

Zhou, Peng; Guo, Dong

**Working Paper**

## Sanctions, co-sanctions, and counter-sanctions: A multilateral, evolutionary game among three global powers

Cardiff Economics Working Papers, No. E2023/28

**Provided in Cooperation with:**

Cardiff Business School, Cardiff University

*Suggested Citation:* Zhou, Peng; Guo, Dong (2023) : Sanctions, co-sanctions, and counter-sanctions: A multilateral, evolutionary game among three global powers, Cardiff Economics Working Papers, No. E2023/28, Cardiff University, Cardiff Business School, Cardiff

This Version is available at:

<https://hdl.handle.net/10419/284190>

**Standard-Nutzungsbedingungen:**

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

**Terms of use:**

*Documents in EconStor may be saved and copied for your personal and scholarly purposes.*

*You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.*

*If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.*

# Cardiff Economics Working Papers



Working Paper No. E2023/28

## Sanctions, Co-sanctions, and Counter-sanctions: A Multilateral, Evolutionary Game among Three Global Powers

*Peng Zhou and Dong Guo*

December 2023

ISSN 1749-6010

Cardiff Business School  
Cardiff University  
Colum Drive  
Cardiff CF10 3EU  
United Kingdom  
t: +44 (0)29 2087 4000  
f: +44 (0)29 2087 4419  
[business.cardiff.ac.uk](http://business.cardiff.ac.uk)

This working paper is produced for discussion purpose. These working papers are expected to be published in due course, in revised form.

Cardiff Economics Working Papers are available online from:

<http://econpapers.repec.org/paper/cdfwpaper/> and

[https://carbsecon.com/wp/index\\_abstracts.html](https://carbsecon.com/wp/index_abstracts.html)

Enquiries: [EconWP@cardiff.ac.uk](mailto:EconWP@cardiff.ac.uk)

**Sanctions, Co-sanctions, and Counter-sanctions:  
A Multilateral, Evolutionary Game among Three Global Powers**

Peng Zhou<sup>1,\*</sup> Dong Guo<sup>2</sup>

<sup>1</sup> Corresponding: Cardiff University; Email: [zhoup1@cardiff.ac.uk](mailto:zhoup1@cardiff.ac.uk); Address: D47, Aberconway Building, Colum Drive, Cardiff, UK, CF10 3EU. ORCID: 0000-0002-4310-9474

<sup>2</sup> China Development Bank; Email: [antoineguo@qq.com](mailto:antoineguo@qq.com); Address: No.18 Fuxingmenwai Street, Xicheng District, Beijing, China.

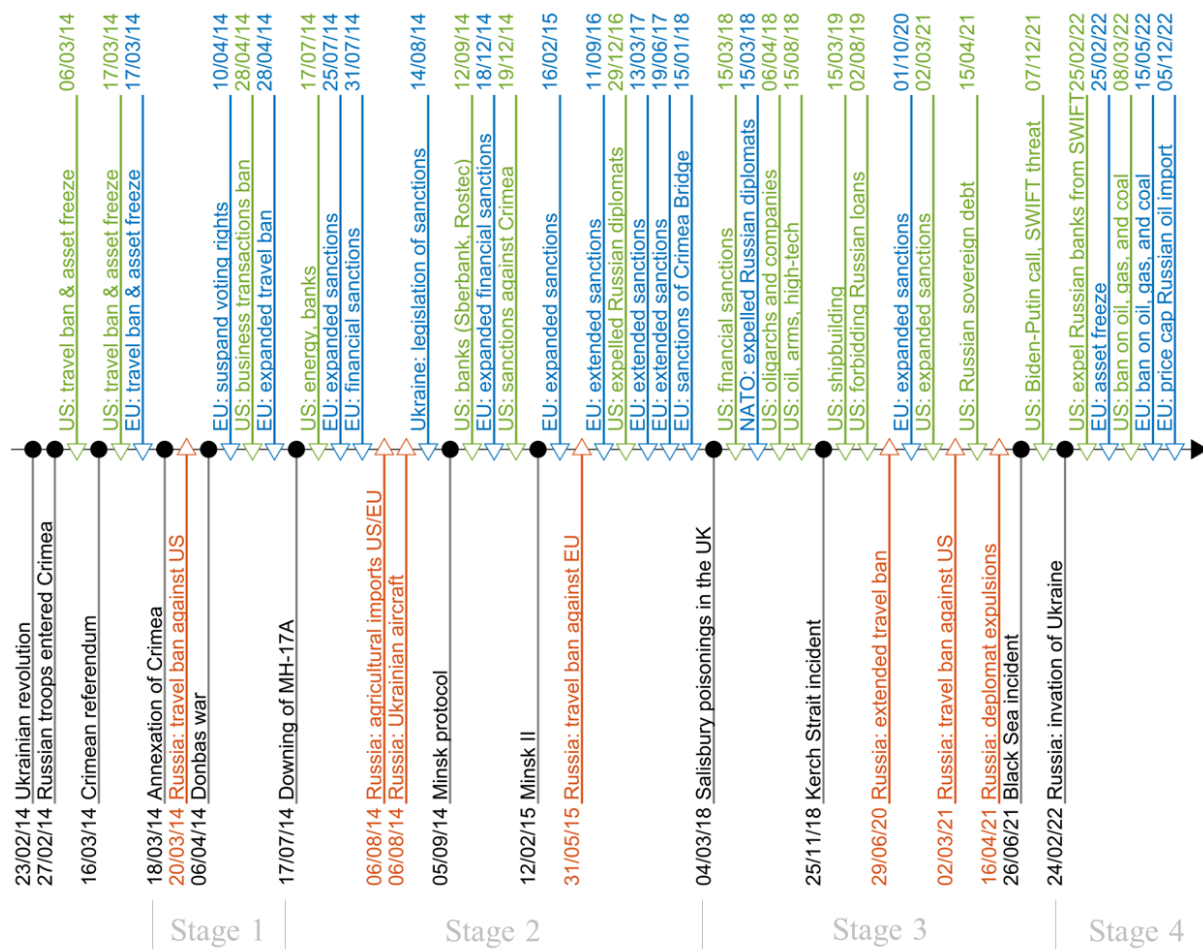
**Abstract:** Facing the sanctions from the West since the annexation of Crimea in 2014, Russia quickly converged to a strong counter-sanction strategy. The US and the EU staggered the strengths of sanctions in turns, with the EU first imposing relatively stronger commercial sanctions first and the US relaying with stronger financial sanctions later. Using US-EU-Russia sanctions as an example, we develop a multilateral, evolutionary game to capture the strategic complementarity between the sanctioners and the sanctionee, as well as the strategic substitutability between the leading sanctioner and the co-sanctioner. In an extended model, the sanction technology is introduced to endogenize how sanctions are designed before deployment. The model is then calibrated to match the summarized stylized facts, to demonstrate the simulated evolutionary paths, and to verify the derived strategic dependence.

**Keywords:** Sanction; Strategic Dependence; Evolutionary Game Theory.

# 1 Introduction

The confrontation between Russia and the West has been one of the thorniest international political issues since the Cold War. After the Ukrainian crisis in 2014, sanctions were imposed by the United States (US), the European Union (EU), and other countries against Russian individuals, officials, and businesses. With an alternating rhythm of strengths between the US and the EU, sanctions were gradually expanded from entities to sectors and from commercial to financial measures (Besedeš et al., 2021). Broader financial sanctions were added since the Russian invasion of Ukraine in February 2022, but the effectiveness of sanctions is under question (Peksen, 2019a, 2019b). In the timeline of Figure 1 we summarize four stages of sanctions, co-sanctions, and counter-sanctions among the three major global powers.

Figure 1 Timeline of sanctions, co-sanctions, and counter-sanctions 2014-2022



**Stage 1** (2014M3) mainly took the form of a travel ban and an asset freeze for a selection of Russian citizens involved in the annexation of Crimea. It was led by the US and followed by the EU during the annexation, but these mild, basic sanctions failed to stop Russia. In the meantime, Russia responded with reciprocal counter-sanctions targeting representative politicians in the West (Peksen & Jeong, 2022). **Stage 2** (2014M7-2018M2) started with the escalating

Donbass war, especially after the downing of MH-17A by a Russian missile. Sanctions were soon expanded from commercial entities (e.g., arms, energy, high-tech) to financial institutions (e.g., banks, bonds, stocks). As shown in Figure 1, the EU was even more active than the US in imposing sanctions at this stage. Meanwhile, Russia retaliated by restricting agricultural imports from the US/EU (Simola, 2014). In this period, Russia underwent a harsh financial crisis (2014-2016). The Minsk protocol and Minsk II were signed but neither halted the war between Russia and Ukraine. **Stage 3** (2018M3-2022M1) begun with the Salisbury poisonings in the UK. As a response, the US led another expanded series of commercial and financial sanctions, restricting Russian businesses and governments from accessing international financial markets (e.g., threatening to cut off Russia from the SWIFT payment system). Russia, suffering from the Russia-Saudi Arabia oil price war and the COVID-19 pandemic during this time, had very limited counter-sanctions apart from travel bans and diplomat expulsions. Lacking financial counter-sanctions, Russia engaged in intermittent military provocations such as Kerch strait incident, Black Sea incident, and ultimately invasion of Ukraine to uphold a strong stance. The EU, nevertheless, had attempted to restore economic links with Russia (e.g., negotiation of Nord Stream 2 between Germany and Russia in 2021). The outbreak of the Russia-Ukraine war marked the beginning of **Stage 4** (2022M2-now). An intensified wave of sanctions has been deployed. The US banned imports of Russian crude oil in March 2022 followed by the European Commission in May 2022. Comprehensive financial sanctions, ranging from freezing assets and seizing funds to expelling Russian banks from the SWIFT network, have been imposed to Russia individuals and entities. Short of counter-sanctions, Russia shifted its focus to military aggression in response.

The four stages demonstrate distinctive forms and different strengths of sanctions. The initial round of sanctions was mild, targeting key politicians involved in the Ukraine crisis. Therefore, it took the form of travel bans and asset freezes, so the impact on both sides was limited. It was a traditional approach of economic sanctions also imposed on Iran and North Korea to a different extent. The second stage became more serious, witnessing an expanding list of entities in strategic sectors in the form of commercial sanctions (e.g., arms, energy, high-tech) and financial sanctions (e.g., access to loans, bonds, equity, payment system, etc.) by the US/EU to *structurally* impede economic growth in Russia (Besedeš et al., 2021). The expanded sanctions led to a 0.2% further deterioration of Russia's growth rate (IMF, 2015, 2019) and a 7.4% loss of total exports (Crozet & Hinz, 2020). The third stage is a continuation of the second stage, but the strength of sanctions is stronger from the leading sanctioner and weaker from the co-sanctioner, as shown in the frequencies of sanctions from the US (green) and the EU (blue) in Figure 1. It suggests strategic substitutability among sanctioners (Joshi & Mahmud, 2020). There have been many efforts within the EU to lift sanctions against Russia because the costs of sanctions are unbalanced between the US and the EU as well as across member countries within the EU. The institutional structure of the EU and conflicting economic interests of

multiple principals make it difficult to impose unanimous sanctions like the US (Weber & Schneider, 2020). Coordination failures among sanctioners contribute to the ineffectiveness of sanctions, making Russia more reckless in its geopolitics. Every stage starts with a stronger push from Russia (Stage 1: Annexation of Crimea, Stage 2: Downing of MH-17A, Stage 3: Salisbury poisonings in the UK, Stage 4: Invasion of Ukraine). To better understand how sanctioners and sanctionee interact and how strategies change over time, this paper aims to address the following research question: *How does strategic dependence affect the effectiveness of sanctions in a multilateral, dynamic setting?*

In fact, both economists and political scientists have cast doubt on the effectiveness of international sanctions in bringing about desired economic and political consequences (Afanasyev et al., 2021). It is argued that sanctions are costly to sanctioners (senders) as well as sanctionees (targets), and severe sanctions can even promote nationalism which “lends increased political support to the ruling regime” (Kaempfer & Lowenberg, 1988). Modern history provides rich examples of ineffectual sanctions, such as the League of Nations sanctions against the Italian occupation of Abyssinia in 1930s (Welk, 1937), the United Nations (UN) sanctions against South Africa in 1980s (Levy, 1999), and the US sanctions against Iraq in 1990s (Eaton & Engers, 1999). Hufbauer et al. (1990) investigate 116 episodes of international sanctions, finding that only one-third of the objectives were achieved. Nevertheless, these studies focus on contexts of unbalanced relationship where the sanctioning country has an overwhelming advantage over the target country. In these studies, sanctionees can only cause regional geopolitical troubles (e.g., Cuba, North Korea), but the sanctioners are either global powers (e.g., the US) or international governmental organizations (e.g., the UN). Strategic interactions between the sender and the target in these cases are quite different from situations where both sides have similar strengths. In recent literature, more attention is shifted to sanctions imposed on global powers like Russia (Hufbauer & Jung, 2020; Weber & Schneider, 2020). Our paper belongs to one of such type.

Moreover, most analytical frameworks of sanctions are bilateral, i.e., between one sender and one target (Eaton & Engers, 1992, 1999). The public choice model proposed by Kaempfer & Lowenberg (1988) elaborates on *internal* interest groups within the sanctioning country and Joshi & Mahmud (2018, 2020) develop a network model with *external* third parties, but these are essentially bilateral models. For political conflicts between global powers like the US and Russia, it is inevitable to involve the EU, which has constant geopolitical concerns with Russia. Therefore, the story is not only between the sanctioner (US/EU) and the sanctionee (Russia), but also between the leading sanctioner (US) and the co-sanctioner (EU)<sup>1</sup>. Multilateral models

---

<sup>1</sup> The roles of leading sanctioner and co-sanctioner are determined based on sanctioning capacities rather than activities. Indeed, the EU is directly exposed to the threat from Russia, and the member countries have greater incentives to lead the sanctions (in fact, many sanctions from the EU predate or dominate those from the US). Nevertheless, the US has been the de facto leading global power, especially in dealing with Russia since the

are common in empirical literature on international trade (Nocco, et al., 2019; Zhou et al., 2021) and international finance (Guo & Zhou, 2021), but multilateral models suitable for the context of sanctions are rare. Multilateral models with evolving strategic dependence are even rarer. International sanctions usually last for years due to the long-term nature of geopolitical conflicts. Throughout the lifecycle of sanctions, equilibrium strategies can change substantially. After all, sanctions will ultimately end under certain conditions, no matter how strongly the senders act (Attia et al., 2020). A static model can only explain a part of the entire sanction cycle. To deal with the dynamic feature, we adopt evolutionary game theory applied previously to crime deterrence (Cressman et al., 1998) and public goods (Gürerk et al., 2006).

Therefore, this paper contributes to the literature on sanctions in the following ways. It develops a trilateral, evolutionary game to capture both multilateral strategic dependence and time-varying equilibrium in one unified framework. In addition, it endogenizes the sanction technology to open the black box of sanction deployment. The choice between co-sanction and sole-sanction is usually taken for granted in existing literature. Once this decision is explicitly modelled, the probabilities of successful sanctions or the strengths of sanctions are also endogenously determined. Moreover, by simulations, we qualitatively demonstrate that the model can fit the stylized facts of sanctions, co-sanctions, and counter-sanctions in the context of US-EU-Russia conflicts. This multilateral, evolutionary game theoretical framework can be extended and applied to a wide range of international political issues.

The remainder of the paper is organized as follows. Section 2 discusses the methodology of evolutionary game theory. In Section 3, the paper develops a trilateral, evolutionary sanction game and formally derives the replicator dynamics and strategic dependence of the three players. Section 4 extends the model with the optimal choice between sole-sanction and co-sanction by endogenizing sanction technologies. In Section 5, conditions for *strategic complementarity* and *strategic substitutability* are verified by simulated evolutionary paths. We find that Russia has a stubborn strategy of strong counter-sanctions. The only possible way of coercing Russia to give up such a strategy is to raise the costs of counter-sanctions, rather than by raising the sanction strength. On the contrary, the US has a temporarily weaker strategy before eventually converging to the strong strategy. This is because the strong sanctions of the EU at the beginning of the game are strategically substitutable for the US sanctions. For the same reason, the EU gradually gave up the strong strategy and lifted its sanctions as observed in the third stage. Section 6 provides some concluding remarks and policy implications.

---

Cold War. The US has the greatest sanctioning capacity even if the capacity may not be fully used. Thus, we can argue that the US is the effective leading sanctioner. Alternatively, we can make leading sanctioner and co-sanctioner flexible roles, rather than two fixed players. Sometimes the US takes the lead, while other times the EU takes the lead. So, our model works as long as there are multilateral interactions among these roles.

## 2 Methodology

Bargaining models are usually used in formal theories of sanctions (Eaton & Engers, 1992, 1999; Garoupa & Gata, 2002; Lacy & Niou, 2004) since sanctions are viewed as an instrument of coercive diplomacy. The purpose of sanctioning countries (the sender) is *not* to affect the ability of the sanctioned country (the target) to take certain actions, but to change the cost-benefit calculations of the target. These bargaining models of sanctions originate from the literature of militarized conflicts (Schelling, 1966; Powell, 1996) and ‘hybrid threats’ (Balcaen et al., 2022). In this view, sanctions and wars are alternatives in the bargaining processes to resolve disputes. However, there are significant differences between sanctions and wars, so direct application of bargaining models of wars to sanctions is problematic (Felbermayr et al., 2021). Specifically, there are three important considerations to be taken.

First, *dynamics*. Unlike most wars, sanctions usually last for years (e.g., against Russia) and sometimes even decades (e.g., against Cuba and North Korea). Eaton and Engers (1992) develop a sequential bargaining game with infinite horizon and complete information to capture the dynamics in strategic dependence. They show how the long-term outcome of sanctions depend on time preferences and costs of sanctions, but the model is essentially a static one because there is no transition or evolution of equilibrium over time.

Second, *uncertainties*. If the game is played into the infinite or indefinite future, the game needs to account for the uncertainties in strengths of sanctions and counter-sanctions (Drezner, 1998; Eaton & Engers, 1999) as well as the uncertainties in durations of sanctions (Krustev & Morgan, 2011). Nevertheless, almost all models assume exogenous probabilities/strengths without a complete model of sanction technology or sanction deployment.

Third, *multilaterality*. The EU is not a unitary but a collective policymaker with heterogeneous interests among member countries. A similar but looser relationship exists between the EU and the US. It is observed in the third stage that counter-sanctions from Russia (e.g., Nord Stream 2 between Germany and Russia) made use of the conflicting interests within the EU and between the EU and the US. Foreign policies are extensions of domestic politics, so intrastate bargaining can influence interstate policies like sanctions (Whang & McLean, 2014). This is the foundation for the so-called “smart sanctions”—to raise discriminative costs of the most influential parties in the target country instead of broad sanctions (Lepez, 2002; Drezner, 2011; Ahn & Ludema, 2020). However, existing models are essentially bilateral because interactions between the US and the EU are not explicitly described.

To capture all the desired features (dynamics, uncertainties, and multilaterality), we adopt Evolutionary Game Theory (EGT) to model the sanction game among the US, the EU and Russia. EGT bridges concepts from evolutionary biology, nonlinear dynamics, and game theory

(Cressman, 1995). In an evolutionary game, players are interpreted as populations of animals or individuals, and probabilities in a mixed strategy of a player are interpreted as shares of the population (Smith, 1982). Individuals within the same part of the population play the same pure strategy. The main “solution” concept is Evolutionary Stable Strategy (ESS) developed by Smith & Price (1973). A strategy  $\sigma$  is evolutionarily stable if and only if, for other strategies  $\sigma'$ , the payoff function  $U(\cdot)$  satisfies:

$$U(\sigma|\sigma) > U(\sigma'|\sigma), \text{ or} \quad [1]$$

$$U(\sigma|\sigma) = U(\sigma'|\sigma) \text{ and } U(\sigma|\sigma') > U(\sigma'|\sigma') \quad [2]$$

In other words, the ESS is preferred to alternative strategies regardless of opponents’ strategies. Therefore, an ESS is always a Nash equilibrium, and any strict Nash equilibrium is also an ESS. However, not all weak NEs are ESS. In fact, all games have an NE if mixed strategies are allowed, but ESSs do not always exist (Taylor & Jonker, 1978; Hofbauer et al., 1979). To justify the use of EGT in the context of sanctions, let us compare evolutionary games and traditional games in terms of both assumptions and solutions.

On the one hand, traditional game theory imposes the so-called hyperrational assumption on players in that it requires all players to have a well-defined, consistent set of preferences and common knowledge (Smith & Price, 1973). However, the strong rationality assumption and the common knowledge assumption do not describe actual human behavior (Sugden, 2021; Lahav, 2015). As a result, traditional game theory is essentially a *static* analysis, because players with hyperrationality can solve the sophisticated equilibrium in one go. In contrast, the EGT does not require hyperrational assumption—it can even successfully explain biological behaviour of animals. It provides a general approach to linking the learning rules used by individuals at the micro level with the dynamics describing changes in the population at the macro level (Sandholm, 2010). Therefore, EGT is a *dynamic* theory which can capture players’ observations of opponents’ behaviour, learning from these observations, and adaptively making the best move in response to what has been learned. This feature is suitable for capturing the evolving strategies of the US, the EU, and Russia throughout the entire course of sanctions.

There are two difficulties associated with the solution of traditional games—Nash equilibrium. First, some games do not have pure strategy Nash equilibrium at all (e.g., the game of matching pennies). To solve this difficulty, the concept of mixed strategy Nash equilibrium is usually used, but the interpretation of mixed strategy is non-intuitive for one shot games. The EGT, by contrast, resolves this difficulty by interpreting mixed strategies as dynamic population shares or the voting shares in the context of sanctions. Second, some games have multiple pure

strategy Nash equilibria, making the model solution indeterminate. The traditional game theory literature has produced numerous refinements to the concept of Nash equilibrium. However, there have been so many refinements that the problem has shifted from choosing among multiple Nash equilibria to choosing among multiple refinements. The EGT is one such refinement, but it provides a natural selection approach to choosing among Nash equilibria from an evolutionary perspective (Samuelson, 1997). It makes better sense in the context of international politics because most countries (e.g., the US, the EU, and Russia) have more than one major political party with different policy stances. The decisions on sanctions, co-sanctions, and counter-sanctions are obviously subject to the political negotiations among conflicting parties within each country (Corda, 2022).

Given the two advantages of the EGT over traditional game theory models, we will develop a trilateral, evolutionary sanction game in the next section to capture the dynamics of strategic dependence among the leading sanctioner, the co-sanctioner, and the sanctionee. To our knowledge, this is the first evolutionary game theoretical model of sanctions in the literature. To keep things simple, we will first assume exogenous strengths of sanctions and co-sanctions and then introduce the sanction technology to endogenize them.

The model developed in this paper has a great potential to explain a wide range of issues in geopolitical and global politics, because international conflicts are seldom bilateral or short-term. Arguably, although a trilateral game is the simplest multilateral game, the structure of the analytical framework is generalizable to any number of players. There may be more than three players in the game, but there are usually only three possible roles: leading sanctioner, co-sanctioner, and sanctionee. One ready application of the same framework is the sanctions and counter-sanctions between Israel and Iran, where the US is part of the sanction game too. Another example is between the US and China, where the EU acts as a co-sanctioner.

### 3 The Sanction Game: Decisions on Sanction Strategies

In the trilateral sanction game, there are three players ( $i = I, II, III$ ):

- Player I: Russia (the sanctionee)
- Player II: The EU (the co-sanctioner)
- Player III: The US (the leading sanctioner)

It is a simultaneous game played repeatedly without a definite time horizon. The status quo at the beginning of the game is that Russia seized some illegal claims (i.e., Crimea annexation), denoted as  $M > 0$ . The US lead sanctions with the EU to coerce Russia to give up or at least reduce its illegal claim. Each player can choose a weak strategy (denoted as 0) or a strong strategy (denoted as 1) or a mixed strategies (denoted as  $x, y, z \in (0,1)$  for the three players

*I, II, III*) to maximize its objective function or net benefit. If sanctions from the US or/and the EU are successful, the benefit received by Russia will be reduced by  $d_I M$ . Nevertheless, sanctions may fail. The probabilities of successful sanctions are denoted as  $0 \leq P \leq 1$  for the US and  $0 \leq Q \leq 1$  for the EU, respectively.  $P$  and  $Q$  are measures of strengths of sanctions and co-sanctions. Note that  $P$  can take two values  $P_0$  and  $P_1$ , depending on whether the weak or the strong strategy is adopted by the sanctioner.

For player I (Russia), if the weak strategy is chosen ( $x = 0$ ), Russia gives up the illegal claim and ends up with zero benefit ( $M = 0$ ) and zero cost ( $C_I = 0$ ). Technically, the assumption of zero cost is to make calibration simpler, but the qualitative conclusions are robust as long as the cost is smaller than that under the strong strategy. Theoretically, according to the Audience Cost Theory (e.g., Kertzer and Brutger, 2016), audiences can punish leaders both for being inconsistent, and for threatening to use force in the first place. Therefore, the reputation cost of “losing face” can be substantial to Putin, but it is still smaller compared to the real costs such as financial loss, human loss, and political loss if a strong strategy is wrongly played.

If the strong strategy is followed ( $x = 1$ ), Russia applies tit-for-tat counter-sanctions against the sanctioners/senders. The total cost of counter-sanctions is equal to  $aM + C_I$ , where  $0 \leq a \leq 1$  is the marginal cost and  $C_I > 0$  is the fixed cost of counter-sanctions. The benefits of Russia’s pure strategies are:

$$U_I(1) = (1 - P)(1 - Q)M - [1 - (1 - P)(1 - Q)]d_I M - (aM + C_I) \quad [3]A$$

$$U_I(0) = 0 \quad [3]B$$

For player II (EU), if it adopts the weak strategy ( $y = 0$ ), then only basic sanctions are imposed (e.g., asset freeze, entity list). If the strong strategy is chosen ( $y = 1$ ), then the EU applies strong co-sanction measures at a fixed cost of  $C_{II}$ . There are two possible outcomes. If interventions (from both the EU and the US) are successful, then the EU will receive a benefit of  $bM$  regardless of its contribution. If interventions fail, then the benefit is  $rM$  ( $b > r$ ) regardless of its contribution. In the case of successful interventions without EU’s strong sanctions, a political cost of  $d_{II} M$  will be requested by the US. The benefits of the EU’s pure strategies are:

$$U_{II}(1) = QbM + (1 - P)(1 - Q)rM - P(1 - Q)d_{II} M - C_{II} \quad [4]A$$

$$U_{II}(0) = (1 - P)rM - Pd_{II} M \quad [4]B$$

For player III (US), if the weak strategy is adopted ( $z = 0$ ), only basic sanctions (e.g., assets freeze and entity list) are implemented. Denote the probability of successful sanctions as  $P_0$ , which can be interpreted as the strength of sanctions of the US against Russia. If the strong strategy is used ( $z = 1$ ), the US expands economic sanctions from individual to commercial and financial dimensions. The corresponding probability of successful sanctions is  $P_1$ . Note that  $P_1$  is not necessarily greater than  $P_0$ , because the outcome depends on complicated actions, reactions, and interactions among the three players. The benefits of the US's pure strategies come from the reduction of the benefit from the sanctionee ( $d_I M$ ) and the reduction of the benefit from the co-sanctioner ( $d_{II} M$ ):

$$U_{III}(1) = [1 - (1 - P_1)(1 - Q)]d_I M + P_1(1 - Q)d_{II} M - QbM - (1 - P_1)(1 - Q)\gamma M - C_{III} \quad [5]A$$

$$U_{III}(0) = [1 - (1 - P_0)(1 - Q)]d_I M + P_0(1 - Q)d_{II} M - QbM - (1 - P_0)(1 - Q)\gamma M \quad [5]B$$

Note that  $0 < \gamma < 1$  is the negative effect of annexation of Crimea to the US if Russia gets away with it, and  $C_{III} > 0$  is the fixed cost of implementing comprehensive economic sanctions. Table 1 summarizes the payoff matrix of the three-player game. There are 8 payoff profiles (indicated by the superscripts) for the three players (indicated by the subscripts). Table 2 lists the payoffs of the three players in the 8 scenarios.

Table 1 Payoff matrix of the trilateral sanction game

I. Russia	III. US			
	Strong ( $z$ )		Weak ( $1 - z$ )	
	II. EU		II. EU	
	Strong ( $y$ )	Weak ( $1 - y$ )	Strong ( $y$ )	Weak ( $1 - y$ )
Strong ( $x$ )	$F_I^{(1)}, F_{II}^{(1)}, F_{III}^{(1)}$	$F_I^{(2)}, F_{II}^{(2)}, F_{III}^{(2)}$	$F_I^{(3)}, F_{II}^{(3)}, F_{III}^{(3)}$	$F_I^{(4)}, F_{II}^{(4)}, F_{III}^{(4)}$
Weak ( $1 - x$ )	$F_I^{(5)}, F_{II}^{(5)}, F_{III}^{(5)}$	$F_I^{(6)}, F_{II}^{(6)}, F_{III}^{(6)}$	$F_I^{(7)}, F_{II}^{(7)}, F_{III}^{(7)}$	$F_I^{(8)}, F_{II}^{(8)}, F_{III}^{(8)}$

Table 2 List of payoffs in different scenarios

	$M$	$Q$	$P$	I. Russia	II. EU	III. US
(1)	$> 0$	$> 0$	$P_1$	$F_I^{(1)} = [3]A$	$F_{II}^{(1)} = [4]A$	$F_{III}^{(1)} = [5]A$
(2)	$> 0$	$= 0$	$P_1$	$F_I^{(2)} = [3]A$	$F_{II}^{(2)} = [4]B$	$F_{III}^{(2)} = [5]A$
(3)	$> 0$	$> 0$	$P_0$	$F_I^{(3)} = [3]A$	$F_{II}^{(3)} = [4]A$	$F_{III}^{(3)} = [5]B$
(4)	$> 0$	$= 0$	$P_0$	$F_I^{(4)} = [3]A$	$F_{II}^{(4)} = [4]B$	$F_{III}^{(4)} = [5]B$
(5)	$= 0$	$> 0$	$P_1$	$F_I^{(5)} = [3]B = 0$	$F_{II}^{(5)} = [4]A = -C_2$	$F_{III}^{(5)} = [5]A = -C_3$
(6)	$= 0$	$= 0$	$P_1$	$F_I^{(6)} = [3]B = 0$	$F_{II}^{(6)} = [4]B = 0$	$F_{III}^{(6)} = [5]A = -C_3$
(7)	$= 0$	$> 0$	$P_0$	$F_I^{(7)} = [3]B = 0$	$F_{II}^{(7)} = [4]A = -C_2$	$F_{III}^{(7)} = [5]B = 0$
(8)	$= 0$	$= 0$	$P_0$	$F_I^{(8)} = [3]B = 0$	$F_{II}^{(8)} = [4]B = 0$	$F_{III}^{(8)} = [5]B = 0$

### 3.1 Replicator Dynamics of the Sanctionee

Now let us derive replicator dynamics of the strategies of the sanctionee (Russia), the co-sanctioner (EU), and the leading sanctioner (US). Replicator dynamics captures the evolutionary idea of selection based on fitness in EGT. It describes how a strategy converges (or diverges) over time. Only the convergent strategies are evolutionarily stable (ESS).

The replicator dynamics of Russia's mixed strategy ( $x$ ) at time  $t$  can be written as:

$$\dot{x} \equiv \frac{dx}{dt} = x(\overline{U_I(1)} - \overline{U_I}) = x(1-x)\Phi_I, \text{ where:} \quad [6]$$

$$\overline{U_I(1)} = z[yF_I^{(1)} + (1-y)F_I^{(2)}] + (1-z)[yF_I^{(3)} + (1-y)F_I^{(4)}] \quad [6]A$$

$$\overline{U_I} = x\overline{U_I(1)} + (1-x)\overline{U_I(0)} = x\overline{U_I(1)} \quad [6]B$$

$$\Phi_I \equiv M\{1 - a + [(1-yQ)(1-P_0 - z(P_1 - P_0)) - 1](1 + d_I)\} - C_I \quad [6]C$$

Therefore, if  $\Phi_I = 0$ , then Russia always keeps its initial strategy whatsoever since  $\dot{x} = 0$ . In general, if  $\Phi_I \neq 0$ , then imposing the steady state condition  $\dot{x} = 0$  on equation [6] results in two stationary points, i.e.,  $x = 0$  and  $x = 1$ . To investigate the evolutionary stationarity of the two points, take derivative of [6] with respect to  $x$ , we have  $\frac{d\dot{x}}{dx} = \Phi_I(1 - 2x)$ . There are two possibilities:

- If  $\Phi_I > 0$ , then  $\frac{d\dot{x}}{dx}\Big|_{x=0} = \Phi_I > 0$  and  $\frac{d\dot{x}}{dx}\Big|_{x=1} = -\Phi_I < 0$ , so  $x^* = 1$  (strong) is ESS.
- If  $\Phi_I < 0$ , then  $\frac{d\dot{x}}{dx}\Big|_{x=0} = \Phi_I < 0$  and  $\frac{d\dot{x}}{dx}\Big|_{x=1} = -\Phi_I > 0$ , so  $x^* = 0$  (weak) is ESS.

The key determinant of replicator dynamics is  $\Phi_I$ , which describes the evolution speed towards the ESS. Now let us investigate the factors that affect  $\Phi_I$ . For the sanctionee, we are more interested in when a weak strategy is the ESS, so we focus on the case  $x^* = 0$ .

**Proposition 1.** *The sanctionee is more likely to give up on its illegal claims if the sanctioner and the co-sanctioner have stronger strengths in sanctions ( $P_0, P_1, Q$ ).*

**Proof of Proposition 1.** The probability distribution of  $x = 0$  can be obtained by integrating the condition  $\Phi_I < 0$ . Combined with the definition in [6]C, we have:

$$\Pr(x^* = 0) = \Pr(\Phi_I < 0) = \Pr\left(z(P_1 - P_0) > 1 - P_0 - \frac{C_I + a + d_I}{(1+d_I)(1-yQ)}\right) \quad [7]$$

There are two cases to discuss. If  $P_1 > P_0$ , then [7] can be written as:

$$\begin{aligned}
\Pr(x^* = 0) &= 1 - \Pr\left(z < \frac{1-P_0}{P_1-P_0} - \frac{\frac{c_I}{M}+a+d_I}{(1+d_I)(1-yQ)(P_1-P_0)}\right) \\
\Pr(x^* = 0) &= 1 - \iint_{x,y=0}^1 \left[ \frac{1-P_0}{P_1-P_0} - \frac{\frac{c_I}{M}+a+d_I}{(P_1-P_0)(1+d_I)(1-yQ)} \right] dx dy \\
\Pr(x^* = 0) &= -\frac{1}{Q} \ln(1-Q) \frac{\frac{c_I}{M}+a+d_I}{(P_1-P_0)(1+d_I)} - \frac{1-P_1}{P_1-P_0}
\end{aligned} \tag{8}$$

If  $P_1 < P_0$ , then [7] can be written as:

$$\begin{aligned}
\Pr(x^* = 0) &= \Pr\left(z < \frac{1-P_0}{P_1-P_0} - \frac{\frac{c_I}{M}+a+d_I}{(1+d_I)(1-yQ)(P_1-P_0)}\right) \\
\Pr(x^* = 0) &= \iint_{x,y=0}^1 \left[ \frac{1-P_0}{P_1-P_0} - \frac{\frac{c_I}{M}+a+d_I}{(P_1-P_0)(1+d_I)(1-yQ)} \right] dx dy \\
\Pr(x^* = 0) &= -\frac{1}{Q} \ln(1-Q) \frac{\frac{c_I}{M}+a+d_I}{(P_0-P_1)(1+d_I)} - \frac{1-P_0}{P_0-P_1}
\end{aligned} \tag{9}$$

The two cases [8] and [9] can be succinctly combined in one equation:

$$\Pr(x^* = 0) = \Pr(\Phi_I < 0) = -\frac{1}{Q} \ln(1-Q) \frac{\frac{c_I}{M}+a+d_I}{|P_1-P_0|(1+d_I)} - \frac{1-\max\{P_0, P_1\}}{|P_1-P_0|} \tag{10}$$

The full proof of  $\frac{\partial \Pr(x^*=0)}{\partial P_0} > 0$  and  $\frac{\partial \Pr(x^*=0)}{\partial P_1} > 0$  is provided in the Appendix. The positive effect of  $Q$  on  $\Pr(x^* = 0)$  is relatively straightforward, so is provided here.

$$\frac{\partial \Pr(x^*=0)}{\partial Q} = \frac{\frac{c_I}{M}+a+d_I}{|P_1-P_0|(1+d_I)} \left[ \frac{\ln(1-Q)}{Q^2} + \frac{1}{Q(1-Q)} \right]$$

The coefficient  $\frac{\frac{c_I}{M}+a+d_I}{|P_1-P_0|(1+d_I)} > 0$ , so we can simply focus on the terms inside the brackets:

$$\frac{\ln(1-Q)}{Q^2} + \frac{1}{Q(1-Q)} \approx \frac{-Q}{Q^2} + \frac{1}{Q(1-Q)} = \frac{1}{1-Q} > 0$$

Note that the approximation of  $\ln(1-Q)$  in the numerator uses the fact that  $\ln(1+\epsilon) \approx \epsilon$  if  $\epsilon$  is small. To summarize, we have derived  $\frac{\partial \Pr(x^*=0)}{\partial Q} > 0$ . This proposition is intuitive—a stronger power of the sanctioner/co-sanctioner can always help coerce the opponent.

### 3.2 Replicator Dynamics of the Co-sanctioner

The replicator dynamics of the EU's mixed strategy ( $y$ ) at time  $t$  can be written as:

$$\dot{y} \equiv \frac{dy}{dt} = y(\overline{U_{II}(1)} - \overline{U_{II}}) = y(1 - y)\Phi_{II}, \text{ where:} \quad [11]$$

$$\overline{U_{II}(1)} = x[zF_{II}^{(1)} + (1 - z)F_{II}^{(3)}] + (1 - x)[zF_{II}^{(5)} + (1 - z)F_{II}^{(7)}] \quad [11]A$$

$$\overline{U_{II}(0)} = x[zF_{II}^{(2)} + (1 - z)F_{II}^{(4)}] + (1 - x)[zF_{II}^{(6)} + (1 - z)F_{II}^{(8)}] \quad [11]B$$

$$\overline{U_{II}} = y\overline{U_{II}(1)} + (1 - y)\overline{U_{II}(0)} \quad [11]C$$

$$\Phi_{II} \equiv xMQ\{b - r + (r + d_{II})[P_0 + z(P_1 - P_0)]\} - C_{II} \quad [11]D$$

Similar to the analysis of the sanctionee, the key determinant of replicator dynamics of the co-sanctioner is  $\Phi_{II}$ . If  $\Phi_{II} = 0$ , then the EU always keeps its initial strategy whatsoever since  $\dot{y} = 0$ . In general, if  $\Phi_{II} \neq 0$ , then imposing the steady state condition  $\dot{y} = 0$  on equation [11] results in two stationary points, i.e.,  $y = 0$  and  $y = 1$ . To investigate the evolutionary stationarity of the two points, take derivative of [11] with respect to  $y$ , we have  $\frac{d\dot{y}}{dy} = \Phi_{II}(1 - 2y)$ . There are two possibilities:

- If  $\Phi_{II} > 0$ , then  $\frac{d\dot{y}}{dy}\Big|_{y=0} = \Phi_{II} > 0$  and  $\frac{d\dot{y}}{dy}\Big|_{y=1} = -\Phi_{II} < 0$ , so  $y^* = 1$  (strong) is ESS.
- If  $\Phi_{II} < 0$ , then  $\frac{d\dot{y}}{dy}\Big|_{y=0} = \Phi_{II} < 0$  and  $\frac{d\dot{y}}{dy}\Big|_{y=1} = -\Phi_{II} > 0$ , so  $y^* = 0$  (weak) is ESS.

Now let us investigate the factors that affect  $\Phi_{II}$ , which describes the evolution speed towards the ESS. For the co-sanctioner, we are more interested in when a strong strategy is the ESS, so we focus on the case  $y^* = 1$ .

**Proposition 2.** *The co-sanctioner is more likely to engage in strong co-sanctions if the probability of the sanctionee adopting strong counter-sanctions passes a threshold ( $x > \bar{X}$ ), if the sanctioner has weaker strengths ( $P_0, P_1$ ), and if the co-sanctioner has stronger strengths ( $Q$ ).*

**Proof of Proposition 2.** The condition  $\Phi_{II} > 0$  implies that [11]D can be expressed as:

$$x > \frac{C_{II}}{MQ\{b - r + (r + d_{II})[P_0 + z(P_1 - P_0)]\}} \geq \frac{C_{II}}{MQ\{b - r + (r + d_{II}) \max\{P_0, P_1\}\}} \equiv \bar{X} \quad [12]$$

Note that in the denominator  $P_0 + z(P_1 - P_0) = (1 - z)P_0 + zP_1$  is a weighted average of  $P_0$  and  $P_1$ , so the term is always smaller than  $\max\{P_0, P_1\}$ . Thus, the denominator of  $x$  is always lower than that of  $\bar{X}$ , and the threshold condition  $x > \bar{X}$  always holds. The intuition is that Russia is expected to push its counter-sanctions over the threshold level  $\bar{X}$  eventually (according to **Proposition 1**), so a deterrence logic of sanctions does not apply. Rather, a punitive logic is more suitable. In this case, co-sanction is preferred by the EU as Russia raises its counter-sanctions. Quoting the old saying, “The enemy of my enemy is my friend,” a stronger enemy can strengthen the bonds between allies.

The probability distribution of  $y^* = 1$  as an ESS can be obtained by integrating the condition  $\Phi_{II} > 0$  over the domain  $x \in [\bar{X}, 1]$  and  $y \in [0, 1]$ . Combine with the definition in [11]D and the additional domain restriction of [12], we have:

$$\Pr(y^* = 1) = \Pr(\Phi_{II} > 0) = \Pr\left(z(P_1 - P_0) > \frac{\frac{c_{II}}{xMQ} + r - b}{r + d_{II}} - P_0\right) \quad [13]$$

There are two cases to discuss. If  $P_1 > P_0$ , then [13] can be written as:

$$\begin{aligned} \Pr(y^* = 1) &= \Pr(x > \bar{X}) - \Pr\left(z < \frac{\frac{c_{II}}{xMQ} + r - b}{(P_1 - P_0)(r + d_{II})} - \frac{P_0}{P_1 - P_0}\right) \\ \Pr(y^* = 1) &= \iint_{x=\bar{X}, y=0}^1 dx dy - \iint_{x=\bar{X}, y=0}^1 \left[ \frac{\frac{c_{II}}{xMQ} + r - b}{(P_1 - P_0)(r + d_{II})} - \frac{P_0}{P_1 - P_0} \right] dx dy \\ \Pr(y^* = 1) &= \frac{\frac{c_{II}}{MQ} \ln \bar{X} + [b - r + P_1(r + d_{II})](1 - \bar{X})}{(P_1 - P_0)(r + d_{II})} \end{aligned} \quad [14]$$

If  $P_1 < P_0$ , then [13] can be written as:

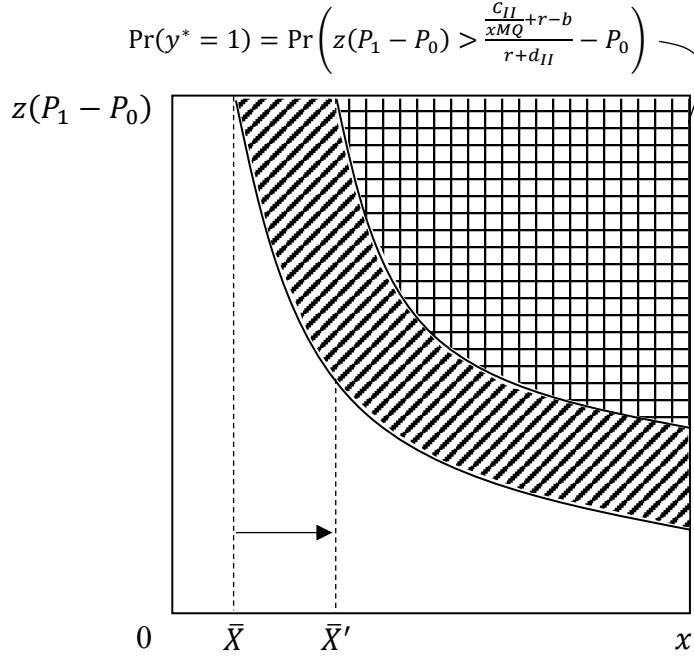
$$\begin{aligned} \Pr(y^* = 1) &= \Pr\left(z < \frac{\frac{c_{II}}{xMQ} + r - b}{(P_1 - P_0)(r + d_{II})} - \frac{P_0}{P_1 - P_0}\right) \\ \Pr(y^* = 1) &= \iint_{x=\bar{X}, y=0}^1 \left[ \frac{\frac{c_{II}}{xMQ} + r - b}{(P_1 - P_0)(r + d_{II})} - \frac{P_0}{P_1 - P_0} \right] dx dy \\ \Pr(y^* = 1) &= \frac{\frac{c_{II}}{MQ} \ln \bar{X} + [b - r + P_0(r + d_{II})](1 - \bar{X})}{(P_0 - P_1)(r + d_{II})} \end{aligned} \quad [15]$$

The two cases [14] and [15] can be succinctly combined in one equation:

$$\Pr(y^* = 1) = \Pr(\Phi_{II} > 0) = \frac{\frac{c_{II}}{MQ} \ln \bar{X} + [b - r + \max\{P_0, P_1\}(r + d_{II})](1 - \bar{X})}{|P_1 - P_0|(r + d_{II})} \quad [16]$$

It is difficult to see the threshold effect of  $\bar{X}$  on  $\Pr(y^* = 1)$  by taking derivative of [16] with respect to  $\bar{X}$ . However, it is easier to visualize the effect based on condition [14] under different  $\bar{X}$ s as illustrated in Figure 2. As the threshold  $\bar{X}$  rises, it becomes more difficult for the threshold condition to be satisfied, so the probability  $\Pr(y^* = 1)$  shrinks. Thus, the threshold effect is negative, i.e.,  $\frac{\partial \Pr(y^*=1)}{\partial \bar{X}} < 0$ .

Figure 2 Threshold effect of sanctionee's strategy on co-sanctioner's strategy



Turn to the effects of strengths on  $\Pr(y^* = 1)$ . It is straightforward to see that  $\frac{\partial \Pr(y^*=1)}{\partial Q} > 0$  from [16] noting that  $\ln \bar{X} < 0$ .  $\frac{\partial \Pr(y^*=1)}{\partial P_0} < 0$  and  $\frac{\partial \Pr(y^*=1)}{\partial P_1} < 0$  can be proven in a similar way as the one in the Appendix. The positive effect of  $Q$  on  $y^*$  chimes with the famous quote in *The Art of War*, “Victorious warriors win first and then go to war, while defeated warriors go to war first and then seek to win.” And the negative effects of  $P$  on  $z^*$  is an example of strategic substitutability, since sanctions and co-sanctions are substitutable.

### 3.3 Replicator Dynamics of the Sanctioner

The replicator dynamics of the US's mixed strategy ( $z$ ) at time  $t$  can be written as:

$$\dot{z} \equiv \frac{dz}{dt} = z(\overline{U_{III}(1)} - \bar{U}_{III}) = z(1 - z)\Phi_{III}, \text{ where:} \quad [17]$$

$$\overline{U_{III}(1)} = x[yF_{III}^{(1)} + (1 - y)F_{III}^{(2)}] + (1 - x)[yF_{III}^{(5)} + (1 - y)F_{III}^{(6)}] \quad [17]A$$

$$\overline{U_{III}(0)} = x[yF_{III}^{(3)} + (1-y)F_{III}^{(4)}] + (1-x)[yF_{III}^{(7)} + (1-y)F_{III}^{(8)}] \quad [17]B$$

$$\bar{U}_{III} = z\overline{U_{III}(1)} + (1-z)\overline{U_{III}(0)} \quad [17]C$$

$$\Phi_{III} \equiv xM(1-yQ)(d_I + d_{II} + \gamma)(P_1 - P_0) - C_{III} \quad [17]D$$

If  $\Phi_{III} = 0$ , then the US always keeps its initial strategy whatsoever since  $\dot{z} = 0$ . In general, if  $\Phi_{III} \neq 0$ , then imposing the steady state condition  $\dot{z} = 0$  on equation [17] results in two stationary points, i.e.,  $z = 0$  and  $z = 1$ . To investigate the evolutionary stationarity of the two points, take derivative of [17] with respect to  $z$ , we have  $\frac{d\dot{z}}{dz} = \Phi_{III}(1 - 2z)$ . There are two possibilities:

- If  $\Phi_{III} > 0$ , then  $\frac{d\dot{z}}{dz}\big|_{z=0} = \Phi_{III} > 0$  and  $\frac{d\dot{z}}{dz}\big|_{z=1} = -\Phi_{III} < 0$ , so  $z^* = 1$  (strong) is ESS.
- If  $\Phi_{III} < 0$ , then  $\frac{d\dot{z}}{dz}\big|_{z=0} = \Phi_{III} < 0$  and  $\frac{d\dot{z}}{dz}\big|_{z=1} = -\Phi_{III} > 0$ , so  $z^* = 0$  (weak) is ESS.

The key determinant of replicator dynamics is  $\Phi_{III}$ , which describes the evolution speed towards the ESS. Now let us investigate the factors that affect  $\Phi_{III}$ . For the sanctioner, we are more interested in when a strong strategy is the ESS, so we focus on the case  $z^* = 1$ .

**Proposition 3.** *The sanctioner is more likely to engage in strong sanctions if the probability of the sanctionee adopting strong counter-sanctions passes a threshold ( $x > \tilde{X}$ ) and if the co-sanctioner has weak strengths of sanctions ( $Q$ ).*

**Proof of Proposition 3.** Note that if  $P_1 < P_0$ , then  $\Phi_{III} < 0$  always holds, so it leads to the ESS of  $z^* = 0$ . To have  $z^* = 1$ ,  $P_1 > P_0$  must always holds. In this case, the condition  $\Phi_{III} > 0$  implies that:

$$x > \frac{C_{III}}{M(1-yQ)(d_I + d_{II} + \gamma)(P_1 - P_0)} \equiv \tilde{X} \quad [18]$$

The right-hand side of [18] is the threshold level ( $\tilde{X}$ ) of sanctionee adopting the strong strategy for the sanctioner to converge to the strong strategy  $y = 1$  (in contrast to the threshold level of  $\bar{X}$  for the co-sanctioner). Therefore, the condition  $x > \tilde{X}$  must be satisfied to have  $z^* = 1$ . The intuition behind this threshold condition is that, as Russia tends for strong counter-sanctions ( $x \rightarrow 1$ ), then the US is more likely to choose expanded sanctions. It is a type of *strategic complementarity* similar to the prisoner's dilemma. The probability distribution of  $z^* = 1$  as an ESS can be obtained by integrating the condition  $\Phi_{III} > 0$  over the domain  $y, z \in [0, 1]$ . Combine with the definition in [17]D and the additional domain restriction of [18], we have:

$$\Pr(z^* = 1) = \Pr(\Phi_{III} > 0) = 1 - \Pr(x < \tilde{X})$$

$$\Pr(z^* = 1) = 1 - \iint_{y,z=0}^1 \frac{C_{III}}{M(1-yQ)(d_I+d_{II}+\gamma)(P_1-P_0)} dydz$$

$$\Pr(z^* = 1) = 1 + \frac{1}{Q} \ln(1 - Q) \frac{C_{III}}{M(d_I+d_{II}+\gamma)(P_1-P_0)} \quad [19]$$

Similar to the co-sanctioner's problem, the threshold effect of  $\tilde{X}$  on  $\Pr(z^* = 1)$  can be shown to be negative, or  $\frac{\partial \Pr(z^*=1)}{\partial \tilde{X}} < 0$ , because a higher level of the threshold makes it more difficult to pass, so less likely to converge to the strong strategy.

Now turn to the effects of strengths of sanctions on  $\Pr(y^* = 1)$ . We can use the same technique in the sanctionee's problem to prove that  $\frac{\partial \Pr(z^*=1)}{\partial Q} < 0$  from [19]. This property suggests that if the co-sanctioner (EU) has great strengths of sanctions ( $Q$ ), then the leading sanctioner (US) is less motivated to adopt the strong strategy. This is a free ride problem due to the non-rival and non-exclusive nature of sanctions against the common sanctionee. This subtle issue can cause coordination failure between sanctioners and co-sanctioners in practice.

The effects of  $P_0$  and  $P_1$  on  $\Pr(z^* = 1)$  are opposite. Based on [19], we can easily see that  $\frac{\partial \Pr(z^*=1)}{\partial P_0} > 0$  and  $\frac{\partial \Pr(z^*=1)}{\partial P_1} < 0$ . The conclusion on the positive effect of  $P_0$  is straightforward—greater strengths of sanctions encourage the sanctioner to adopt a strong strategy. The negative effect of  $P_1$ , however, appears new. In fact, this conclusion is consistent with the effect of  $Q$ . To see this, note that  $P_1$  measures the strengths of sanctions if either the sanctioner or the co-sanctioner adopts a strong strategy. When  $P_1$  rises, it implies that the co-sanctioner can inflict substantial impact on the sanctionee. As argued earlier, the sanctioner is motivated to take a free ride and specializes in basic sanctions with less cost.

### 3.4 Strategic Dependence

To better understand the three propositions, we take the perspective of strategic dependence. In general, there are two types of strategic dependence. If the strategies are positively correlated, then it is called **strategic complementarity**. A classic example of such is prisoner's dilemma where both players tend to choose the same strategy. The other is **strategic substitutability**, in which strategies of different players tend to move in opposite directions. The implied strategic dependence of the three hypotheses can be efficiently organized in the impulse-response matrix (Table 3), noting that the dependence may vary if the impulse occurs on different sides of the pair. The impulse can be any exogenous changes in the structural parameters of any players.

To understand how Table 3 is mapped from the three propositions, take proposition 1 as an example. Any exogenous changes leading to a stronger sanction is an impulse on the sanctioner side (e.g., a higher  $P \rightarrow$  a higher  $x$ ). It implies a weaker strategy for the sanctionee as a response (a lower  $x$ ) according to proposition 1. This is an example of strategic substitutability, so we have an input of “substitutability” on the first row (impulse: sanction) third column (response: sanctionee). Use proposition 2 as another example. Any exogenous changes resulting in a stronger counter-sanction is an impulse on the sanctionee side (e.g., a lower cost of  $C_I \rightarrow$  a higher  $x$ ). It implies a stronger strategy for the co-sanctioner (a higher  $y$ ), which is an example of strategic complementarity at the third row (impulse: sanctionee) second column (response: co-sanctioner).

Table 3 Strategic dependence among the three players in the evolutionary game

		Response		
		Sanctioner	Co-Sanctioner	Sanctionee
Impulse	Sanctioner	–	substitutability	substitutability
	Co-Sanctioner	substitutability	–	substitutability
	Sanctionee	complementarity	complementarity	–

There are various ways of exogenous impulses, such as changes in benefits received by the three players (benefit-related parameters), costs paid by the three players (cost-related parameters), and strengths measured by probabilities of successful sanctions (probability-related parameters). Specifically, the strengths/probabilities ( $P_0, P_1, Q$ ) are key structural parameters which are assumed exogenous in the model up to now. To further understand how sanctions and co-sanctions are developed, we extend the model by introducing the sanction technology to endogenize these probabilities.

#### 4 Extension: Decisions on Sanction Technologies

In the sanction model above, we assume different sanction strengths under the weak strategy ( $P_0$ ) and under the strong strategy ( $P_1$ ), but these probabilities are treated as exogenous. In practice, the sanctioner (US) can also make an *ex ante* decision on “sanction technology” (sanction development), in addition to the *ex post* decision on sanction strategy (sanction deployment). This section attempts to endogenize the decision on sanction development.

Early literature usually argues for an unconditional conclusion that either unilateral (Kaempfer & Lowenberg, 1999) or multilateral (Haass, 1997) sanctions are more effective. Recent development in the field has identified various conditions under which unilateral or multilateral sanctions can be more effective (Early & Spice, 2015; Weber & Schneider, 2020). Our model specifies three competing choices of sanction technologies for the US including basic sole-

sanctions, expanded sole-sanctions, and expanded co-sanctions. The choice is endogenously determined by rational optimization.

If the weak strategy is adopted, the probability of successful interventions,  $P_0$ , is determined by the given “technology” of developing unilateral, basic sole-sanctions:

$$P_0 = \eta \times (1 - C_B) \quad [20]$$

where 1 represents the 100% resources allocated to dealing with Russia issues,  $0 \leq C_B \leq 1$  is the fixed costs of sanction development, and  $0 \leq \eta \leq 1$  is the productivity of the sanction technology. The “output”  $P_0$  is the probability of successful interventions, representing the baseline strengths of sanctions of the US against Russia.

If the strong strategy is adopted instead, there are two further choices. First, it can solely rely on its domestic resources to develop unilateral sanctions (expanded sole-sanctions). In this case, the probability of successful interventions  $P_1$  is “produced” by:

$$P_1 = \mu(l_E - C_E) \times (l_B - C_B) \quad [21]$$

where  $0 \leq l_E \leq 1$  is the foregone resources allocated to expanded sanctions and  $l_B = 1 - l_E$  is the rest of resources allocated to basic sanctions.  $C_B$  and  $C_E$  are fixed costs of the two types of sanction measures respectively, while  $0 \leq \mu \leq 1$  represents the productivity of sanctions. In fact, the term  $\mu(l_E - C_E)$  can be interpreted as  $\eta$ , noting that if  $l_E = 0$ , [21] becomes [20]. Given all the assumptions, the leading sanctioner (US) solves the maximization problem:

$$\max_{l_B, l_E} P_1, \text{ subject to: } l_B + l_E = 1$$

The optimal choices in the case of sole-sanctions are:

$$l_E^* = \frac{1+C_E-C_B}{2} \text{ and } l_B^* = \frac{1-C_E+C_B}{2}, \text{ so } P_1^* = \frac{1}{4}\mu(1 - C_B - C_E)^2$$

Alternatively, the US can coordinate with its allies (such as the EU, the UK, Canada, Australia, New Zealand, Japan, etc.) to collectively sanction Russia (expanded co-sanctions). The impact of co-sanctions is non-exclusive and non-rival, so all resources in the US ( $1 - C_B$ ) can be saved for basic political negotiations, while all resources in the EU ( $1 - C_E$ ) can be used for expanded economic sanctions—“division of labor” in international political economy. In the equation

below,  $0 \leq \lambda \leq 1$  is the productivity of co-sanctions. However, coordination failure among allies can reduce the impact of co-sanctions by a factor of  $k$ . The probability  $P_1$  is therefore equal to:

$$P_1^{**} = (1 - k)\lambda(1 - C_E) \times (1 - C_B) \quad [22]$$

Therefore, the optimal choice depends on the maximum of  $P_1^*$  and  $P_1^{**}$ . To investigate the effects of different factors on the decision, we take difference between the two and treat  $Z \equiv 1 - C_E - C_B \in [-1, 1]$ . The difference can be expressed as a quadratic function of  $Z$ :

$$P_1^* - P_1^{**} = \frac{1}{4}\mu Z^2 - (1 - k)\lambda(Z + C_E C_B)$$

$$P_1^* - P_1^{**} = \left(\frac{1}{4}\mu\right) \times Z^2 - (1 - k)\lambda \times Z - (1 - k)\lambda C_B C_E \equiv f(Z) \quad [23]$$

According to the property of quadratic functions,  $f(Z)$  has two distinct real roots because  $\Delta \equiv (1 - k)^2 \lambda^2 + \mu(1 - k)\lambda C_B C_E$  is obviously always positive. Denote the two real roots as  $Z_1$  and  $Z_2$  ( $Z_1 < Z_2$ ). In addition, we know that  $f(0) = -(1 - k)\lambda C_B C_E < 0$ , so the smaller root must be negative ( $Z_1 < 0$ ). Also, the minimum of the function lies in the positive domain  $\frac{2(1-k)\lambda}{\mu} > 0$ , so the bigger root must be positive ( $Z_2 > 0$ ). At the lower bound  $-1$ , the function returns  $f(-1) = \frac{1}{4}\mu + (1 - k)\lambda(1 - C_B C_E) > 0$ , but at the upper bound  $1$ , the sign of  $f(1) = \frac{1}{4}\mu - (1 - k)\lambda(1 + C_B C_E)$  is ambiguous. Combine all the information above on  $f(Z)$ , we can illustrate two possibilities:  $f(1) < 0$  and  $f(1) > 0$  in Table 4 suggests that which way of sanctions to choose boils down to a cost-benefit analysis. If the costs of developing sanctions ( $C_B, C_E$ ) are high compared to the productivity ratio between sole-sanctions ( $\mu$ ) and co-sanctions ( $\lambda(1 - k)$ ), then the US is more likely to choose sole-sanctions over co-sanctions (case 1 and case 3). Nevertheless, if the productivity ratio is high, then the US is also tempted to conduct sole-sanctions even if the costs are low (case 5). These cases are in line with the findings of Weber & Schneider (2020).

Figure 3. Based on Table 4 suggests that which way of sanctions to choose boils down to a cost-benefit analysis. If the costs of developing sanctions ( $C_B, C_E$ ) are high compared to the productivity ratio between sole-sanctions ( $\mu$ ) and co-sanctions ( $\lambda(1 - k)$ ), then the US is more likely to choose sole-sanctions over co-sanctions (case 1 and case 3). Nevertheless, if the productivity ratio is high, then the US is also tempted to conduct sole-sanctions even if the costs are low (case 5). These cases are in line with the findings of Weber & Schneider (2020).

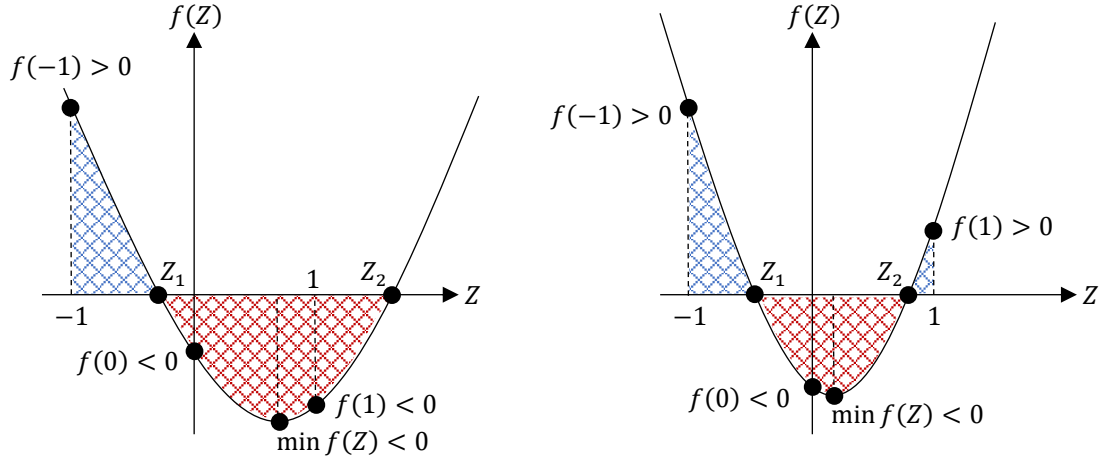
Figure 3, we can summarize five cases across the parameter space (Table 4). The decision depends on the relationship between cost parameters ( $C_B, C_E$ ) and productivity parameters ( $\lambda, \mu, k$ ).

Table 4 The decision on expanded sanction technology

	$f(1)$	$Z$		Decision
(1)	$1 + C_B C_E > \frac{\mu}{4\lambda(1-k)}$	$1 - C_B - C_E \in [-1, Z_1]$	$P^* > P^{**}$	sole-sanctions
(2)		$1 - C_B - C_E \in [Z_1, Z_2]$	$P^* < P^{**}$	co-sanctions
(3)	$1 + C_B C_E < \frac{\mu}{4\lambda(1-k)}$	$1 - C_B - C_E \in [-1, Z_1]$	$P^* > P^{**}$	sole-sanctions
(4)		$1 - C_B - C_E \in [Z_1, Z_2]$	$P^* < P^{**}$	co-sanctions
(5)		$1 - C_B - C_E \in [Z_2, 1]$	$P^* > P^{**}$	sole-sanctions

Table 4 suggests that which way of sanctions to choose boils down to a cost-benefit analysis. If the costs of developing sanctions ( $C_B, C_E$ ) are high compared to the productivity ratio between sole-sanctions ( $\mu$ ) and co-sanctions ( $\lambda(1-k)$ ), then the US is more likely to choose sole-sanctions over co-sanctions (case 1 and case 3). Nevertheless, if the productivity ratio is high, then the US is also tempted to conduct sole-sanctions even if the costs are low (case 5). These cases are in line with the findings of Weber & Schneider (2020).

Figure 3 Differences in strengths between sole-sanctions and co-sanctions



## 5 Numerical Simulations

This section calibrates the model to demonstrate dynamics of the trilateral evolutionary game. The structural parameters of the model (summarized in Table 5) belong to three categories: (i) benefit-related parameters ( $M, b, r, d_I, d_{II}$ ), (ii) cost-related parameters ( $a, C_I, C_{II}, C_{III}, \gamma$ ), and (iii) probability-related parameters ( $P_0, P_1, Q$ ). Note that probabilities of successful sanctions ( $P_0, P_1$ ) are endogenous variables once sanction technology ( $C_B, C_E, \eta, \mu, \lambda, k$ ) is introduced.

To make calibration realistic and meaningful, magnitudes are normalized by the illegal claim  $M = 1$ , since it is the starting point of the game. Therefore, the benefits of the EU ( $b = 0.2 > 0.1 = r$ ) and the US ( $d_I = 0.4 > 0.1 = d_{II}$ ) are all defined relative to 1.

The same applies to the cost-related parameters. The fixed costs of the US ( $C_{III} = 0.2$ ) is assumed to be greater than those of the EU and Russia ( $C_I = C_{II} = 0.1$ ) because the US is the leading sanctioner responsible for both development and deployment of sanctions. The fixed costs of developing basic sanctions are assumed to be more than expanded sanctions ( $C_B > C_E$ ) because the latter are extensions based on the former. The negative effect of the Russian illegal claim to the US ( $\gamma$ ) is assumed to be greater than  $M$  due to its negative externality effect on European geopolitics.

Table 5 Summary of symbols of parameters and variables

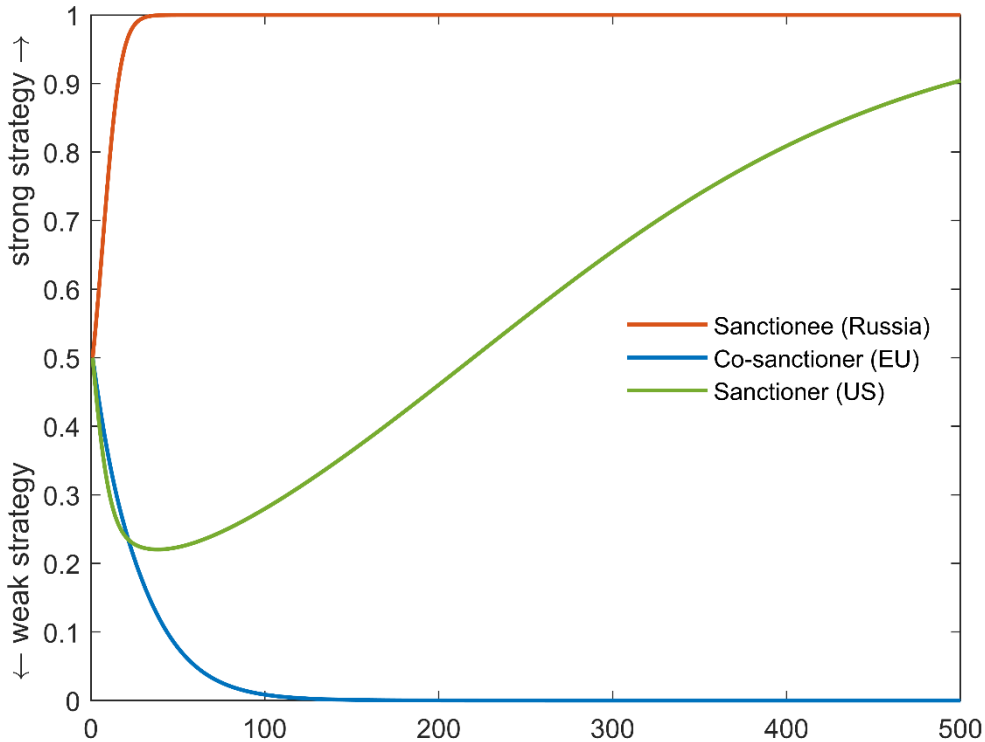
Symbol		Definition	Baseline
Benefit Related	$M$	The illegal claim	1
	$b$	Benefit to the EU if sanctions are successful	0.2
	$r$	Benefit to the EU if sanctions are unsuccessful	0.1
	$d_I$	Reduction of Russian illegal claim paid to the US	0.4
	$d_{II}$	Reduction of the EU benefits paid to the US	0.1
Cost Related	$a$	Marginal cost of counter-sanctions	0.05
	$C_I$	Fixed cost of deploying counter-sanctions	0.1
	$C_{II}$	Fixed cost of deploying co-sanctions	0.1
	$C_{III}$	Fixed cost of deploying sanctions	0.2
	$\gamma$	Negative effect of the Russian illegal claim to the US	1.5
Probability Related	$\eta$	Productivity of basic sanctions	0.5
	$\mu$	Productivity of expanded sole-sanctions	1
	$\lambda$	Productivity of expanded co-sanctions	1
	$k$	Loss of efficiency due to coordination failure in co-sanctions	0.3
	$C_B$	Fixed cost of developing basic sanctions, e.g., entity list	0.2
	$C_E$	Fixed cost of developing expanded sanctions, e.g., finance	0.1
	$Q$	Probability of success by the EU	0.3
	$P = P_0$	Probability of success by the US under basic sanctions	Endogenous
	$P = P_1$	Probability of success by the US under expanded sanctions	Endogenous
	$l_B$	Resources allocated to basic sanctions	Endogenous
	$l_E$	Resources allocated to expanded sanctions	Endogenous
Strategy	$x$	Russia's strategy: 0 = weak; 1 = strong	$x_0 = 0.5$
	$y$	EU's strategy: 0 = weak; 1 = strong	$y_0 = 0.5$
	$z$	US's strategy: 0 = weak; 1 = strong	$z_0 = 0.5$

Probability-related parameters are either exogenously fixed ( $Q$ ) or endogenously determined ( $P$ ) by comparing different types of sanction technologies. If weak strategy is adopted by the US, then the productivity of sanctions ( $\eta$ ) is assumed to be less than those under strong strategies ( $\mu, \lambda$ ) because  $P_1 = 0.504$  is greater than  $P_0 = 0.4$  under the baseline calibration. Moreover, we can also verify that  $1 - C_B - C_E = 0.7$  lies between the two roots of equation [23],  $Z_1 = -0.0621$  and  $Z_2 = 0.9021$ . Therefore, it falls to case 2 of Table 4, and the optimal strong

sanction technology is co-sanctions ( $P_1^{**} = 0.5040$ ), which are more effective than sole-sanctions ( $P_1^* = 0.1225$ ). This is also what happened in practice. The implied optimal allocations of political resources between basic and expanded sanctions are  $l_B = 0.55$  and  $l_E = 0.45$ .

Under the baseline calibration, the ESS strategies are  $x^* = 1$ ,  $y^* = 0$ , and  $z^* = 1$ . It predicts that Russia will stick to strong counter-sanctions in response to strong sanctions imposed by the US, while the EU will eventually choose weak co-sanctions. We can also simulate the evolutionary paths of optimal strategies of the three players based on replicator dynamics (Figure 4). It is shown that, Russia fast converges to its ESS strategy (strong counter-sanctions) around 30 periods, while it takes the EU about 180 periods to converge to its ESS strategy (weak co-sanctions). In contrast, the evolutionary path of the US strategy displays a hump-shape—it first becomes weaker and then bounces back stronger. The turning point occurs around 40 periods, after when Russia sticks to strong counter-sanctions. The adjustment speed of the US is very slow, only converging to its ESS (strong sanctions) in about 1000 periods. Based on the analysis of replicator dynamics and the simulation, the convergence speeds of the three players follow that  $|\Phi_I| > |\Phi_{II}| > |\Phi_{III}|$ .

Figure 4 Evolutionary paths of the baseline model



The simulated evolutionary paths can even quantitatively match the timing of the historical stages summarized in introduction. If we treat a period as one day, then Russia made its mind

within one month to act strong against all sanctions (Stage 1). The EU phased out from strong co-sanctions to weak co-sanctions when the Minsk protocol was signed in half a year (Stage 2). In contrast, the US first imposed basic sanctions initially (Stage 1) and slowly expanded its sanctions over the following three years (Stage 2 and 3).

The baseline calibration can replicate the observed historical interactions among the three players in the sanction game. Now we turn to the effects of structural parameters on the ESS strategies and the associated replicator dynamics. We focus on effects of a selection of key parameters in the following subsections.

### 5.1 Effects of Benefit-Related Parameters

There are five benefit-related parameters ( $M, b, r, d_I, d_{II}$ ). The benefit of the illegal claim to Russia,  $M$ , is the numeraire, so changes in other parameters reflect relative changes to  $M$ . The benefit to the EU under successful sanctions cannot be less than that that under unsuccessful sanctions ( $b \geq r$ ), so we range  $b$  from 0.1 to 0.3 and  $r$  from 0 to 0.2 to see the effect of the benefit parameters of the EU. As shown in Figure 5, a rise in  $b$  does not affect Russia's strategy much. However, a greater  $b$  motivates the EU to actively engage in co-sanctions, leading to a longer duration of a stronger strategy. Reversely, it induces the US to adopt a weaker strategy at the beginning, since the EU is doing the job for the team. It verifies the strategic substitutability at row 2 column 1 of Table 3. Nevertheless, changes in  $b$  only alter the convergence speeds, rather than the ESS of all three players. Expectedly, the effect of the other benefit parameter of the EU ( $r$ ) is opposite to that of  $b$ , because the two benefit parameters usually appear in pairs in the form of  $b - r$  in the solutions. Appendix 2 verifies this conjecture.

Figure 5 Effects of  $b$  on ESS and replicator dynamics

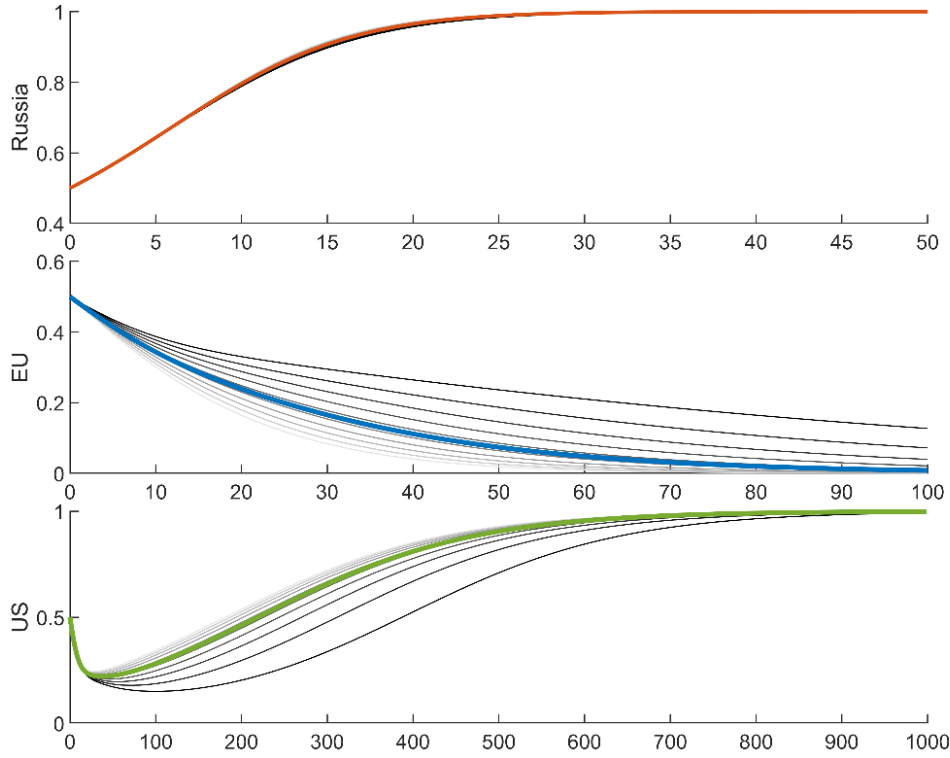


Figure notes: The coloured curves are based on the baseline calibration ( $b = 0.2$ ). The grey curves are based on  $b \in [0.1, 0.3]$ , with the lightest being the lower bound and the darkest being the upper bound.

The benefit of the US is obtained from the deductions of the benefits of Russia and the EU, captured by the two deduction parameters ( $d_I, d_{II}$ ). As shown in Figure 6, as  $d_I$  rises, the convergence speed of Russia to strong counter-sanctions becomes slower. This result is in line with the strategic substitutability at row 1 column 3 of Table 3. Reversely, the US is more motivated to engage in strong sanctions as the benefit rises. It is noted that if  $d_I$  is too low (e.g.,  $d_I = 0.3$ ), the US may choose weak sanctions as the ESS instead of strong sanctions. Given that  $d_I$  works on Russia, there is trivial effect on the EU.

The other benefit parameter of the US is  $d_{II}$ , which describes the benefit requested from the EU. A lower  $d_{II}$  motivates the EU to engage in strong sanctions while the US has less incentive to deploy strong sanctions. This strategic substitutability is predicted at row 1 column 2. At extremely low levels of  $d_{II}$ , the ESS can switch between strong and weak sanctions for the EU and the US (Appendix 2). To summarize,  $d_I$  reflects the power of the US relative to Russia, and  $d_{II}$  reflects the power of the US relative to the EU. A rise in either motivates the US to engage in strong sanctions, because the benefit received by the US comes from both Russia and the EU.

Figure 6 Effects of  $d_I$  on ESS and replicator dynamics

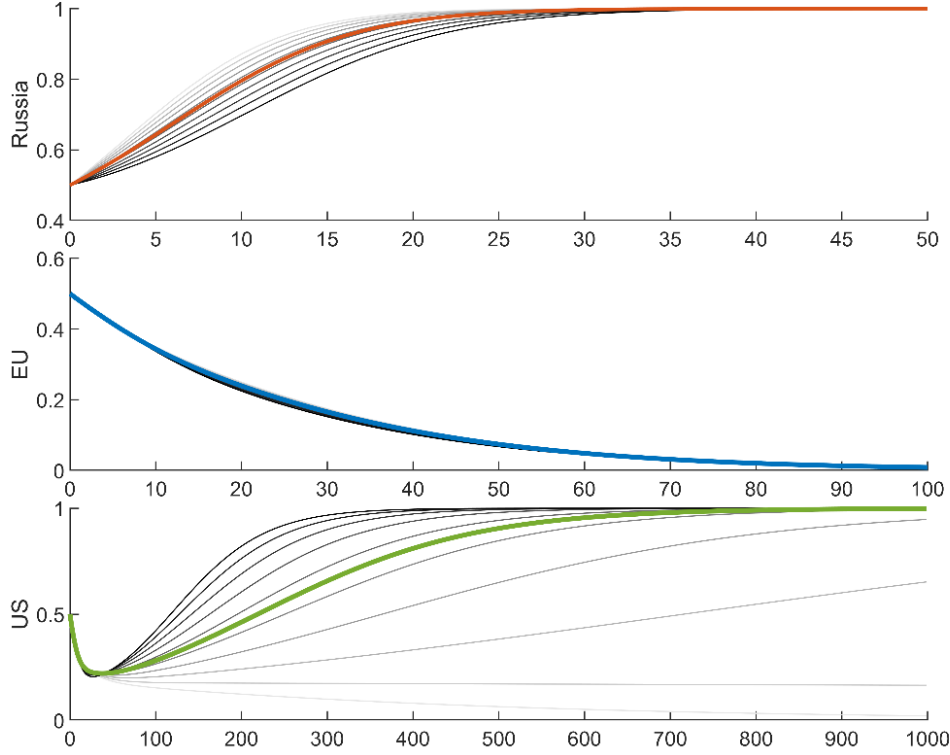


Figure notes: The coloured curves are based on the baseline calibration ( $d_I = 0.4$ ). The grey curves are based on  $d_I \in [0.3, 0.5]$ , with the lightest being the lower bound and the darkest being the upper bound.

## 5.2 Effects of Cost-Related Parameters

Among all cost-related parameters,  $C_I, C_{II}, C_{III}$  dominate changes in costs since a different value of  $a$  and  $\gamma$  can always be interpreted as changes in  $C_I$  and  $C_{III}$ . This subsection therefore focuses on the analysis of the three cost parameters.

As shown in Figure 7, a higher counter-sanction cost ( $C_I$ ) for Russia steers Russia away from a strong strategy with a prolonged convergence speed. It also reduces the necessity of deploying strong sanctions for the US at the same time. A similar effect is seen for the EU, but the magnitude is much smaller. Again, we see the pattern of *strategic complementarity* between the sanctionee and the sanctioners when there is an exogenous change on the sanctionee side. Moreover, it is noted that Russia may give up the strong strategy if the cost of counter-sanctions is too high (e.g.,  $C_I = 0.4$ ). In fact, as shown in earlier and later simulations, the ESS of Russia is extremely stubborn to converge to strong counter-sanctions. Changes in other parameters (e.g., benefit-related and probability-related parameters) can prolong its convergence but are unlikely to overturn the long-run strategy. The only possible way to coerce Russia to give up strong counter-sanctions seems to be increasing the cost of counter-sanctions ( $C_I$ ). As the old saying goes, the opportunity of defeating the enemy is provided by the enemy himself.

Figure 7 Effects of  $C_I$  on ESS and replicator dynamics

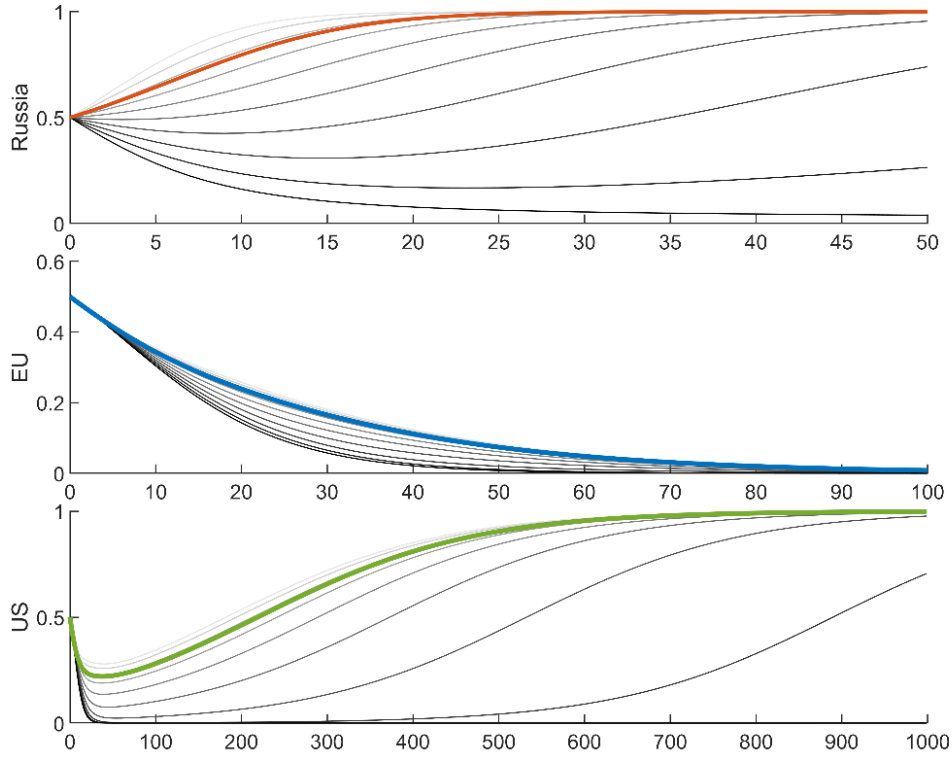


Figure notes: The coloured curves are based on the baseline calibration ( $C_I = 0.1$ ). The grey curves are based on  $C_I \in [0, 0.4]$ , with the lightest being the lower bound and the darkest being the upper bound.

In Figure 8, a higher co-sanction cost ( $C_{II}$ ) for the EU significantly discourages the EU to adopt a strong strategy, while pushing the US to the frontline of confronting Russia. At very high levels of  $C_{II}$ , the ESS can even switch between strong and weak strategies for both the US and the EU. This is another case for strategic substitutability between the leading sanctioner and the co-sanctioner. Moreover, in response of the weaker strategy of the co-sanctioner, Russia is more likely to engage in a stronger strategy. This is a case for the abovementioned pattern of strategic substitutability when exogenous changes occur on the sanctioner side.

Figure 8 Effects of  $C_{II}$  on ESS and replicator dynamics

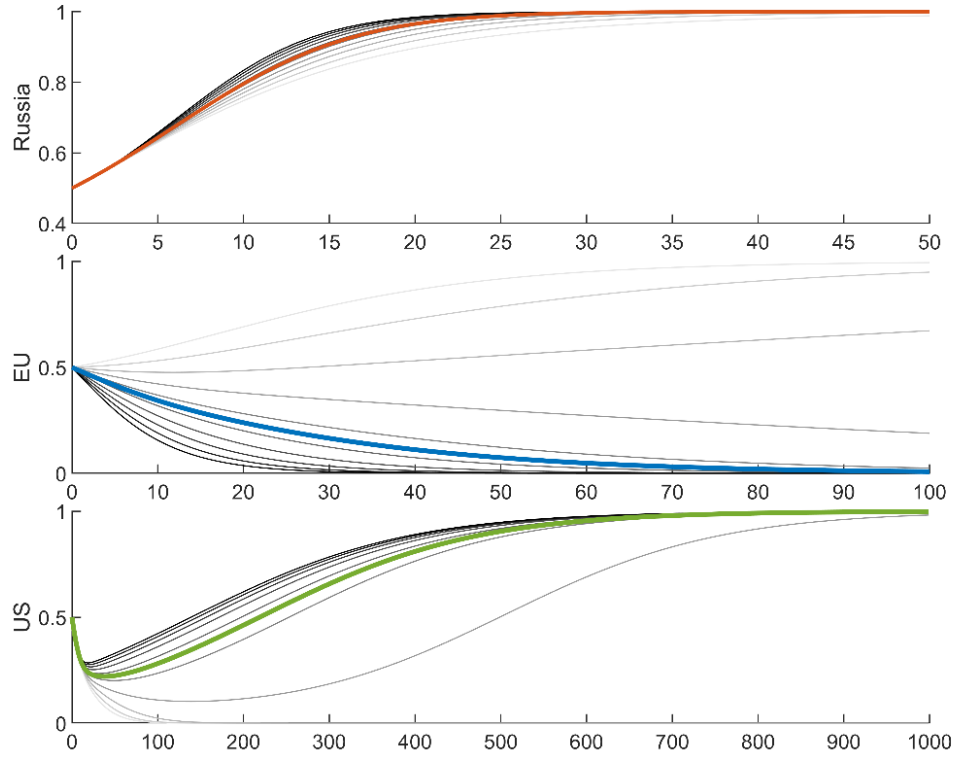


Figure notes: The coloured curves are based on the baseline calibration ( $C_{II} = 0.1$ ). The grey curves are based on  $C_{II} \in [0, 0.2]$ , with the lightest being the lower bound and the darkest being the upper bound.

Finally, Figure 9 shows the effect of sanction cost ( $C_{III}$ ) for the US. It does not have much effect on Russia or EU's strategies, but the US strategy is sensitive to different values of  $C_{III}$ . A lower sanction cost encourages the US to choose a stronger strategy sooner, while a higher sanction cost keeps the US away from the strong strategy. At high cost levels, it can even lead the US to giving up strong sanctions. The pattern of strategic substitutability between the sanctioner and the sanctionee is again verified.

Figure 9 Effects of  $C_{III}$  on ESS and replicator dynamics

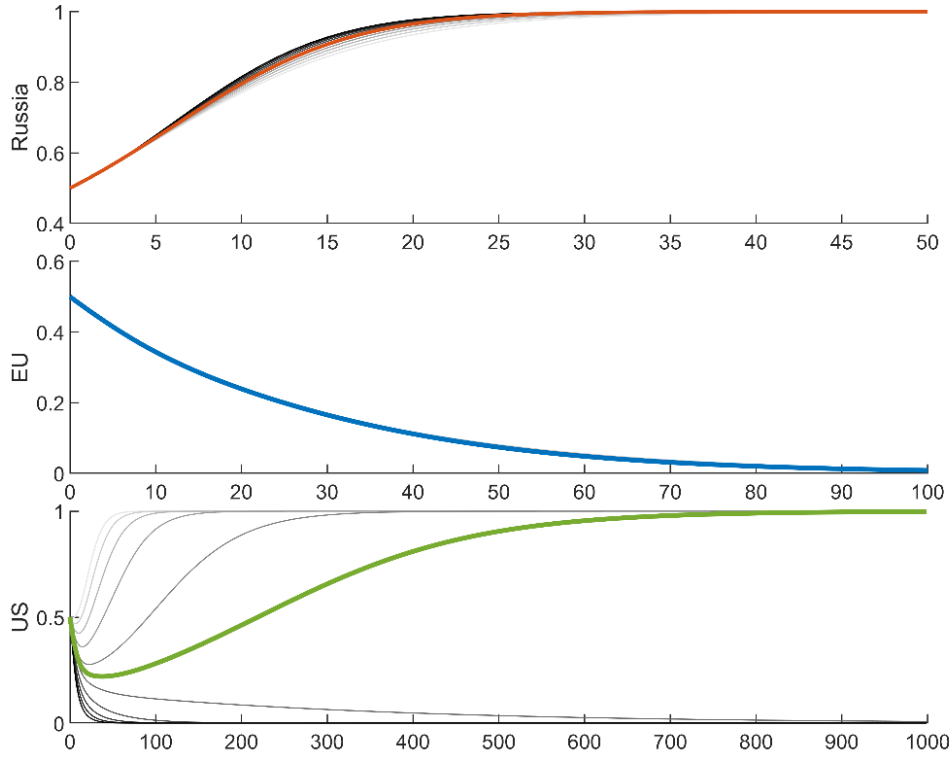


Figure notes: The coloured curves are based on the baseline calibration ( $C_{III} = 0.2$ ). The grey curves are based on  $C_{III} \in [0.1, 0.3]$ , with the lightest being the lower bound and the darkest being the upper bound.

### 5.3 Effects of Probability-Related Parameters

If we assume that the probabilities of successful sanctions ( $P_0, P_1, Q$ ) are exogenous, then we can demonstrate the three hypotheses derived in section 3. For example, Figure 10 demonstrates that a higher  $Q$  (a greater strength of the EU) can coerce Russia to adopt a weaker strategy. Therefore, strategic substitutability between the sanctioner and the sanctionee is found when the exogenous change comes from the sanctioner side (EU). Moreover, the effects on the US and the EU are opposite, confirming that the strategies of the sanctioner and the co-sanctioner are substitutable. Effects of exogenous changes in  $P_0$  and  $P_1$  are qualitatively similar, so will be omitted from the results here.

Figure 10 Effects of  $Q$  on ESS and replicator dynamics

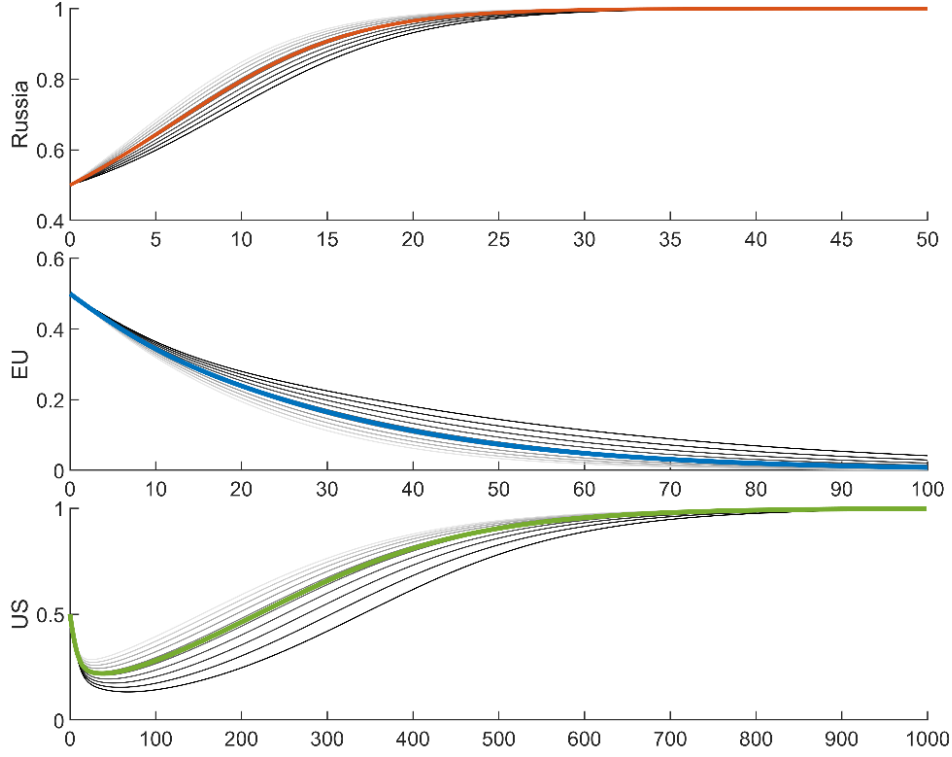


Figure notes: The coloured curves are based on the baseline calibration ( $Q = 0.3$ ). The grey curves are based on  $Q \in [0.2, 0.4]$ , with the lightest being the lower bound and the darkest being the upper bound.

If we endogenize the probabilities of successful sanctions ( $P_0, P_1$ ) for the leading sanctioner as in the extended model (section 4), changes in sanction technology parameters ( $C_B, C_E, \eta, \mu, \lambda, k$ ) can lead to endogenous changes in probabilities. It is observed that changes in productivities ( $\eta, \mu, \lambda$ ) can be absorbed by changes in costs ( $C_B, C_E$ ), so we will focus on the latter.

As the fixed cost of developing basic sanctions ( $C_B$ ) rises, the leading sanctioner (US) is discouraged to stick to the strong strategy (Figure 11). At higher levels of  $C_B$ , the US can even switch to a weak strategy. In this case, Russia tends to take the advantage and adopt a stronger strategy (i.e., strategic substitutability). However, there is little effect on EU's strategy. These patterns are found in other probability-related parameters, such as  $C_E$  and  $k$  (see Appendix 2).

Figure 11 Effects of  $C_B$  on ESS and replicator dynamics

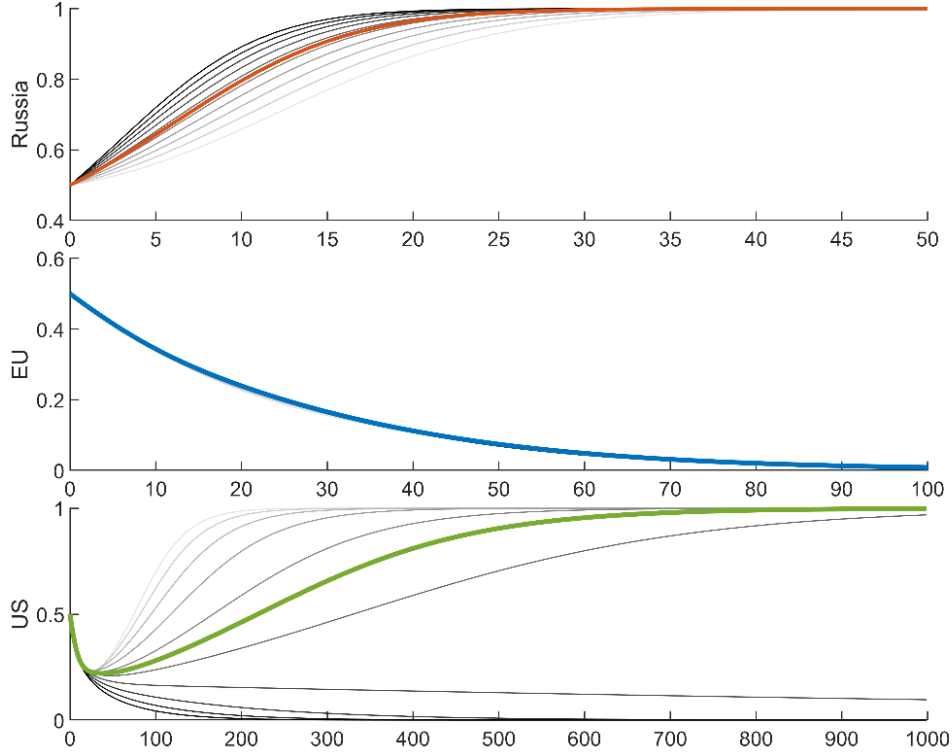


Figure notes: The coloured curves are based on the baseline calibration ( $C_B = 0.2$ ). The grey curves are based on  $C_B \in [0.1, 0.3]$ , with the lightest being the lower bound and the darkest being the upper bound.

## 6 Conclusion

This paper develops a multilateral, evolutionary game of sanctions to capture the strategic dependence and evolutionary dynamics of sanctions, co-sanctions, and counter-sanctions among three major global powers. The model can successfully match three important features summarized in Figure 1. First, strategic dependence between the sanctioners and the sanctionee depends on which side the exogenous change occurs. If it originates from the sanctioners, then it is strategic substitutability; if it originates from the sanctionee, then it is strategic complementarity. Second, there is strategic substitutability between the leading sanctioner's and the co-sanctioner's actions. It can be attributed to coordination failure among sanctioners or heterogeneous impact of counter-sanctions. The sanctioner's strategy becomes weaker first before converging to the strong strategy later, while the co-sanctioner's strategy is relatively stronger than the sanctioner initially but monotonically converging to the weak strategy eventually. Third, organizing co-sanctions is not always the optimal choice for the leading sanctioner. Under different sanction technologies and sanction costs, sole-sanctions can be more favourable. Apart from the qualitative success in replicating the dynamic features in the sanction history, the model can also match some quantitative features, such as the timing/duration of sanctions, co-sanctions, and counter-sanctions. For example, the convergence speeds to their ESSs of the three players can well match those in observed history.

Simulation results shed light on three important policy implications. First, the sanctionee has a super-stable choice of the strong strategy, robust to various scenarios and calibrations. This conclusion is similar to other studies in the literature (Dong & Li, 2018). We find that the only possible way of coercing the sanctionee to give up its strong counter-sanctions is to raise its costs of counter-sanctions, rather than increasing the strengths of sanctions or co-sanctions—which are only useful to prolong the convergence, but not strong enough to change the direction of the convergence. This finding is useful for sanctioning countries—it is not the most effective way to strengthen sanctions if the policy objective is to force the sanctionee to give up its illegal claims or reduce its counter-sanctions (Bělin & Hanousek, 2021). Instead, sanctioners should focus on measures which can reduce the sanctionee’s strengths of counter-sanctions or raising the costs of counter-sanctions. For example, it can be more effective to limit the channels from which Russia can import agriculture products other than from the US/EU, given that the agriculture embargo is one of Russia’s counter-sanction tools. By targeting strategic sectors like agriculture, the US/EU can effectively raise the economic and political costs of counter-sanctions to force Russia to change its behaviour. Compared to financial sanctions which affect the entire economic system of Russia, agricultural sanctions have a disproportionately heavy impact on the ordinary people in Russia. This pressure can provoke greater conflicts between the ruling party (United Russia) and the opposition parties (especially CPRF, SRZP, and LDPR, which claim to represent the working class of Russia). This implication is in line with smart sanctions (Drezner, 2011; Ahn & Ludema, 2020). The disproportionate impacts also open up the current lively debate on humanitarian effects. It raises the question of whether the economic and political objectives of the sanctions are justifiable when weighed against the potential negative impacts on the general population. Sanctions may raise concerns about food security, access to essential agricultural products, and overall living conditions for ordinary people in both Russia and the EU. Additionally, there are broader questions of ethics and the responsibilities of the international community when using sanctions as a diplomatic tool.

Second, the co-sanctioner has a very unstable stance in strong co-sanctions due to heterogeneous interests (benefits) and unbalanced impacts (costs). Too many cooks spoil the broth. There are more restrictive conditions for sustained co-sanctions. As shown in proposition 2, a sufficiently high proportion of counter-sanctions ( $\bar{X}$ ) must be reached for the strengths of co-sanctions start to take positive effect. Also, due to the strategic substitutability between the leading sanctioner and the co-sanctioner, a stronger US always demotivates the EU to engage in full sanctions. It implies that the EU may be the weakest link as the sanctioning ally. If Russia wanted to break through the sanctions, the EU, especially the member countries sharing greater economic links with Russia (e.g., Germany), would be their target.

Finally, for the leading sanctioner, the strong strategy is a relatively stable choice unless the cost of sanctions is too high. Due to strategic complementarity, a stronger strategy from the

sanctionee induces the sanctioner to raise its sanctions. As shown in proposition 3, there is also a threshold of counter-sanctions ( $\tilde{X}$ ) above which the strengths of sanctions start to take positive effect. In practice,  $\tilde{X}$  (US threshold) is usually a lower threshold than  $\bar{X}$  (EU threshold) because the US is the *de facto* leading sanctioner. If the magnitudes switches, then the sanctioning roles of the US and the EU will swap. At the same time, due to strategic substitutability, a stronger strategy from the EU relieves the US from the pressure temporarily. The choice of co-sanctions to implement a strong strategy depends on how efficient the collaboration is. We have shown that sole-sanctions may be a more efficient choice in many cases (e.g., when  $k$  or  $\mu$  is high).

These policy implications of the sanction game elucidate modern international conflicts among global powers, which mainly take non-military forms after the Cold War. Specifically, commercial sanctions only target at specific entities and/or sectors, while financial sanctions aim at monetary systems and financial infrastructure to inflict more comprehensive damages. The sender of financial sanctions usually has monetary hegemony and asymmetric advantage in the global financial market. For the exact reason, the target of financial sanctions, lack of counter-sanctions in financial fields, may be forced to resort to nonfinancial responses (e.g., China), as we have seen in Russia's later actions. Involving another major global power China into the sanction game can elevate the conflicts from regional to global as the sanctionees also form a collective bloc—the leading sanctionee (Russia) and the co-sanctionee (China). Theoretical consequences of such a sanction game are beyond the scope of the paper, but logically it resembles a bilateral sanction game with greater heterogeneities on both sides. Furthermore, financial sanctions can also weaken the sender's credit and influence when the target is excluded from the financial system (Guo, 2021). The sanctionees may be driven away to a decentralized monetary and financial system such as cryptocurrencies to avoid being sanctioned in the future (Department of the Treasury, 2021).

Some reflection is due here. As shown, sanctions are a triple bladed sword because they hurt all three parties involved, though in different ways and at different degrees. Moreover, expanded measures like financial sanctions can have extensive costs for ordinary people in Russia and the EU, which is not part of the policy objectives. The paper focuses on optimal sanctions if sanctions are to be chosen, but we do not discuss if there are better alternatives to sanctions in the first place. Ultimately, sanctions are extended wars against other countries using economic weapons. Again, inspired by the old wisdom in *The Arts of War*, “There is no instance of a nation benefitting from prolonged warfare... The supreme art of war is to subdue the enemy without fighting.” There must be better ways beyond wars and sanctions to deal with international political conflicts and to avoid the trap of strategic complementarity. They call for innovative wisdoms from politicians, researchers, media, as well as from the people of conflicting countries.

## References

- Afanasyev, D; Fedorova, E.; Ledaeva, S. (2021). Strength of words: Donald Trump's tweets, sanctions and Russia's ruble. *Journal of Economic Behavior and Organization*, 184, pages 253-277. doi:10.1016/j.jebo.2021.02.002
- Ahn, D. P., & Ludema, R. D. (2020). The sword and the shield: The economics of targeted sanctions. *European Economic Review*, 130, 103587. doi:https://doi.org/10.1016/j.euroecorev.2020.103587
- Balcaen, P., Bois, C. D., & Buts, C. (2022). A Game-theoretic Analysis of Hybrid Threats. *Defence and Peace Economics*, 33(1), 26-41.
- Bělin, M., & Hanousek, J. (2021). Which sanctions matter? analysis of the EU/Russian sanctions of 2014. *Journal of Comparative Economics*, 49(1), 244-257. doi:https://doi.org/10.1016/j.jce.2020.07.001
- Besedeš, T., Goldbach, S., & Nitsch, V. (2021). Cheap talk? Financial sanctions and non-financial firms. *European Economic Review*, 134, 103688. doi:https://doi.org/10.1016/j.euroecorev.2021.103688
- Corda, T. (2022). Constraining Compliance? Reconsidering the Effect of Veto Players on Sanctions Success. *Defence and Peace Economics*, 1-13.
- Cressman, R. (1995). Evolutionary Game Theory with Two Groups of Individuals. *Games and Economic Behavior*, 11(2), 237-253. doi:https://doi.org/10.1006/game.1995.1050
- Crozet, M. & Hinz, J. (2020). Friendly fire: the trade impact of the Russia sanctions and counter-sanctions. *Economic Policy*, 35(101), 97-146.
- Department of The Treasury. *Treasury Department Review of the Nation's Sanctions Program*. Washington.
- Dong, Y., & Li, C. (2018). Economic sanction games among the US, the EU and Russia: Pay-offs and potential effects. *Economic Modelling*, 73, 117-128. doi:https://doi.org/10.1016/j.econmod.2018.03.006
- Doxey, M. (1980). *Economic Sanctions and International Enforcement* (2nd ed.). New York: Oxford University Press.
- Drezner, D. W. (2011). Sanctions sometimes smart: Targeted sanctions in theory and practice. *International Studies Review*, 13(1), 96-108. doi:10.1111/j.1468-2486.2010.01001.x
- Early, B. R., & Spice, R. (2015). Economic sanctions, international institutions, and sanctions busters: When does institutionalized cooperation help sanctioning efforts? *Foreign policy analysis*, 11(3), 339-360.
- Eaton, J., & Engers, M. (1992). Sanctions. *Journal of Political Economy*, 100(5), 899-928. Retrieved from <http://www.jstor.org/stable/2138628>
- Felbermayr, G., Morgan, T. C., Syropoulos, C., & Yotov, Y. V. (2021). Understanding economic sanctions: Interdisciplinary perspectives on theory and evidence. *European Economic Review*, 135, 103720. doi:https://doi.org/10.1016/j.euroecorev.2021.103720
- Garoupa, N. R., & Gata, J. (2002). A Theory of International Conflict Management and Sanctioning. *Public Choice*, 110(1/2), 41-65.
- Guo, D., & Zhou, P. (2021). The rise of a new anchor currency in RCEP? A tale of three currencies. *Economic Modelling*, 104, 105647. doi:10.1016/j.econmod.2021.105647
- Gürerk, Ö., Irlenbusch, B., & Rockenbach, B. (2006). The Competitive Advantage of Sanctioning Institutions. *Science*, 312(5770), 108-111. doi:doi:10.1126/science.1123633
- Haass, R. N. (1997). Sanctioning madness. *Foreign Affairs*, 76, 74.
- Hofbauer, J., Schuster, P., & Sigmund, K. (1979). A note on evolutionary stable strategies and game dynamics. *Journal of Theoretical Biology*, 81, 609-612.
- Hufbauer, G., Schott, J., & Elliott, K. (1990). *Economic sanctions reconsidered: History and current policy* (2nd ed.). Washington, DC: Institute for International Economics.

- International Monetary Fund. (2019). Russian Federation. *IMF Country Report*.
- Joshi, S., & Mahmud, A. S. (2020). Sanctions in networks. *European Economic Review*, 130, 103606. doi:<https://doi.org/10.1016/j.euroecorev.2020.103606>
- Kaempfer, W. H., & Lowenberg, A. D. (1988). The Theory of International Economic Sanctions: A Public Choice Approach. *The American Economic Review*, 78(4), 786-793. Retrieved from <http://www.jstor.org/stable/1811175>
- Kaempfer, W. H., & Lowenberg, A. D. (1999). Unilateral versus multilateral international sanctions: A public choice perspective. *International Studies Quarterly*, 43(1), 37-58. doi:10.1111/0020-8833.00110
- Kertzer, J. D., & Brutger, R. (2016). Decomposing Audience Costs: Bringing the Audience Back into Audience Cost Theory. *American Journal of Political Science*, 60(1), 234-249.
- Krustev, V. L., & Morgan, T. C. (2011). Ending economic coercion: Domestic politics and international bargaining. *Conflict Management and Peace Science*, 28(4), 351-376. doi:10.1177/0738894211413057
- Nocco, A., Ottaviano, G. I. P., & Salto, M. (2019). Geography, competition, and optimal multilateral trade policy. *Journal of International Economics*, 120, 145-161. doi:<https://doi.org/10.1016/j.jinteco.2019.05.005>
- Peksen, D. (2019a). Autocracies and Economic Sanctions: The Divergent Impact of Authoritarian Regime Type on Sanctions Success. *Defence and Peace Economics*, 30(3), 253-268. <https://doi.org/10.1080/10242694.2017.1368258>
- Peksen, D. (2019b). When Do Imposed Economic Sanctions Work? A Critical Review of the Sanctions Effectiveness Literature. *Defence and Peace Economics*, 30(6), 635-647.
- Peksen, D., & Jeong, J. M. (2022). Coercive Diplomacy and Economic Sanctions Reciprocity: Explaining Targets' Counter-Sanctions. *Defence and Peace Economics*, 33(8), 895-911. <https://doi.org/10.1080/10242694.2021.1919831>
- Powell, R. (1996). Bargaining in the shadow of power. *Games and Economic Behavior*, 15(2), 255-289. doi:10.1006/game.1996.0068
- Samuelson, L. (1997). *Evolutionary Games and Equilibrium Selection*. Cambridge, MA: MIT Press.
- Sandholm, W. (2010). *Population games and evolutionary dynamics*. Cambridge, MA: MIT Press.
- Schelling, T. C. (1966). *Arms and Influence*. New Haven, Conn: Yale University Press.
- Simola, H. (2014). Russia's restrictions on food imports. *BOFIT Policy Brief*.
- Smith, J. M. (1982). *Evolution and the theory of games*. Cambridge, UK: Cambridge University Press.
- Smith, J. M., & Price, G. R. (1973). The Logic of Animal Conflict. *Nature*, 246(5427), 15-18. doi:10.1038/246015a0
- Sugden, R. (2021). Hume's experimental psychology and the idea of erroneous preferences. *Journal of Economic Behavior & Organization*, 183, 836-848. doi:<https://doi.org/10.1016/j.jebo.2020.11.017>
- Taylor, P. D., & Jonker, L. B. (1978). Evolutionary stable strategies and game dynamics. *Mathematical Biosciences*, 40(1-2), 145-156. doi:10.1016/0025-5564(78)90077-9
- Weber, P. M., & Schneider, G. (2020). How many hands to make sanctions work? Comparing EU and US sanctioning efforts. *European Economic Review*, 130, 103595. doi:<https://doi.org/10.1016/j.euroecorev.2020.103595>
- Zhou, B., Zhang, Y., & Zhou, P. (2021). Multilateral political effects on outbound tourism. *Annals of Tourism Research*, 88, 103184.