy market and US sanctions against Russia cannot completely prevent Russia's political exploitation of energy. Also, Popescu and Hurduzeu (2015) theoretically analyzed the existing energy dependence between Russia and the EU in different scenarios. They used the classical prisoner's dilemma. The research findings highlight the urgency of reducing the EU's reliance on Russian gas and exploring alternatives. Morbée and Proost (2008) researched the EU's vulnerability to Russian gas market power, similar to what happened in 2006 in the markets of Belarus, Ukraine, Moldova, and Georgia. They used a Cournot game to analyze the situation and found that the market power of Russian gas is limited. The study also revealed that if the mistrust toward Russia increases, other sellers' shares will surpass Russia's expected profit.

No studies have been found so far regarding the use of the evolutionary game approach in examining the gas relations between the EU and Russia. Therefore, in the following, we first investigate the theoretical framework related to liberal and realistic approaches in the energy context. Then, the gas strategies adopted by Russia and the EU and their game, corresponding to their political developments, are identified and introduced. In the fourth section, we will conduct the game, analyze the results, and present its conclusion in the final section.

Literature Review

Both liberal and realist approaches play a role in shaping energy relations, particularly gas relations between Russia and the EU. Russia's foreign policy is often linked with realism, while the EU's foreign policy is associated with liberalism. However, in reality, neither approach is applied purely.

The realism approach to foreign policy aims to strengthen power and extend influence over others. Governments view political power as a means to achieve specific international policy goals (Simionov, 2017), and they operate

with the logic of the zero-sum game in the power balance. Early realism in international relations was known as a contrast with utopianism and deep pessimism with utopian plans for perpetual peace (Carr, 1939). However, contemporary realism is often identified with neorealism and neoclassical realism, both of which were attempts to incorporate international economic relations into the theories of realism and the scholarly narrative of early realism. Waltz, Krasner, and Gilpin are among the most important neorealist theorists, who emphasize the structural conditions of the international system and prioritize the preservation and protection of the existence and security of the state (Moshirzadeh, 2005).

According to Waltz (1979), despite international anarchy, governments are compelled to rely on their power to ensure security (self-help component). He emphasizes changing the distribution of power to achieve a balance of power. Also, in his perspective, governments may gain from economic collaboration, but the economic benefit will be affected by political interests. Additionally, the level of cooperation is determined by relative gains from cooperation. Therefore, even if economic interdependence increases, it does not necessarily imply an increase in the government's cooperation (Waltz, 1979).

Gilpin (1975) and Krasner (1976) consider the international economic system dependent on the political order resulting from the hegemon's power. Accordingly, governments seek to increase their power and security. Since economic changes can change the balance of power between them, great powers try to determine the rules governing economic relations to maximize their power. As a result, economic policies are guided by political interests. In this case, economic relations are not necessarily a zero-sum game, but political relations will follow a zero-sum game. Generally, neorealism acknowledges that cooperation is not impossible. However, it argues that cooperation and interdependence are due to the presence of a dominant power capable of imposing it on others (Moshirzadeh, 2005).

The concept of realism in energy relations is rooted in the neorealist theories. In this case, according to the emphasis of this approach on policies related to power, energy is a strategic commodity rather than an ordinary commodity, and it is interpreted as a foreign and military policy issue that emphasizes geostrategic foundations (Kilinç-Pala, 2021). In this approach, producers manage their exploration, production, and transportation of energy resources either independently or through political agreements. Meanwhile, they position themselves as guarantors of energy security. Consequently, international

energy deals are often made with significant involvement from government institutions (Romanova, 2021).

On the other hand, realism and geopolitics have a close relationship. The emphasis on national power in security, which is defined in the realism approach, gives importance to geopolitics in determining energy security. Geopolitics is one of the foundational elements of national power and security and is therefore studied in the context of realism (Kilinç-Pala, 2021). Geopolitical theories examine how governments' actions are influenced by geographical factors such as boundaries and access to natural resources. The combination of geopolitics and realism means that the great powers seek to dominate their neighborhoods and the region. A competing power's encroachment into its neighborhood is seen as a direct threat to the national interests of the regional powers. Dominant governments in the region seek to maximize their power and security by expanding their influence and deterring competing hegemonic governments from their region (Mearsheimer, 2003).

According to the perspective of geopolitical realism, energy is a strategic tool in the competition between great powers, so the EU-Russia energy relationship is considered a security issue. As a result, Russia tries to use its natural resources as a lever to achieve political goals and a tool to confront NATO and the EU. The EU's reliance on Russian gas is a weakness and increases the EU's vulnerability to Russian geopolitics. So, a realist approach is required to manage energy relations between the EU and Russia given the Union's dependence on Russian gas (Siddi, 2017).

The theory of contemporary liberalism is more heterogeneous than realism and consists of separate and sometimes related hypotheses. Liberalism believes that the existing international system can be transformed into an orderly international system with the help of international institutions. The main goal of liberalism is to establish a world order based on liberal principles, such as democracy, human rights, the importance of international institutions, international trade, and the creation of a peaceful region (McCallion, 2023). Some liberal schools of thought argue that economic interdependence and international institutions are independent forces for peace and order (Gartzke and Boehmer, 2001). According to the economic interdependence approach, deepening economic relations between countries leads to the development and consolidation of bilateral political relations and greatly reduces the possibility of tension and conflict (Simionov, 2017). As a result, governments can agree on a set of common norms and cooperate internationally.

Liberalism in energy policies is explained based on the free market approach of neoliberals. Keohane and Nye (1977) are the most important neoliberal theorists who propose interdependence in an anarchic space. Their complex interdependence theory emphasizes the importance of economic interdependence in shaping the behavior of governments. The existence of complex interdependence increases the likelihood that governments will cooperate on a wide range of issues despite their differing interests. This view refers to the neoclassical view of markets. In this situation, energy is just a commodity like other commodities, and the market is the most suitable way to manage it and promote win-win outcomes in global energy (Romanova, 2016). In this view, governments have the role of providing property rights and guaranteeing the market situation.

In this situation, with the existence of mutual relations in the global economy, the energy security of an actor depends on the security of all other actors, and the possibility of conflict between powers is less with the establishment of this type of economic order. In the context of gas relations, mutual dependence, mutual profit, and shared loss for all parties from the natural gas trade are emphasized (Chadwick and Long, 2023), and both gas-producing and gas-consuming countries have mutual and compatible interests. Interdependence creates a strong incentive for both sides to cooperate, and Russia and the EU are keen to maintain a stable gas supply and mutual trust. From the liberals' viewpoint, such a process leads to moderation between governments. But, from the realists' viewpoint, in this interdependence situation, an imbalance will eventually arise favoring one side, which will first lead to the damage of the more dependent side (the belief that the EU is vulnerable due to high dependence on Russian gas), and then the fragility of the system will become global (Kilinç-Pala, 2021).

Methods and Materials

In an evolutionary game, the concept of human rationality is replaced by that of evolutionary stability in seeking the solution of a game. In classical games, the Nash equilibrium is a pivotal concept where players lack the motivation to violate it, and they choose the best response to each other. The ESS is a similar concept in evolutionary games. ESS is a static notion that attempts to capture dynamic stability. Understanding the ESS is essential for predicting the long-term outcomes of evolutionary processes. It is defined as a strategy that can persist in a population and outperform new and competing strategies. The existence of ESS

in the game guarantees that an evolutionary game converges to a final stable state over time (Schecter and Gintis, 2016). In the stable state, the existence of a single strategy type will result in a pure ESS. On the other hand, if there are multiple strategy types, the outcome will be referred to as an Evolutionarily Stable Mixed Strategy (Webb, 2007).

In evolutionary games, there are two types of games: symmetric and asymmetric. In a symmetric game, two players have identical strategy sets and the same payoff matrix, resulting in interchangeable positions within the normal-form game (Schecter and Gintis, 2016). Therefore, it is the strategies themselves, not the players' individual characteristics, that define the game's symmetry. As both players have the same payoff matrix (explained in subsequent sections), this research focuses on a symmetric game.

In the following section, we will explain three strategies discovered for players, their corresponding payoffs, and the solution of this game.

Russia-EU's Relations: Determining Strategy and Payoffs

Transformation of Russian-EU Gas Relations

Regarding the introduced approaches and how they appear in the relations between these two regions, the developments and evolution of the energy relations between Russia and the EU can be followed in three periods, the late 90s to 2006, 2006 to 2014, and 2014 until now.

-The Late 90s to 2006:

In 2000, Russia and the EU initiated an energy dialogue aimed at securing the European energy supply and developing the potential of the Russian economy (Seliverstov, 2009). In this period, the flow of Russian gas to the EU was carried out without major disruptions, and they collaborated to facilitate investment in the European energy sector, ensure the security of the EU's energy supply, and gain access to European markets for Russia. Along with the cooperation with the EU, Russia was trying to increase its strategic position in the former Soviet countries. Russia bought utilities, pipelines, refineries, and infrastructure through Gazprom and other major energy companies, thus expanding its monopolies (Larsson, 2006).

Also, during the studied period, EU energy policies were increasingly shaped by free and competitive market forces and by the approach of separating energy issues from political and strategic forces (Umbach, 2010). During this period, Russia adopted a Europe-oriented approach, and the EU adopted an

approach to liberalize and make the gas market more competitive. Table (1) provides a comprehensive overview of the performance of these two players during this specific timeframe. Based on these observed events, both players applied their strategies in this period using the neoliberal approach in their gas interactions.

Table 1. The Overview of Russian-European Energy Relations, the Late 90s and 2006

Player	Actions
Russia	• Enhancement of collaboration with the EU in facilitating investment processes in the energy sector and security of the Union's energy supply (Belyi, 2003) • Initiation of Energy Dialogue in October 2000 for greater participation and cooperation between the EU and Russia in the energy sector • Establishment of the EU-Russia Energy Technology Centre in Moscow in 2002 to promote cooperation in advanced energy technologies (Oettinger and Shmatko, 2010) • Strengthening strategic position in former Soviet countries and enhancing the Gazprom monopolies (Larsson, 2006)
E-U	• Establishing a market-oriented approach, defining energy security as physical access and providing energy supply for economic development (Kalicki and Goldwyn, 2005; Umbach, 2010) • Adopting the first[1] and second[2] energy packages and promoting competition and extensive liberalization in the gas market (See European Parliament, 2023, Articles 114 and 194) • The competitiveness of the market, the low unity of the members of the union, and the absence of a single actor about the energy policies of the member countries in front of a large and dominant firm like Gazprom (Brunekreeft and Guliyev, 2009)

Source: Research finding.

- 2006 – 2014:

Following the Orange Revolution in Ukraine, political and economic conflicts started between Russia and the EU. Controlling the supply of gas and energy resources as the pulse of the Western economy for Russia was like a balance weight against the EU and NATO (Larsson, 2006; Bershidsky, 2014). In a situation where there is not much diversity on the supply side, a large exporter

[1]. It consisted of a first liberalization of the electricity and gas national markets (1998 and 2000).
[2]. With adopting this in 2003, Industrial and domestic consumers were free to choose their own gas and electricity suppliers from a wider range of competitors.

can use its control over supply as leverage to advance its political goals and national economic agenda.

The gas disputes between Russia and Ukraine questioned Russia's credibility as a major gas supplier, highlighted the issue of energy security, and led Europe to think about diversifying its gas sources (Mankoff, 2009). During this period, the parties attempted to buy and sell gas amid security competition, each striving to impose their security interests on the other. Table (2) provides a summary of the policies and performance of the parties.

Table 2. The Overview of Russian-European Energy Relations, 2006 – 2014

Player	Actions
Russia	• Passing a law in 2006 that granted exclusive rights for exporting natural gas to Gazprom[1] (Kramer, 2006) • Transition to a period of domestic uncertainty and rebalancing foreign policies, changing view toward exiting the Euro-orientation situation (Trenin et al., 2013) • Trying to become the exclusive source of European gas, and leveraging gas to achieve foreign policy goals (Brunekreeft and Guliyev, 2009)-controlling gas resources and preventing the entry of alternative Energy resources such as preventing the implementation of the Nobacu project in 2013 (reflexive control) • Connecting its neighbors to its own energy network, and using energy weapons against the unpleasant policies of neighbors in various ways, including gas supply interruptions (total or partial), threatening to cut off gas supply, policy pricing (Carrot and Stick policy), use of energy debt or hostile takeover of companies or infrastructure (Larsson, 2006; Christie, 2009). • Russia's refusal to pass the Energy Charter Treaty (ECT) due to provisions that open third-party access to Russian gas pipelines (Grigoriev and Belova, 2009) • Gas disputes with Ukraine in 2006[2], 2009[3], and the Crimean crisis in 2014 • Trying to exempt Gazprom from the restrictions of the third energy package and lobbying with countries like Germany (Siddi, 2015) • Allowing other Russian producers besides Gazprom to export LNG and the development of LNG-related facilities by the Russian government in 2013 (Mitrova, 2013)
E-U	• Understanding that Europe is influenced by Russia in terms of energy security (Mankoff, 2009), questioning Russia's gas credibility and creating a tendency to mutual avoidance in the EU • Expanding the definition of EU energy security to include additional

[1]. This implied political control over natural gas exports that was not previously enshrined in law.
[2]. Cutting off gas supplies to Ukraine prior to the country's parliamentary.
[3]. Ukrainian gas cut off before the 2010 Ukraine presidential election.

dimensions such as politics, government, efficiency, and sustainable energy (Kirchner and Berk, 2010; Jansen, 2009; Bahgat, 2006) • Europe's effort to ratify the Energy Charter Treaty by Russia • Taking measures to limit the dominance of Gazprom monopoly, such as the adopting of the third energy package[1] and restrictions on Gazprom's power (EC, 2023; 2020) • Investing in alternative pipeline projects and striving to upgrade the Ukrainian gas transmission network (Sherr, 2015) - assisting in rebuilding and developing the Shah Deniz gas field

Source: Research finding.

- From 2014 onwards:

With the Ukraine crisis, the path ahead for the EU and Russia to further cooperation became darker. The EU's efforts to enhance the diversity of its energy mix and reduce its dependence on gas imports made Russia's ability to exploit the pipeline and Gazprom as leverage in foreign policy more difficult. This issue was evident in both the EU's energy strategy until 2035 (EC, 2020) and the Russian energy security doctrine (Russian Federation, 2019). According to these documents, it was expected to decrease the share of the EU in Russian oil and gas exports and increase the variety of Russian export markets to Asia.

However, despite the various challenges and conflicting actions between these two regions, Russia's presence and influence in the gas market of the EU had been steadily growing until the current war between Russia and Ukraine. Russia's share of EU gas demand increased from 26% in 2010 to over 40% on average during 2018-2021 (IEA, 2023, See Russia's War on Ukraine). The crisis that arose from the suspension of Russian gas supplies to Europe in the Russia-Ukraine war (2022) demonstrated that, except when compelled by circumstances, no initiative was taken to realize the goal of ending the EU's dependence on Russian gas. However, crises inevitably create an opportunity to change policies.

According to the REPowerEU plan, the EU should phase out all fossil energy imports from Russia as soon as possible by 2027, apply energy-saving measures, and diversify its energy imports (European Parliament, 2023). Reducing the demand for fossil fuels by consuming nations can have detrimental effects on exporters by influencing conflict situations, and it is not a new tactic (Kuzemko et al., 2022).

Table (3) provides a summary of their energy interactions since 2014.

[1]. Under the third energy package, the responsibilities of the energy supply operator and the energy transmission and transit operator must be separate from each other.

Table 3. The Overview of Russian-European Energy Relations from 2014 onwards

Player	Actions
Russia	• Priority to negative compulsory power strategies • Russia's turn toward the Asian and Chinese gas market (Massalin, 2021) and the signing of an agreement between Russia and China on gas trade in May 2014 with the help of the Sila-Siberia pipeline. • War with Ukraine and gas cut from the Nord Stream and Yamal pipelines to the EU • Expansion of LNG projects such as Sakhalin-2 and the proposed Murmansk project
E-U	• The addition of the components of disruption in energy supply, the vulnerability of critical energy systems, and risks related to the energy system in the definition of energy from 2013 onwards (Kucharski and Unesaki Procedia, 2015; Jewell et al., 2013) • Adopting the fourth and fifth energy packages • The imposition of sanctions packages against Russia, including the arms embargo, the restriction of Russian banks' access to European financial markets, and the restriction of technological investments in the Russian energy sector in response to the 2014 Crimean crisis (Donaldson et al., 2014). • Designing and operationalizing the Southern Gas Corridor in 2015[1] - Proposing the Morocco-Nigeria pipeline in 2016 - Carrying out the Greece-Bulgaria Interconnector project • Approval of the RepowerEU plan - approval of heavier sanctions a in response to the current war between Russia and Ukraine - the unity of most members against Russia in applying policies related to energy security • Suspension of Nord Stream 2 certification by Germany due to the current war between Russia and Ukraine • Reduction of about 75% of Union gas imports from Russia at the end of 2022 compared to June 2021 (Zachmann et al., 2023) and the expansion of LNG relations with the United States, Qatar, and Algeria and the increase of LNG imports from about 1608 million cubic meters at the end of 2021 to 2417 million cubic meters at the end of 2022 (Zachmann et al., 2023). • The embargo on Russian crude oil, coal, and diesel fuel on December 5, August 10, and February 5, 2022, respectively.

Source: Research finding.

Introducing Game

Historically and based on the observed events, both players have applied their strategies in each period using one of these three approaches: neoliberalism, neorealism, and realism-geopolitics. Europe-oriented, reflexive control, and Asia-oriented are strategies for Russia, which we call (Eu), (RC), and (CH),

[1]. The initial idea was proposed in 2008.

respectively. The EU's strategies include relying on market structure and competitiveness (CO), sustainable energy (ER), and energy security (ES). The first strategy of each of the two players (Eu, CO) refers to the cooperation and interdependence of the parties. According to the theoretical framework, in this situation, economic interests also serve political interests, and if both players play it simultaneously, a win-win game occurs in the gas relations of the parties.

The second set of strategies, RC for Russia and ER for the EU, signify avoidance and mutual distrust in the security relations of the players. Both Russia and the EU try to impose their interests. Russia uses energy leverage, and the EU controls and limits Russia's power by enforcing gas laws. As a result, despite the increase in gas trade between these two players, there is a sense of security competition between them. The benefits from the gas trade are non-zero-sum in this game, but their security and political benefits become zero-sum. Although both players meet each other's gas business interests, the political interests become unmet and zero if both players play them simultaneously.

Their third strategy has turned toward geopolitical realism. Their priority is removing interdependence, increasing their security, and prioritizing political interests over economic interests. As a result, they tend toward mutual avoidance behavior. Russia's CH strategy means to counter EU threats, enhance its geopolitical position, and bolster its bargaining power by extending its influence into the Asian gas markets. The EU's ES strategy is enhancing energy security, diversifying the gas import market and enforcing sanctions against Russia. This situation will result in a zero-sum game for both players.

Despite the uniqueness of the implementation of strategies chosen by both countries, the theoretical approaches of each strategy are similar for the players. As a result of this adaptation in approaches, both players have the same payoff matrix, and the game is symmetric. If, for simplicity, we assume that half of the payoffs are economic benefits from gas trade and the rest are security benefits,

(1) in (Co, Eu), the players have mutual interests, so they both achieve a payoff of 1.

(2) in (ER, RC), both players attempt to impose their interests. Despite their security interests being at risk, they continue gas trading and commercial dealings, so that leads to a reduction in their payoff to half.

(3) in (ES, CH), both political and economic relations are characterized by mutual avoidance, and the confrontation between these two strategies is neutralized. Therefore, the players achieve a zero payoff.

(4) in (ER, Eu), the EU imposes its interests on Russia. As a result, Russia's payoff will be zero, and the Union's payoff will be 1. The opposite form of this game occurs in (Co, RC), and Russia imposes its interests.

(5) in (ER, CH), Russia applies the CH strategy in response to restrictions to increase its bargaining power while minimizing those of the Union. Russia will receive a payoff of 1 for providing economic and geopolitical benefits simultaneously, but the Union's payoff will be (-1). The reverse of this situation occurs in (ES, RC) case. In this situation, the EU has minimized Russia's ability to use energy as a weapon by sanctioning Russia and diversifying its gas suppliers. In this case, the EU minimizes Russia's interests and maximizes its energy security interests.

When considering the payoff of implementing the CH strategy against the CO strategy or the payoff of applying the ES strategy against the Eu strategy, it is essential to consider some specific important factors.

- Based on the observations made before 2006, when the parties were implementing a softer strategy against each other, neither party had the desire to diversify the export and import gas markets. The EU had access to a cheap gas market, and Russia gained influence in the European gas markets.
- Implementing the CH strategy from Russia's side, while the EU is a cooperative player, would mean losing part of the market, collapse of supply chains and logistics, and a setback in Russia's energy resources development (Fazelianov, 2022). Moreover, some experts argue that because of Russia's pivot toward China in this strategy, the gas pipeline from Russia to China is not strategically justified due to China's monopsony power over Russia.
- European countries remain dependent on gas in the short and medium term. A supplier diversity policy by the Union involves some costs. Eastern EU countries have an extremely high reliance on Russian gas resources. Therefore, implementing ES could potentially result in a gas shortage for them (Flanagan et al., 2022). Developing new gas infrastructure is imperative for diversifying gas imports in the European market — LNG terminals, pipelines, and storage facilities. Implementing this strategy can significantly raise energy prices, at least in the short term, leading to higher production and transportation costs for European companies and decreasing real income. Even an uptick in prices could

result in a surge in coal consumption and environmental pollution (Fazelianov, 2022).

Considering these three points mentioned earlier, we can assume that the payoff of CH versus CO, or ES versus EU, is between zero and one. The closer this is to one, the easier it is for the EU to find a cheap alternative to Russian gas. On the other hand, the Asian gas market and its geopolitical benefits for Russia can rival Russia's benefits from cooperating with the EU. Consequently, this presents a more believable threat, maybe encouraging cooperation instead of threatening each other. The closer the number is to zero, the more it presents an unbelievable threat that prioritizes self-interest and reduces cooperation. In this study, we assume a payoff of 0.5 (since this strategy turns the game into a zero-sum situation, the other party's payoff is -0.5). Table 4 displays the normal representation of the payoff table for these two players.

Table 4. The Normal Form of the Gas Game between Russia and the EU in the International Landscape

		Russia		
		Eu(1)	RC(2)	CH(3)
EU	CO(1)	(A, a)	(C, c)	(E, e)
	ER(2)	(B, b)	(D, d)	(F, f)
	ES(3)	(L, l)	(M, m)	(N, n)

(A)

		Russia		
		Eu(1)	RC(2)	CH(3)
EU	CO(1)	(1, 1)	(0, 1)	(-0.5, 0.5)
	ER(2)	(1, 0)	(0.5, 0.5)	(-1, 1)
	ES(3)	(0.5, -0.5)	(1, -1)	(0, 0)

(B)

Source: Research finding.

In each cell in Table 4(A), the first numbers in parentheses indicate the payoff of the EU, and the second numbers indicate the payoff of Russia. Table 4(B) shows the payoff matrix in this research. In the same vein, Matrices G and H represent the payoffs of the EU and Russia, respectively. Since the payoff matrix of both players is equal, the game is symmetric.

$$H_{3\times3} = \begin{bmatrix} a & b & l \\ c & d & m \\ e & f & n \end{bmatrix} = G_{3\times3} = \begin{bmatrix} A & C & E \\ B & D & F \\ L & M & N \end{bmatrix} \rightarrow \begin{bmatrix} 1 & 0 & -0.5 \\ 1 & 0.5 & -1 \\ 0.5 & 1 & 0 \end{bmatrix}$$

The following section analyzes the equilibrium point and stability (ESS) of the game.

Results and Discussion

There are two players and a finite strategy set $S = \{E_1, E_2, E_3\}$. It is assumed that these strategies can be adopted by both players. Since the set of strategies is

finite, each type of strategy E_1 to E_3 corresponds to the probability or frequency p_1 to p_3, so that $(p_i \geq 0,\ \sum_i p_i = 1)$. To investigate the evolutionary game, we first examine the classical Nash equilibrium. The game has two Nash equilibriums located at (ES, CH) and (CO, Eu) points. Therefore, the game has a mixed Nash equilibrium at $\mathrm{p}^* = (\mathrm{p}_1, \mathrm{p}_2, \mathrm{p}_3) = (0.6, 0.2, 0.2)$. In other words, these two players have cooperated 60% of the time in the gas sector and have an interdependent relation. In 20% of the cases, they have collaborated in the gas sector despite security competition, and in the remaining 20%, they have avoided each other completely in economic and political matters.

If this obtained equilibrium is stable, then during the evolution process over time, the players will apply these three strategies against each other with probability p^*, and there will be no desire to change it. However, if this equilibrium is unstable, the combination of these strategies can change over time and during the evolution process. The probability of taking a strategy can even become zero or one. p^* will become a long-term equilibrium if it is an ESS.

Under these conditions, the expected payoff in this game is being discussed. If there is a different probability combination, denoted by q, the ESS condition p^* is given by (Hofbauer and Sigmund, 1998):

- $V(q, p^*) \leq V(p^*, p^*)$
- If $p^* \neq q$, $V(q, p^*) = V(p^*, p^*)$ therefore $V(q, q) < V(p^*, q)$ and $V(p^*, q) - V(q, q) > 0$

Together, the two conditions thus characterize evolutionary stability. Thus, p^* is an evolutionary stable strategy if it is a symmetric Nash equilibrium, and if, in addition, for every q in the neighbor of p^*, p^* fares better against q than q against itself[1]. Because the expected payoff of player p^* against player q is higher than q against itself, this dissident behavior will not spread. The combination p^* is transferred to the next period and will be chosen by all players.

The ESS test results for the ongoing research game are as follows:

$$V(p^*, q) - V(q, q) = -q_1(q_1 - 0.9) - q_2(q_1 + 0.5q_2 - 0.3) - 0.5q_3 \qquad (1)$$

We can find combinations of q that can make equation (1) negative. This implies that the mixed Nash equilibrium p^* in this game is unstable, ultimately rejecting the stability condition (or ESS).

[1]. If p is a symmetric Nash equilibrium, then it is a fixed point of the replicator dynamics, and if p is a strict Nash equilibrium of a symmetric two-player game, then p is an evolutionarily stable and phase path convergences to this point. But if this equilibrium is a weak Nash, the stability condition (second condition) must be checked.

We also discuss the replicator dynamic equations and show the phase trajectories of strategy changes over time. The replicator dynamics controls the selection process. It is a powerful tool for describing how strategies evolve within a population and describes the evolution of the frequencies of strategies in a population. It offers a clear demonstration of how deviant strategies are eliminated through natural selection and how successful strategies become more prevalent during evolution (Hofbauer and Sigmund, 1998).

To calculate RD, we assume that p_1 represents the frequency of Strategy 1 or the number of times that Russia and the Union select it; p_2 represents the share of Strategy 2; and p_3 represents the share of Strategy 3 among the population. It is important to note that $\sum p_i = 1$. The payoff obtained by a p_i - strategist against p_j- opponents is $A = a_{ij}$. The rate of increase $\dot{p}_i/p_i$ of type strategy E_i is a measure of its evolutionary success. This success can be expressed as the difference between the payoff of E_i and the average pyoff of the population (Hofbauer and Sigmund, 1998).

$$\dot{p}_i/p_i = \text{payoff of } \mathrm{E_i} - \text{average payoff}$$
$$\dot{p}_i = p_i((Ap)_i - p^T Ap) \quad (2)$$

Under these conditions, this strategy will overcome other strategies during time (t) and converge to the stable point. The success speed depends not only on the payoffs but also on the popularity of strategies because the more popular a strategy is, the more probable it is to be copied or imitated (Khandan, 2018).

The differential equations related to the RD (Equation 2) are equal to:

$$A = \begin{bmatrix} 1 & 0 & -0.5 \\ 1 & 0.5 & -1 \\ 0.5 & 1 & 0 \end{bmatrix}$$

$$p_2 = 1 - p_1 - p_3$$
$$\dot{p}_1 = p_1(p_1 - 0.5 + 0.5p_3 - 0.5p_1^2 - 0.5p_3^2)$$
$$\dot{p}_3 = p_3(0.5 - 0.5p_1 - 0.5p_1^2 - 0.5p_3^2)$$

The phase diagram resulting from these differential equations displays a spiral source and divergent point equilibrium (red point) under the line $1 = p_1 + p_3$. The phase trajectories indicate that, over time, any point in the neighborhood to this equilibrium point will tend to move away from it.

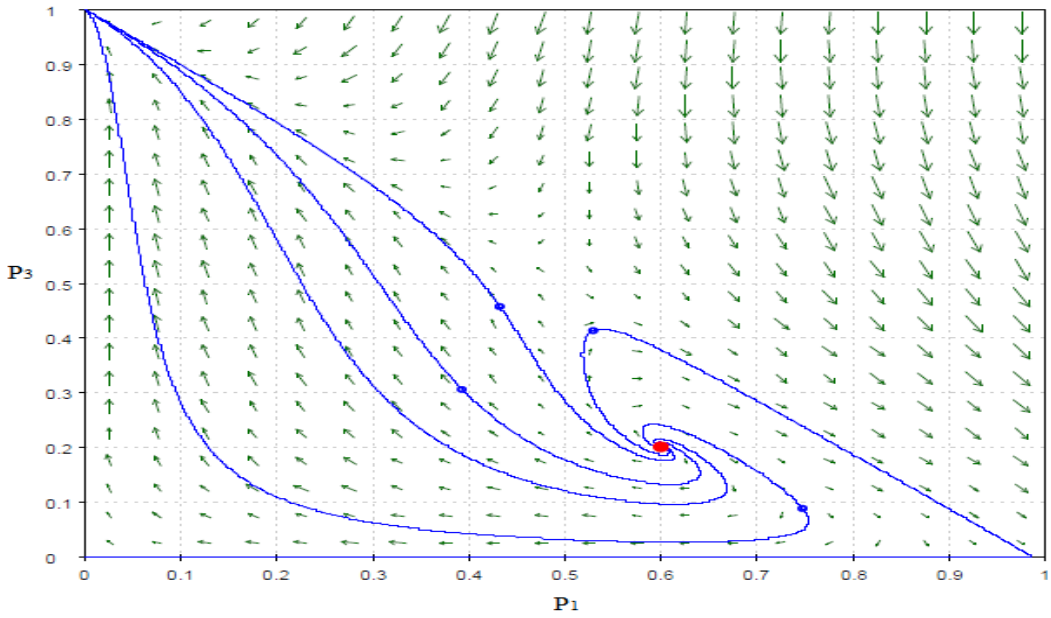

Figure 1. Illustrating Population Divergence from Nash Equilibrium Using a Phase Diagram (e =L =0.5, E=l= -0.5).
Source: Research finding.
Note: The equilibrium point is a spiral source under the line $1 = p_1 + p_3$, thus rejecting the ESS.

The results indicate the potential for altering, modifying, or revising gas-related energy policies between Russia and the EU. Moreover, the combination of choices and the implementation of these strategies by the parties will transform. The phase paths demonstrate a movement away from the equilibrium point and toward $p_3 = 1$. This highlights the significance of strategies focused on mutual avoidance in interdependence and the presence of security dimensions in energy decisions, as evidenced by the probability of p_3.

To conduct a more comprehensive analysis of the results, we also examined the scenario of a booming LNG market and the elimination of obstacles in the gas market (mentioned in the third section) in these two regions.

The future of the LNG market will play a crucial role in shaping the gas relations between these two players. According to BP (2023), the LNG trade trend until 2030 is on the rise. If the changes in the gas market continue in such a way that the mentioned obstacles are removed, and the LNG market can be easily replaced with cheap gas from pipelines, and if the cost of investing in LNG projects is reduced, the payoff matrix of this research suggests that the outlook for both (e) and (L) will increase from 0.5 to 1.

In this case, the Nash equilibrium point of the game is equal to $p^* = (1,0,0)$ which means an equilibrium in cooperation (CO, Eu) for these two players in the gas trade (red point). However, the evolutionary analysis of this game and its phase diagram (Figure 2) reveal that this cooperation and interdependence will also be unstable.

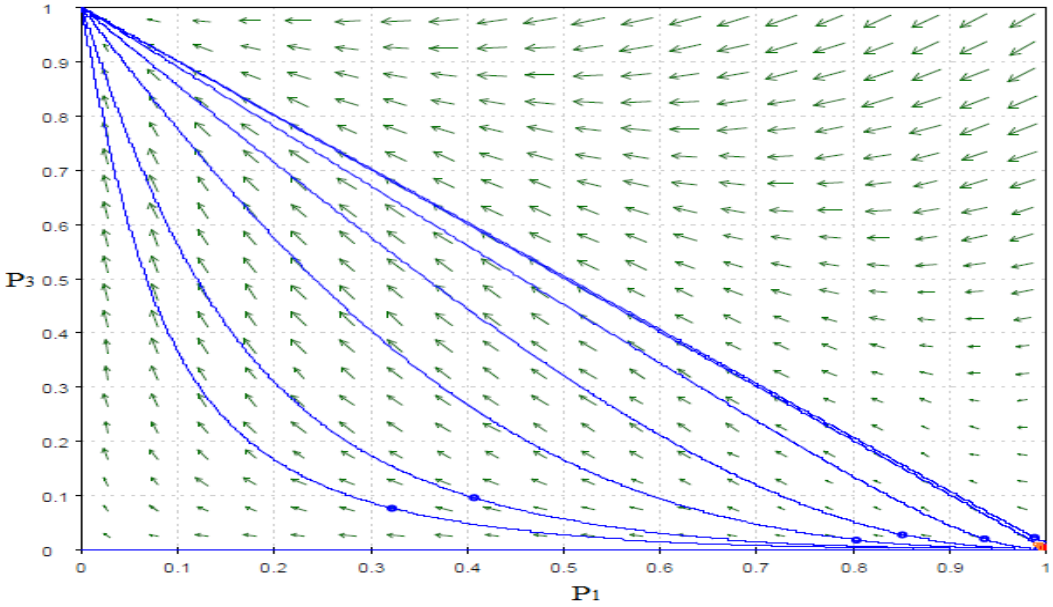

Figure 2. Illustrating Population Divergence from Nash Equilibrium Using a Phase Diagram (e =L =1, E=l= -1).

Source: Research finding.

Note: When any point in the neighborhood of the equilibrium point is chosen, all phase trajectories under the $1 = p_1 + p_3$ move away from the equilibrium point (rejecting ESS).

The game's results show that despite the development of LNG and the smooth gas market transactions, the two players cannot have a cooperative strategy based on interdependence in their gas relationships in the long term. Security and political issues will continue to play a significant role in the strategic decisions of the two players.

The consequence of Figures 1 and 2 reveals that Russia's gas energy relations with the EU are not solely economic, and economic interests cannot provide political interests. Therefore, the actors in the political arena, particularly governments, will continue to play a critical role in decisions related to energy trade. The gas trade between these two players does not merely follow a free market, and as a result, the role of security issues in the gas policy decisions of the parties will remain, but in the long run, its percentage of influence in strategic decisions will be different and will undergo changes.

In the strategy of Russian gas export to Europe, there is generally no component of maintaining and supporting the market share, and the general direction has been toward pricing strategy (Corbeau and Yermakov, 2016). The entry of American and Qatari LNG into the EU market, as well as the penetration of Qatari LNG into the European and Asian markets, can destroy a large share of the Russian market in these regions and reduce Russia's pricing power (BP, 2023). This issue is a threat to the share of the Russian gas market in Europe and Asia, which will also be affected by the power confrontation between Russia and America in addition to economic issues. In this case, Russia's strategy will change, and it will be forced to maintain and support its share in the gas market. In addition, the change in Russia's gas strategy due to changes in the LNG market also depends on China's willingness to trade in LNG (Corbeau and Yermakov, 2016). This issue can lead to share-seeking security measures by Russia in the gas market and reciprocal security measures by the EU to maintain its energy security against Russia.

Conclusion

This research aims to study the gas interactions influenced by the political relations between Russia and the EU using evolutionary game theory to analyze the strategies employed by the parties based on the market and their policy observations.

The importance of security-political and geopolitical factors has increased in the gas energy partnerships between these two regions. The Crimean crisis in 2014 and the war between Russia and Ukraine in 2022 have significantly

deepened the mutual avoidance and mistrust in the relations. There has been a significant mutation in their gas relations, transitioning from an energy neoliberalism approach to a geopolitical realism approach.

In confirming this, strategic developments also suggest a transition from a desire for mutually beneficial payoffs (win-win) to a more competitive mindset (zero-sum). A study of their gas relationship history reveals that they have employed three strategies against each other in three periods. The initial strategy involves collaboration and liberalism, as seen in Russia's Europe-oriented behavior (Eu) and the EU's push for gas market competitiveness (CO). The second strategy reflects cooperation with security concerns, as seen in Russia's reflexive control (RC) and the EU's sustainable energy supply strategy (ER). The third strategy involves mutual avoidance, as seen in Russia's Asia-oriented action (CH) and the EU's energy security strategy (ES).

To conduct a more comprehensive analysis, the evolutionary game of this study has been examined in two scenarios: the current state of the LNG market and the possibility of a booming LNG market. Based on an analysis of the game's equilibrium in the first scenario, it is evident that these two players exhibit a cooperative strategy more than 50% of the time in their gas interactions with each other. The remaining portion is influenced by political and security interests. However, the evolutionary analysis of this game indicates that this equilibrium will not be stable, and this is a short-term equilibrium. In such a situation, the equilibrium point and the percentage of the use of these strategies may change in the long run, and there is the potential for revising gas-related energy policies between Russia and the EU in the long run.

Alongside factors such as the course of events in the Russia-Ukraine war and the role of third parties such as China, Qatar, and the United States, changes in the LNG market play an essential role in the future of gas relations between Europe and Russia. With more expansion in the LNG market, the threat of playing a third strategy by opponent players becomes more believable. The third strategy is a situation in which the parties seek to minimize each other's political and economic interests.

Analyzing the game within the context of the LNG market boom scenario reveals a mutually cooperative equilibrium ($p = (1,0,0)$). As a result, when the threat of implementing the third strategy becomes more believable, a rational Nash equilibrium shows the interaction of these two players in a situation of cooperation and non-implementation of strategies with security threats against each other. However, the evolutionary study shows that this equilibrium will not

be stable and rejects the ESS. This equilibrium is only a short-term situation. As the LNG market expands, the gas relations between these regions are likely to become more political.

The booming LNG market has the potential to elevate the influence of competing nations like the United States and Qatar in the gas market of the Union. Additionally, this competition, combined with how Russia's relations with China are, raises the probability of encountering political security concerns within the region's gas market. In this case, Russia may change its strategy from gas pricing policies to strategies for maintaining its market share, which could potentially lead to the formation of a gas cartel (or Gas OPEC). Under these conditions, the EU and its member states may consider forming an energy alliance to protect their interests in the gas market, ensure energy security, and counter Russia's policies.

Considering the two possible outcomes, it can be concluded that security interests will continue to play a significant role in determining the gas strategies of both Russia and the EU, but with varying degrees of intensity. It is not always the case that mutual dependence and economic benefits resulting from gas trade can provide political benefits in this region. Therefore, governments will maintain their key role and be involved in decisions related to energy trade.

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