NATO defense demand, free riding, and the Russo-Ukrainian war in 2022

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Abstract

The article applies the economic theory of alliances to uncover military expenditure burden sharing in the North Atlantic Treaty Organization (NATO) during 1991–2020, prior to Russia’s invasion of Ukraine in February 2022. In so doing, our analysis accounts for the relative locations of NATO allies through various spatial or economic weights applied to the allies’ defense spending. Such weights include NATO membership status, contiguity, US power projection, inverse distance between members’ capitals, economic trade, and contiguity to Russia. In the post-Cold War era, we uncover allies’ free riding on the aggregate military expenditure of other allies. Free riding also included reliance on the defense spending of NATO allies in proximity to Russia. Surprisingly, NATO allies reduced their defense spending as Russia increased its defense spending. The pattern of free riding and lack of response to heightened Russian defense spending likely encouraged the Russian invasion as NATO appeared divided.

Keywords Russo-Ukrainian war of 2022 · NATO defense spending · Economics of alliances · Free riding · Spatial econometrics

JEL classification D74 · H56 · C21
1 Introduction

With the collapse of the Soviet Union in 1991, the future mission of the North Atlantic Treaty Organization (NATO) was in doubt because the Russian Federation (henceforth, Russia) did not appear to pose a territorial or existential threat to Europe (Gompert & Larrabee, 1997; Sandler & Hartley, 1999). In fact, Russian military expenditure (ME) fell during 1992–1999 by about 63% in constant 2019 US dollars (Stockholm International Peace Research Institute (SIPRI), 2022a). Many of NATO’s 16 allies during the 1990s reduced their share of gross domestic product (GDP) devoted to ME in order to take advantage of a “peace dividend” as government spending shifted from defense to social welfare. As a consequence, there were short- and long-run downsizing of the military-industrial complex among many NATO allies, which reduced the size of their armed forces, limited the procurement of weapon systems, and reconsidered the next generation of weapon platforms. The post-Cold War era brought nontraditional warfare involving nonstate actors (namely, terrorist groups) and a greater incidence of intrastate wars. The military arsenals or tactics of the Cold War did not necessarily serve to protect NATO members against the new threats and foes.

To address reduced defense spending on weapon platforms and the concomitant smaller production runs, the post-1991 era witnessed mergers among defense firms in order to promote economies of scale and learning in a shrinking arms market (Hartley, 2014, 2017; Sandler & Hartley, 1999, Chap. 5). Competition among defense firms drove smaller firms out of business as their reduced production runs could not cover the large, fixed cost of weapon development for defense systems (e.g., fighter jets, bombers, frigates, tanks, and armored vehicles). Thus, defense manufacturers exited, either closing altogether or shifting to consumer goods. The arms manufacturers that emerged during the post-Cold War reorganization were larger and more efficient. Some of those defense producers offer a wider variety of defense systems to further reduce unit costs through economies of scope as multiple systems utilized the same fixed inputs.

To maintain a post-Cold War relevance, NATO sought new missions by embracing peacekeeping operations outside of NATO territory when its interests were at stake. Such operations protected NATO’s concerns by limiting the spillover of conflicts, preserving resource supply lines, maintaining trade flows, curbing refugee inflows, and curtailing the spread of transnational terrorism. Noteworthy NATO peacekeeping missions involved Bosnia and Herzegovina (1992–2004), Kosovo (1999–present), Afghanistan (2001–2014, 2015–2021), and elsewhere (Kim & Sandler, 2020; Shimizu & Sandler, 2010). The need for NATO peacekeeping increased with the rise in intrastate conflicts after 1991 and the overburdening of UN peacekeeping (Sandler & Hartley, 1999). For continued relevance, NATO also expanded its membership between 1999 and 2020 by 87.5% from 16 to 30 allies. Two potential members – Finland and Sweden – are currently applying for membership in reaction to the Russian invasion of Ukraine in 2022 (The Economist, 2022a). NATO expansion not only serves to augment North America-European military cooperation, but also to confront an ever-nationalistic Russia under President Putin. NATO enlargement included seven countries, once members of the ex-Warsaw Pact, which confronted NATO dur-
ing the Cold War. The ex-Soviet members of today’s NATO view their membership as a mean to ensure their security from a future Russian threat.

Even though NATO is a defensive alliance, Putin views the alliance’s eastward expansion to the borders of Russia in the case of a number of new NATO allies (e.g., Estonia, Latvia, and Lithuania) as a threat to Russia. Ukraine’s expressed ambition to join both NATO and the EU eventually culminated in Russia’s invasion of Ukraine on 24 February 2022 with an apparent objective to install a pro-Russia puppet government (The Economist, 2022b; Wikipedia, 2022).

The primary purpose of the current study is to apply the Olson and Zeckhauser’s (1966) economic theory of alliances to uncover the pattern of ME burden sharing among NATO allies for 1991–2020 and 2000–2020, prior to the 2022 Russian invasion of Ukraine. Additionally, our burden-sharing analysis accounts for the spatial connectivity among NATO allies in terms of contiguity, inverse distance, economic trade, contiguity and US power projection, contiguity to Russia, and contiguity to Russia and Ukraine. The spatial analysis of ME among allied and adversarial countries traces back to Flores (2011), George & Sandler (2018, 2021), Goldsmith (2007), Skogstad (2016), Xiaoxin & Bo (2021), and Yesilyurt & Elhorst (2017). Our current approach shows that, despite NATO’s expansion and enhanced ME, the alliance displayed a great deal of free riding or relying on the defense spending of other NATO allies.¹ Such free riding is the hallmark of a non-unified alliance where members largely pursue their unilateral interests, including supporting their social programs over defense outlays. The large buildup in Russian real ME from 2000 to 2020 of 183.4% was not met with commensurate increases in NATO allies’ ME. Similar ME trends are difficult to compute for NATO because 11 allies joined during 2000–2020, which artificially bolsters the rise in NATO ME when accession dates are used. If we compute NATO’s ME trend for the members in 2020 excluding Iceland and North Macedonia, ME increases by just 46.9% in constant 2019 US dollars during 2000–2020. Figure 1 displays the pattern of Russian ME (solid line) and the 28 NATO allies’ ME (dashed line) in constant 2019 US dollars during 1992–2020.² Because of scale differences, Russian ME is measured on the left-hand vertical axis, and NATO aggregate ME is measured on the right-hand vertical axis. The buildup of Russian ME is clearly seen in Fig. 1 from 2000 on, following a marked decrease during much of the 1990s; however, 28 NATO allies’ ME trend, though non-monotonic, is slightly down after 2010.

Surprisingly, NATO allies responded negatively to the increases in the ME of allies, which are either contiguous to Russia or contiguous to Russia and Ukraine during 1991–2020 or 2000–2020. The associated free riding to frontline allies’ ME suggests that, prior to the Russian 2022 invasion of Ukraine, NATO allies did not act as though Russia was a threat. That characterization is further supported by NATO allies’ negative response to Russian ME found in three of five spatial models. Despite the threat to NATO allies embodied by the Russian takeover of Crimea and its support to Russian separatist in Eastern Ukraine, we uncover little or no increase in NATO

¹ In fact, NATO members generally reduced their ME in reaction to rises in various spatially weighted increases in the other allies’ ME.
² Because data for Russian ME are not available for 1991, we start with 1992.
ME during 2015–2020. This post-2014 finding also suggests that NATO allies have not made much progress in their pledged increase in defense spending, agreed upon during the 2014 Wales Summit (George & Sandler, 2021; NATO, 2014). At the summit, NATO allies agreed to spend at least 2% of their GDP on defense by 2024. Moreover, allies pledged to allocate 20% of their annual defense budgets to the purchase of new weapons to address challenges posed by Russia and other potential adversaries. If those procurement pledges are eventually fulfilled, then the defense industries in the United States, France, Germany, the United Kingdom, Spain, and Italy will expand since these countries are the main weapon suppliers in NATO (SIPRI, 2021).

In a counterfactual exercise, we include Finland and Sweden as though they were NATO members during 1991–2020 to gauge what impact their recently requested membership application may have on free riding if they continue their past defense spending trend. If past is prologue, then their inclusion will worsen free riding in NATO for all of the various weighting schemes. Our counterfactual result strongly suggests that both potential entrants must devote a larger share of their respective GDP to defense and that NATO allies must not free ride on these entrants’ increased ME if free riding is to be curbed in the contemplated 32-member NATO.

Prior to the recent Russian invasion of Ukraine, any Russian leader studying the free-riding pattern characterizing NATO would conclude that the alliance would not have responded with a united front as has been the case thus far. In many ways, the invasion seemed to renew the NATO mission and energized more allies to allocate more GDP to ME. We will not know if this is the case until years in the future; however, recently announced ME increases by Germany, the United Kingdom, and France strongly suggest greater defense burden sharing as we will discuss in the conclusions.

The remainder of the paper contains seven additional sections. Section 2 provides background on NATO, while Sect. 3 reviews the economic theory of alliances. In Sect. 4, we present the theoretical model, whose reduced-form equations give the various defense equations to be estimated for different spatial connectivity. Section 5 presents the empirical methodology and data for our estimates, followed by empirical results and robustness tests in Sect. 6. For NATO, arms producers and exporters are indicated and discussed for three five-year intervals in Sect. 7 in light of pledged

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**Fig. 1** Russian and NATO military expenditure, 1992–2020
increased burden sharing and Russian challenges to its defense exports. Section 8 contains concluding remarks.

2 On NATO

Stalin invaded the Baltic States – Estonia, Latvia, and Lithuania – so as to bring them under the Soviet’s sphere of influence in June 1940. After World War II, the Soviet Union took over Albania, Bulgaria, Czechoslovakia, Hungary, Poland, and Romania. On 4 April 1949, the North Atlantic Treaty was framed by 12 countries – Belgium, Canada, Denmark, France, Iceland, Italy, Luxembourg, the Netherlands, Norway, the United Kingdom, and the United States. The treaty entered into force on 24 August 1949 to check the westward expansion of the Soviet Union in Europe.

NATO is governed by 14 Articles that set forth its institutional structure. We briefly review the key articles germane to our analysis. Under Article 3, allies pledge to separately and jointly develop their armed forces to resist and repeal an invasion or affront to their territorial integrity. If any ally views its territorial or political territory challenged, then it agrees to consult other NATO allies (Article 4). The essential governance article is:

Article 5: Members will consider an armed attack on one or more of them as an attack against the collective and will assist individually or collectively as they deem necessary. Such assistance may or may not include the use of force depending on the consensus of the allies, following consultation.

Article 5 pledges consultation before formulating the appropriate response but does not necessarily commit the allies to an automatic military response or any required reaction. In the 70+ years of NATO, Article 5 has only been invoked once following the four US hijackings on 11 September 2001 (henceforth, 9/11). The other essential article of the treaty is the sixth, which extends an armed attack under Article 5 to that on the territory or interests of any NATO ally. Article 6 permits the application of force beyond NATO and allows for peacekeeping operations, mentioned earlier, outside of NATO territory. The North Atlantic Council, NATO’s decision-making body, is established under Article 9 and employs unanimity when reaching decisions. By unanimous agreement, any European country may join NATO (Article 10). After the treaty is in effect for twenty years, any ally may exit the alliance following a one-year notice (Article 12).

NATO has been an amazingly stable alliance for 73 years. Since its inception, NATO expanded from its 12 original members to 30. Greece and Turkey joined NATO in 1952, followed by West Germany in 1955. Spain became the sixteenth NATO ally in 1982. During 1990, unified Germany replaced West Germany in the alliance after the fall of the Berlin Wall. The observation of the 50th anniversary of NATO set in motion an unprecedented expansion, made possible by the earlier collapse of the Soviet Union in 1991 and the worry by entrants that Russia could

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3 In this section, information is drawn from NATO Information Service (1989), NATO Office of Information and Press (1995, 231–234), and Sandler & Hartley (1999).

4 On the 14 articles of the NATO Atlantic Treaty, see Sandler & Hartley (1999, Table 2.1).
again pose concerns to their sovereignty. In 1999, Hungary, the Czech Republic, and Poland entered; in 2004, Bulgaria, Estonia, Latvia, Lithuania, Romania, Slovakia, and Slovenia joined; and in 2009, Albania and Croatia became members. This post-1999 expansion included seven of the original satellite states of the Warsaw pact – only Russia, the eighth Warsaw Pact member had not joined NATO. The inclusion of four states contiguous to Russia – the three Baltic States and Poland in NATO – became a particular irritant to Putin. Recent NATO additions involved Montenegro in 2017 and North Macedonia in 2020, bringing the membership to 30 allies, with Finland and Sweden applying for membership in May 2022.

3 The economic theory of alliances

In the current paper, our main empirical analysis of NATO allies’ demand for defense is based on the economic theory of alliances, which is likely unfamiliar to many readers, thus necessitating some background. Olson and Zeckhauser’s (1966) alliance theory views shared defense, particularly deterrence of an adversary’s attack on an alliance as a pure public good.

Ideally, effective deterrence in NATO possesses two properties of a pure public good: namely, nonrival and nonexcludable benefits. Nonrival benefits require that one ally’s consumption of deterrence from any ally’s armed forces does not detract, in the slightest, from the deterrence still available to other allies from those same forces. If deployment of NATO’s easternmost allies’ forces inhibits Russia from invading, then this deterrence protects all NATO allies from a pending attack, provided that Russia views the allies as united. The nonrival benefits of NATO’s nuclear strategic forces of the United States, France, and the United Kingdom stem from the unacceptable retaliatory response inflicted on an aggressor to an attack on any NATO ally. Intercontinental ballistic missiles (ICBM) can reach Russia in 30 min or less, unleashing incalculable destruction and loss of life. Since the start of the Cold War, the unacceptable consequence of nuclear retaliation has kept both adversaries from attacking one another’s territory. Nonrival benefits from nuclear deterrence is undiminished whether it is made on the behalf of 12, 30, or any number of allies.

Once provided, the deterrence from deployed NATO forces cannot be withheld from its allies. Excludability hinges on the alliance being unified and unable to deny any member from NATO’s threatened retaliatory protection when invaded. For NATO, the stationing of US troops and equipment in Europe serves as a tripwire and helps ensure that the United States will honor its pledge to protect its European allies. US massive foreign direct investment (FDI) in Europe, along with its large number of American citizens residing there, further bolsters the credibility of the commitment to safeguard Europe if invaded. In so doing, the deployment of US arsenals and soldiers embody nonexcludable deterrent benefits.

5 On deterrence’s public benefits, see Cornes & Sandler (1996), Dudley & Montmarquette (1981), Hilton & Vu (1991), McGuire & Groth (1985), Murdoch (1995), Murdoch & Sandler (1982), Sandler (1993), Sandler & Hartley (2001), and Sandler & Murdoch (1990, 2000).
The public good model of alliance implies free riding as an ally is motivated to limit its ME when the collective of other allies raises their ME (e.g., Murdoch 1995; Murdoch & Sandler, 1982; Sandler & Hartley, 2001; Smith, 1980, 1990, 1995). When defense spending gives rise to purely public benefits among allies, any ally’s defense outlays are perfect substitutes for those of other allies. Nonexcludability ensures that the allies-generated defense benefits are freely available. Moreover, nonrivalry means that there is no diminution in those benefits as more allies share them. Defense spillover substitutability in an alliance fuels free riding in which allies do not fully reveal their true preference for defense by relying to some extent on the defense provision of other allies. By limiting defense spending, free riding permits an ally to allocate more of its income to excludable consumption goods, not freely available from others. The ME of ally $i$ responds negatively to the ME of other allies so that a dollar rise in ME spillovers from the rest of the alliance is met with less than a dollar decreases in ally $i$’s ME (Sandler & Hartley, 2001). The greater the negative response to spillovers, the larger is the extent of free riding. Bigger alliances tend to display enhanced free riding (Cornes & Sandler, 1996). Generally, the largest ally shoulders the defense burden for the smaller allies (Olson & Zeckhauser, 1966; Sandler & Forbes, 1980). Free riding is associated with underprovision of defense in which an ally does not equate the sum of the allies’ derived marginal defense benefits to marginal defense costs. Rather, the ally equates only its own derived marginal defense benefits to marginal defense costs, thereby ignoring the marginal defense benefits that its defense provision confers on other allies. Those ignored marginal benefits mean that suboptimality rises with alliance size.

The joint product model of alliance, where allies’ defense provision yields multiple outputs of varying publicness, generalizes the pure public good model of alliance (Sandler, 1977; Sandler & Forbes, 1980; van Ypersele de Strihou, 1967). For instance, an ally’s defense spending may render country-specific gains from guarding coastal assets, keeping domestic order, limiting home terrorism, or protecting its territorial interests, along with alliance-wide deterrence. Those country-specific outputs are excludable and rival insofar as only the providing ally benefits from them in contrast to the jointly produced deterrence. Given country-specific benefits, allies’ defense provision is now less substitutable, thereby limiting free-riding prospects among allies. If, moreover, the country-specific gains are complementary to deterrence (i.e., best consumed together), then the presence of jointly produced defense outputs may even reverse free riding as an ally provides more defense in reaction to alliance-based defense spillovers in order to get country-specific defense gains (Murdoch & Sandler, 1984). The latter can only be had from the ally’s own defense spending.

Spatial considerations make an ally’s relative position vis-à-vis its allies and adversaries an essential determinant for defense substitutability and free riding. For conventional armaments (e.g., tanks, artillery, and ground forces), allies’ defense spending is more substitutable when the providing allies are contiguous or nearer in distance (i.e., the inverse distance between allies’ capitals is larger) so that one ally can come more quickly to the assistance of another. Ally’s spatial propinquity enhances substitutability and, hence, free riding. If, however, an ally, such as the United States, can rapidly project its power through air or sea transport, then nearness...
is not so important for free riding. Nuclear strategic forces limit greatly the importance of propinquity.

4 The spatial theoretical model of alliance

Next, we put forward a theoretical model for an ally’s demand for defense spending that is sufficiently rich to permit a variety of spatial connectivity regarding spillovers influenced by the relative locations of the \( N \) allies.\(^6\) Like the original Olson-Zeckhauser representation, the current model is a game-theoretic one, based on the Nash assumption that each ally treats the spillovers derived from its other allies as a parameter set at these allies’ best-response level. Each ally is a unitary actor, who, like the executive decision maker, maximizes the country’s social welfare, \( U \), by allocating the country’s income, \( I \) or GDP, between defense, \( q \), and a catchall private consumption good, \( y \). For convenience, we assume that the unit price of defense and the private good are set at unity.\(^7\) Henceforth, we employ superscripts to denote the allies; thus, \( q^i \) is the defense provided or spent (given the unit price) by ally \( i \).

The income constraint of ally \( i \) is denoted by

\[
I^i = y^i + q^i, \tag{1}
\]

which represents the defense-social welfare tradeoff that confronts the government decision maker. To capture the publicness of defense spending, we must introduce defense spillovers, \( Q_{-i} \), to ally \( i \) as:

\[
Q_{-i} = \sum_{k \neq i}^{N} \delta^k q^k, \quad k = 1, \ldots, N, \tag{2}
\]

but \( k \neq i \). In (2), \( \delta^k \) is a spatial weight attached to the \( k^{th} \) ally’s defense outlay. For the standard economic theory of alliance, the spatial weight is 1 for all \( N \) allies so that \( Q_{-i} = \sum_{k}^{N} q^k \), which reflects the perfect substitutability of each ally’s defense where \( \partial Q_{-i}/\partial q^k = \partial Q_{-i}/\partial q^j = 1 \) for all \( k \neq j \). For contiguous allies, \( \delta^k \) equals 1 when ally \( k \) shares a land or water border with ally \( i \), and 0 otherwise. In the case of inverse distance, \( \delta^k \) equals the inverse distance between the capitals of allies \( i \) and \( k \), where more geographically separated capitals result in a smaller inverse-distance weight being applied to ally \( k \)’s defense outlay. Other spatial weight measures are presented in Sect. 5.1.

Returning to the theoretical model, we express ally \( i \)’s social welfare function as:

\[
U^i = U^i \left( y^i, q^i + Q_{-i}, X, T \right), \quad i = 1, \ldots, N, \tag{3}
\]

\( ^6 \) This model borrows, in large part, from those presented in George & Sandler (2018, 2021).

\( ^7 \) Allowing for a relative price of defense of \( p \) does not promote our empirical estimates because there is no panel data on \( p \).
which increases with the private consumption good and allies’ defense spending.\(^8\) In (3), social welfare is influenced by a vector \(X\) of other considerations such as population, energy trade with Russia, and transnational terrorist attacks on \(i\)'s interests at home or abroad. \(T\) is a threat variable tied to Russian ME. By substituting the budget and spillover constraints in (1) and (2), respectively, into (3), we represent ally \(i\)'s maximization problem for choosing its defense as:

\[
\max_{q_i} U_i^i \left( I_i - q^i, q^i + \sum_{k \neq i}^N \delta^k q^k, X, T \right), \quad i = 1, \ldots, N,
\]

for which ally \(i\) chooses its defense spending, while treating defense spillovers as a constant. The ensuing first-order conditions implicitly define the reduced-form defense equation for ally \(i\) as:

\[
q^i = q^i \left( I_i, \sum_{k \neq i}^N \delta^k q^k, X, T \right), \quad i = 1, \ldots, N.
\]

The simultaneous satisfaction of (5) for all allies gives each ally’s optimizing \(q^i\) for the best-response defense spending of the other allies.

Through standard comparative statics, we can show that each ally’s ME increases with national income or GDP.\(^9\) For an increase in defense spillovers, each ally decreases its defense demand, except in the case of economic-trade-weighted spillovers. The latter may augment an ally’s ME when enhanced trade requires greater protection of trade routes and resource sources. Population may exert a positive or negative influence on an ally’s ME; however, population reduces defense spending when the need for social welfare expenditure overwhelms any enhanced defense to protect a larger population (Dunne & Perlo-Freeman, 2003). Enhanced energy trade with Russia should decrease an ally’s defense spending since Russia may then be viewed as a benign threat. Additionally, raised ME may anger Russia and induce an energy cut-off. If an ally experiences more transnational terrorist attacks against its interests, then the ally may raise ME in order to take a proactive stance against terrorist groups. This may not be the case when the ally relies on its police rather than its military to counter terrorism, which is true for most NATO allies. Finally, enhanced Russian ME poses a threat that should induce greater defense spending by an ally.

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\(^8\) To fulfill sufficiency for maximization, we assume that each ally’s social welfare function is strictly quasi-concave in the private and defense goods.

\(^9\) This assumes that defense is an income-normal good, see George & Sandler (2021) for comparative statics details.
5 Methodology and data

5.1 Empirical strategy

To operationalize our theoretical model, we empirically estimate a NATO member country’s demand for its ME as a function of the spillover term, GDP, population, other controls, and a threat variable. Although estimating this demand equation is generally straightforward, the presence of the spillover term, by construction, raises serious concerns about endogeneity so that conventional OLS demand estimation is problematic. We overcome that concern by applying Spatial Auto-Regressive (SAR) models for which spatial dependence between geographical units are captured using a spatially lagged dependent variable (Elhorst, 2003; Franzese & Hays, 2007).

Based on the SAR model representation, the spillover term in Eq. (5) can be modeled as the spatially lagged dependent variable. Formally, the demand for ME for ally \( i \) during year \( t \) is represented as:

\[
Y_{it} = \rho \sum_{k \neq i} w_{ikt} y_{kt} + \beta X_{it} + \gamma Z_{it} + \mu_i + \tau_t + \epsilon_{it}. \tag{6}
\]

In (6), \( Y_{it} \) is measured as the log of ally \( i \)'s ME at time \( t \). The first term on the right-hand side is the SAR representation of the theoretical spillover term, defined as the spatially weighted sum of the log of ME for all other countries \( (y_{kt}, k \neq i) \) in the sample at time \( t \). \( w_{ikt} \) is the spatial weight variable and reflects the degree of spatial dependence between countries \( i \) and \( k \) for year \( t \), which measures the relative degree of influence that other allies’ defense spending has on a NATO member’s defense spending decisions. \( X_{it} \) is the vector of time-varying control variables that affect ally \( i \)'s demand for ME. We employ the log of GDP, log of population, transnational terrorist attacks, and the value of energy trade with Russia as our control variables. The use of log for GDP and population allows us to interpret their coefficients as elasticities. \( Z_{it} \) denotes the threat variable of Russian ME. \( \mu_i \) and \( \tau_t \) are the country and year fixed effects, respectively, while the error term is represented as \( \epsilon_{it} \).

In addition to the above location-based spatial weights, we utilize three spatial weights, based on the geographical locations of NATO allies. First, we employ a contiguity weight, which equals 1 when ally \( k \) shares land or water borders with ally \( i \), and 0 otherwise. Second, an inverse distance weight, measured as the inverse of the distance between capital cities of allies \( i \) and \( k \), is applied, whose inclusion reflects that an ally’s ME is more influenced by nearer allies. Third, we introduce a contiguity to Russia spatial weight, which equals 1 when an ally borders Russia, and 0 otherwise. The rationale for this weight is that if NATO countries perceive Russia as a serious security threat, then they are more apt to follow signals from the ME decisions of frontline allies.

In the standard spatial econometric literature, the spatial weight term, \( w_{ikt} \), represents some form of geographical connectivity between two spatial units. To begin with, we employ three main connectivity measures based on the geographical locations of NATO allies. First, we employ a contiguity weight, which equals 1 when ally \( k \) shares land or water borders with ally \( i \), and 0 otherwise. Second, an inverse distance weight, measured as the inverse of the distance between capital cities of allies \( i \) and \( k \), is applied, whose inclusion reflects that an ally’s ME is more influenced by nearer allies. Third, we introduce a contiguity to Russia spatial weight, which equals 1 when an ally borders Russia, and 0 otherwise. The rationale for this weight is that if NATO countries perceive Russia as a serious security threat, then they are more apt to follow signals from the ME decisions of frontline allies.

In addition to the above location-based spatial weights, we utilize three weights, founded on political and economic dependence between NATO allies. The NATO alliance membership measure, another binary spatial weight, assigns a value of 1 to all NATO members, based on their year of accession into the alliance. The US plus contiguity spatial weight variable equals 1 when ally \( k \) is contiguous to ally \( i \), or when
ally $k$ is the United States. This spatial weight captures the military power projection ability of the United States (through its superior air and sea transport platforms), which extends beyond its nearby allies. Finally, we construct an economic trade spatial weight, which equals the value of exports plus imports between two NATO allies, measured in millions of constant 2019 US dollars. Bilateral trade relationships could act as soft power, often an imperfect substitute for military power projection. In other instances, this trade could increase the need to protect trade flows, thus, raising a trading ally’s ME.

Following Neumayer & Plümper (2016) and George & Sandler (2018), we do not row-standardize the spatial weights by dividing each spatial weight by the sum of the spatial weights of all other sample countries for a given year. Although a standard practice in the spatial econometric literature, row-standardization is not well-suited for military alliance studies when the membership size changes significantly over time (Plümper & Neumayer, 2010). For example, under the row-standardization practice, the NATO expansion in 1999, 2004, 2009, and thereafter would automatically diminish the ME influence of key members, such as the United States, the United Kingdom, France, and Germany, despite them still spending relatively sizable amounts on defense post-expansion.

As explained earlier, SAR models require non-OLS estimators, given endogeneity concerns. In our estimation method, we use the two-step efficient generalized methods of moments (GMM) estimator, where the spatial lags of the explanatory variables are used as external instruments for the spillover term (Kelejian & Prucha, 1998). All regressions are estimated using standard errors, clustered at the country level.

5.2 Data

We estimate the defense demand for a sample of 28 NATO countries from 1991 to 2020 in which Iceland is left out because it has virtually no ME. In some models, we also add Finland and Sweden, owing to their imminent accession into NATO. Our main dependent variable is the log of ME, measured in constant 2019 US dollars. The ME data is drawn from the SIPRI Military Expenditure Database, which records annual time-series information on the military spending of countries from 1949 to 2021 (SIPRI, 2022a). Data on GDP and population are taken from World Bank’s World Development Indicators database (World Bank, 2022), which compiles current and internationally comparable cross-national statistics on multiple global development indicators. The GDP variable is measured in constant 2019 US dollars, the same unit as the ME data. We transform both GDP and population variables into log forms to obtain coefficients as elasticities. The transnational terrorism variable, another control, is defined as the total number of transnational terrorist incidents experienced at home or abroad by an ally for a given year. The variable is constructed using the International Terrorism: Attributes of Terrorist Events (ITERATE) database, which records information on transnational terrorist events and their various attributes (Mickolus et al., 2022). Lastly, the data on energy trade with Russia is derived from the UN Comtrade Database (United Nations, 2021), which provides information on the total value of bilateral trade between two countries in US dollars, disaggregated by commodity codes. We combine trade data on two commodity
codes: (a) 2709- Petroleum oils and oils obtained from bituminous minerals, and (b) 2711- Petroleum gases and other gaseous hydrocarbons.

Data on NATO members and their year of accession to the alliance are from the NATO official website. For bilateral contiguity and contiguity with Russia, data are obtained from the Correlates of War (COW) Direct Contiguity Data, which record all direct contiguity relationships by land or water (Correlates of War Project, 2006; Stinnet et al., 2002). The data on distance between capital cities are drawn from Gleditsch & Ward (2001), measured in kilometers. Finally, the economic trade spatial weights are constructed using the Direction of Trade Statistics (DOTS) database of the International Monetary Fund (IMF) (2021). The database provides information on the value of merchandise exports and imports disaggregated according to a country’s trading partners.

Table 1 provides summary statistics for the main non-spatial variables used in our empirical analysis. Because the number of observations for each empirical model varies depending on the data availability of the included variables, we report statistics for the whole sample, namely, 28 NATO countries (excluding Iceland) for 1991–2020 (30 years). Hence, the full sample size N is 840 (= 28 × 30), corresponding to the number of observations for the population and transnational terrorism variables. For all other variables, some observations are missing so that there are fewer observations as indicated. ME, GDP, and population variables are all expressed in log terms. Transnational terrorist attacks are measured as annual counts per country, with an annual mean of 1.73 attacks per country. During the analysis period, the maximum number of transnational terrorist attacks were recorded for Germany in 1993 (182 attacks), followed by the United Kingdom in 1991 (87 attacks) and Turkey in 1991 (48 attacks). The Energy trade with Russia variable is measured in millions of 2019 US dollars, while the Russian ME variable is measured in billions of 2019 US dollars. The major energy trading partners with Russia are the Netherlands, Germany, Poland, and Italy. The Netherlands is associated with the maximum bilateral energy trade with Russia in 2012, followed by this country’s energy trade with Russia in 2013 and 2014. Table 1 also depicts the standard deviation (Std. Dev) and Min values of each main variable.

| Variable                   | N   | Mean | Std. Dev | Min  | Max  |
|----------------------------|-----|------|----------|------|------|
| Log of ME                  | 815 | 22.02| 2.06     | 17.75| 27.49|
| Log of GDP                 | 814 | 26.12| 1.89     | 21.78| 30.70|
| Log of Population          | 840 | 16.19| 1.54     | 12.87| 19.61|
| Transnational terrorist attacks | 840 | 1.73 | 0.30     | 0.0  | 182  |
| Energy trade with Russia   | 657 | 3330 | 7030     | 0    | 65,951|
| Russian ME                 | 812 | 44.80| 18.17    | 15.74| 80   |

Note: Transnational terrorist attacks is measured as annual counts. Energy trade with Russia is measured in millions of 2019 US dollars. Russian ME is measured in billions of 2019 US dollars.
6 Empirical results

6.1 Determinants of NATO ME

Table 2 reports empirical results for our baseline SAR models, where the log of ME is regressed against the spillover term and other control variables for 1991–2020. Results for six models are displayed, where the only difference among them involve the spatial weight applied when constructing the spatial lag (SL) spillover term. In Model 1, the spillover term has a negative and significant effect on the demand for ME, indicating that a NATO ally reduces its defense spending in response to the collective increase in the defense spending of its allies. During the sample period, the
negative response shows clear evidence of free riding among the NATO allies, consistent with the findings of George & Sandler (2018) but for a different time period. As discussed earlier, the over-time stability and resilience of NATO as a military alliance provide assurances for its members, thereby offering free-riding opportunities in terms of defense spending.

In Models 2–6, we examine whether the free-riding tendencies of allies hold true for alternative spatial-weighting schemes used in engineering the spillover term. In all models, except Model 4 where the value of economic trade between two countries is used as the spatial weight, the coefficient for the spillover term is significant and negative. Thus, NATO members decrease their ME in response to an increase in ME by contiguous allies (Model 2), allies weighted by propinquity (Model 3), US plus contiguous allies (Model 5), and frontline allies (Model 6). The free-riding response to the ME by frontline allies is particularly concerning given the ongoing war in Ukraine. Over the sample period, the NATO allies failed to respond appropriately to the ME spending signals sent by the frontline allies with respect to the possibility of an imminent Russian threat. In Model 4, the small positive response to economic trade is consistent with ally trade creating a small need for protection. This may require some hardening of borders, especially after 9/11.

Next, we examine how the control variables, whose effects are hypothesized in Sect. 4, influence the defense demand decisions for NATO allies. As expected, in all models, the log of GDP shows a significant and positive relationship with the log of ME. In Models 1–5, the income elasticity is greater than 1, suggesting that ME is income normal and highly elastic for NATO allies. The log of population variable has a negative and significant association with the dependent variable in four of the six models. That negative association is consistent with the need for more populated countries to allocate more resources toward social welfare and public benefits programs away from military spending (Dunne & Perlo-Freeman, 2003). Transnational terrorism and energy trade with Russia variables have generally no significant effects on the ME variable. The negative response on transnational terrorism is unexpected and likely due to relatively small number of attacks or the use of police rather than the military to control attacks. Only for the NATO membership model do we find that energy trade with Russia has the anticipated negative influence on an ally’s ME.

In Table 3, we replicate the models in Table 2, but for the 2001–2020 subperiod. Those post-2001 years hold interest for two reasons. First, this period coincides with the drastic upward trend in Russia’s ME and the subsequent inability of NATO allies to match proportionately that increase. Second, the period also witnessed an uptick in the number of transnational terrorist incidents, primarily driven by a global surge in religious extremism (Gaibulloev & Sandler, 2019). As a result, some of the military priorities of the United States and its allies shifted toward the fragile and failing states in the Middle East and North Africa. In Models 1, 3, and 6, the spillover term still has a negative and significant relationship with the ME variable, indicative of free-riding behavior characterizing the post-2001 era. However, for US-plus-contiguity weighted spillover terms, the relationship is not significant. This may be due, in part, to US cutbacks in ME owing to US sequestration of defense spending during 2013–2021, which, in turn, limited free-riding opportunities for NATO allies. As before, economic-trade weighted spillover leads to a small, but significant, positive
coefficient. The coefficient for the log of GDP is positive and greater than one, confirming the income normal and elastic nature of defense. Population, transnational attacks and energy trade with Russia variables are generally not significant, similar to results in Table 2.

6.2 Determinants of NATO ME (with Sweden and Finland)

As a counterfactual exercise, we next examine whether the inclusion of Finland and Sweden to the sample would alter the previous free-riding results. In Table 4, our counterfactual exercise indicates spillover coefficients in Models 1–3 and 5–6 that are entirely consistent with the free-riding behavior observed in Tables 2 and 3. Those coefficients suggest that the inclusion of the two new members will not automatically change the adverse burden-sharing dynamics within NATO unless more deliberate structural changes are instituted to curb free-riding tendencies of existing and new members. The results for the control variables are consistent with the baseline model (Table 2) results.

Table 3 NATO military expenditure, 2001–2020

|                                | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    |
|--------------------------------|--------|--------|--------|--------|--------|--------|
| **SL (NATO membership)**      | -0.00066*** |        |        |        |        |        |
|                                | (-3.25) |        |        |        |        |        |
| **SL (Contiguity)**           |        | -0.0696 |        |        |        |        |
|                                |        | (-0.72) |        |        |        |        |
| **SL (Inverse distance)**     |        |        | -9.461*** |        |        |        |
|                                |        |        | (-4.70) |        |        |        |
| **SL (economic trade)**       |        |        |        | 8.34e-09** |        |        |
|                                |        |        |        | (2.34) |        |        |
| **SL (US+contiguity)**        |        |        |        |        | -0.0621 |        |
|                                |        |        |        |        | (-0.65) |        |
| **SL (Contiguity to Russia)** |        |        |        |        |        | -0.515*** |
|                                |        |        |        |        |        | (-5.34) |
| **Log of GDP**                | 1.116*** | 1.163*** | 1.147*** | 1.143*** | 1.168*** | 0.943*** |
|                                | (10.35) | (10.48) | (11.91) | (12.33) | (10.55) | (8.92)  |
| **Log of Population**         | -0.374 | -0.548 | -0.746** | -0.422 | -0.570 | -0.0801 |
|                                | (-0.95) | (-1.24) | (-2.21) | (-1.30) | (-1.30) | (-0.36) |
| **Transnational terrorist attacks** | 0.000490 | 0.00248 | -0.000114 | 0.000388 | 0.00143 | 0.000835 |
|                                | (0.22) | (0.92) | (-0.06) | (0.21) | (0.59) | (0.48)  |
| **Energy trade with Russia**  | -3.45e-12** | 1.76e-12 | 1.33e-12 | 2.50e-13 | 1.76e-12 |        |
|                                | (-2.51) | (1.41) | (1.23) | (0.23) | (1.46) |        |
| **Country FE**                | YES    | YES    | YES    | YES    | YES    | YES    |
| **Year FE**                   |        |        |        |        |        |        |
| **R**                         | 0.406  | 0.555  | 0.580  | 0.584  | 0.550  | 0.705  |
| **F**                         | 24.97  | 12.29  | 12.91  | 13.11  | 12.10  | 23.20  |
| **jp**                        | 0.143  | 0.791  | 0.338  | 0.379  | 0.942  | 0.0203 |
| **N**                         | 475    | 456    | 475    | 475    | 475    | 490    |

Significance levels: * p<0.10, **p<0.05, and ***p<0.01. t-statistics in parentheses.
In Table 5, we rerun the baseline models of Table 2, with one major change. In each model, we interact the ME spillover term with the post-2014 variable, which assumes a value of 1 during 2015–2020, and 0 otherwise. This variable represents the post-Wales Summit pledge era when the members were directed to allocate at least 2% of their GDP to ME and spend 20% of their annual defense budget on major weapon procurement by 2024. If the member countries are seriously committed to the pledge, we expect to see a reduction in the free-riding behavior among member countries during this period. As shown in Model 1 of Table 5, the coefficient for the interaction term is positive and significant, suggesting that the period after the Wales Summit pledge is characterized by less free riding among member countries when

### Table 4 NATO military expenditure, 1991–2020 (including Sweden and Finland)

|                | (1)          | (2)          | (3)          | (4)          | (5)          | (6)          |
|----------------|--------------|--------------|--------------|--------------|--------------|--------------|
|                | logme        | logme        | logme        | logme        | logme        | logme        |
| **SL (NATO membership)** | -0.000605*** | (4.26)       |              |              |              |              |
| **SL (Contiguity)** | -0.163**     | (2.13)       |              |              |              |              |
| **SL (Inverse distance)** | -9.955***    | (-5.67)      |              |              |              |              |
| **SL (economic trade)** | 8.60e-09***  | (2.86)       |              |              |              |              |
| **SL (US+contiguity)** | -0.190***    | (-2.70)      |              |              |              |              |
| **SL (Contiguity to Russia)** | -0.528***    | (-5.29)      |              |              |              |              |
| **Log of GDP** | 0.963***     | 1.069***     | 0.992***     | 1.022***     | 1.084***     | 0.743***     |
|                | (9.77)       | (10.36)      | (12.26)      | (12.45)      | (10.29)      | (7.99)       |
| **Log of Population** | -0.375       | -0.810**     | -0.940***    | -0.520*      | -0.966**     | -0.00490     |
|                | (-1.09)      | (-2.05)      | (-3.11)      | (-1.84)      | (-2.41)      | (-0.02)      |
| **Transnational terrorist attacks** | -0.00229     | -0.00093     | -0.00276*    | -0.00234     | -0.00126     | -0.0000413   |
|                | (-1.21)      | (-0.33)      | (-1.84)      | (-1.46)      | (-0.55)      | (-0.10)      |
| **Energy trade with Russia** | -1.92e-12**  | 9.00e-13     | 1.39e-12     | -3.11e-13    | 1.02e-12     |              |
|                | (-2.09)      | (0.74)       | (1.36)       | (-0.32)      | (0.84)       |              |
| **Country FE** | YES          | YES          | YES          | YES          | YES          | YES          |
| **Year FE**    | NO           | YES          | YES          | YES          | YES          | YES          |
| **R²**         | 0.364        | 0.424        | 0.536        | 0.526        | 0.413        | 0.651        |
| **F**          | 23.30        | 7.718        | 11.04        | 9.865        | 7.516        | 16.39        |
| **jp**         | 0.0276       | 0.155        | 0.0111       | 0.266        | 0.613        | 0.00394      |
| **N**          | 615          | 590          | 615          | 615          | 615          | 724          |

Significance levels: * p<0.10, **p<0.05, and ***p<0.01. t-statistics in parentheses
compared with the earlier years. However, the post-2014 years only had a positive effect on the alliance membership-weighted spatial lag term. For all other weighting schemes, the relationship is not significant, except for Model 3, where the coefficient is significant and negative. This result is not surprising given that the potential effect of the post-pledge period is more relevant to the alliance membership-weighting scheme than other geographical schemes or economic-trade weights.
6.3 Determinants of NATO ME (with russian ME as a threat measure)

Finally, in Table 6, we replace the variable measuring bilateral energy trade relations with Russia with Russian ME to reflect the embodied threat. Because of the absence of Russian ME data for 1991, the runs now encompass 1992–2020. Additionally, we expand the definition of the contiguity to Russia variable to expanded contiguity to Russia by adding Hungary, Slovakia, Romania, Bulgaria, and Turkey. In so doing, the expanded contiguity involves NATO allies contiguous to Russia, the Ukraine, or the Black Sea. In Table 6, there is still evidence of free riding for models involving NATO membership, inverse distance, contiguity to Russia and expanded contiguity to Russia-weighted spillover terms. There is, however, a notable decrease in free riding evident when the negative coefficient attached to expanded contiguity with Russia and Ukraine is compared with that of contiguity with Russia. The GDP variable is still significant and positive, but with slightly inelastic coefficients. Both population and transnational terrorism variables remain insignificant, except for Models 3 and 1, respectively. In fact, transnational terrorism assumes the anticipated positive influence on ME in Model 1. The threat variable – Russian ME – displays a significant and negative association with the ME in Models 2, 4, and 5. This suggests that, despite the looming security threats posed by Russian military expansion and its growing nationalism during this period, NATO allies failed to respond in kind. The response failure could be because many NATO allies did not view Russia as a major threat for most of this period, and hence rechanneled much of their defense spending to social welfare programs and other forms of government expenditure owing to domestic political pressure. The negative response sent the wrong signal to the Kremlin as an invasion of Ukraine was contemplated.

7 On arms producers and exporters

Before concluding, we speculate on how the ongoing Ukrainian War and the push of NATO allies to revamp their armaments (see the concluding section) and burden sharing will likely impact defense industries in NATO members and in Russia. Clearly, NATO allies’ pledge to increase their shares of GDP devoted to ME (Machi, 2022; Muvija & Ravikumar, 2022; SIPRI, 2022b) will not only result in an expansion of members’ arms industry but also its evolving modernization and technological advances. Reduced NATO free riding greatly augments the need for up-to-date arms from NATO suppliers. Table 7, drawn from SIPRI (2011, 2016, 2021) Yearbooks, lists the twelve largest exporters of major weapons in descending order (in column 4) during 2016–2020. Columns 1–3 display the rank-orders of the exporters for the three successive five-year intervals – 2006–2010, 2011–2015, and 2016–2020. The last three right-hand columns denote each exporter’s percentage share of world arms exports for the three time periods.

There are some noteworthy, stylized facts to highlight from Table 7. First, the United States and Russia maintained their first and second rank as arms exporters, respectively, throughout the three five-year periods. Second, the next four arms-exporting countries, ranked third to sixth, display some rank reshuffling over the
three intervals. In terms of rankings, there are much greater changes for the next six lower-ranked arms exporters. Third, US share of global arms exports have risen from 30 to 37% over the three intervals, while Russian share fell markedly from 26 to 20% from 2011 to 2015 to 2016–2020. Fourth, most of the major armament exporters are concentrated among the top seven exporters — the United States, Russia, France, Germany, China, the United Kingdom, and Spain. If we were to examine defense indus-

| Table 6 | NATO military expenditure, 1991–2020 (with Russian ME and expanded contiguity measure) |
|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| SL (NATO membership) logme | -0.0007*** | | | | | | |
| SL (Contiguity) | 0.000320 | | | | | | |
| SL (Inverse distance) | -2.291*** | | | | | | |
| SL (economic trade) | 6.95e-09*** | | | | | | |
| SL (US+contiguity) | 0.000759 | | | | | | |
| SL (Contiguity to Russia) | -0.485*** | | | | | | |
| SL (expanded contiguity to Russia) | -0.287** | | | | | | |
| Log of GDP | 0.861*** | 0.971*** | 0.961*** | 1.011*** | 0.969*** | 0.792*** | 0.772*** |
| Log of Population | -0.398 | -0.343 | -0.469* | -0.362 | -0.323 | -0.0435 | -0.175 |
| Transnational terrorism | 0.001** | -0.0001 | -0.0001 | 0.0005 | 0.000003 | 0.0001 | 0.0003 |
| Russia ME | 0.00279 | -0.509*** | 0.205 | -0.779*** | -0.56*** | | |
| Significance levels: * p<0.10, **p<0.05, and ***p<0.01. t-statistics in parentheses | | | | | | | |
tries, we would find a highly concentrated industry by weapon type, which became even more concentrated through post-1991 mergers, acquisitions, and exits (Hartley, 2017; Sandler & Hartley, 1999; SIPRI, 2021).

Another essential feature to note about arms suppliers is that seven of the top twelve supplying countries are NATO members – namely, the United States, France, Germany, the United Kingdom, Spain, Italy, and the Netherlands. As NATO allies seek to fulfill their 2014 Wales Summit pledge by devoting at least 2% of their GDP to ME and spending 20% of their annual defense budget on major weapon procurement (NATO, 2014), defense industries in the above seven NATO allies will expand greatly since a lot of weapon platforms need upgrading. The current push to carry a defense burden beyond 2% of GDP will expand NATO allies’ defense industries even further, leading to longer production runs, greater economies of scale and learning, and falling unit prices. Those ME and arms-investment commitments are made urgent, even existential, with the Russian brutal invasion of Ukraine, thereby likely reversing past free-riding behavior. By having this concentration of arms producers in NATO, the current push in the alliance to increase defense spending can be more readily achieved. This concentration of producers assists members to purchase weapons that are interoperable. Also, these arms producers allow NATO allies to more rapidly replace defense equipment that they had shipped to Ukraine to meet Russian aggression in Eastern Ukraine. As NATO ME increases, there will be some cutbacks in social programs in NATO allies, marking a reversal of the peace dividend of the post-Cold War era.

Another essential industrial consequence of the Russo-Ukrainian War stems from the heavy losses of Russian armaments and enhanced US supply of arms to Ukraine and NATO allies. During 2021–2025, Russia’s rank as an arms exporter is anticipated to decline greatly for at least three reasons. First, Russia has a pressing need to restock its armaments lost in Ukraine, which will curtail Russian arms exports. Second, Western-imposed sanctions will hurt Russia’s ability to make transactions with some would-be weapon importers. Third, those sanctions hurt Russia’s capabilities to produce major weapon systems, some of which rely on computer chips.

Table 7 Twelve largest exporters of arms 2006–2020

| Rank | 2006–10 | 2011–15 | 2016–20 | Exporter | 2006–10 | 2011–15 | 2016–20 |
|------|---------|---------|---------|---------|---------|---------|---------|
| 1    | 1       | 1       | 1       | United States | 30       | 32       | 37       |
| 2    | 2       | 2       | 2       | Russia    | 23       | 26       | 20       |
| 3    | 3       | 3       | 3       | France    | 7        | 5.6      | 8.2      |
| 4    | 6       | 4       | 4       | Germany   | 11       | 5.5      | 4.5      |
| 5    | 4       | 5       | 5       | China     | 3        | 5.6      | 5.2      |
| 6    | 5       | 6       | 6       | United Kingdom | 4       | 4.6      | 3.3      |
| 7    | 7       | 7       | 7       | Spain     | 3        | 3.5      | 3.2      |
| 8    | 11      | 8       | 8       | Israel    | 2        | 1.9      | 3.0      |
| 9    | 15      | 15      | 9       | South Korea | 1       | 0.9      | 2.7      |
| 10   | 10      | 10      | 10      | Italy     | 2        | 2.8      | 2.2      |
| 11   | 9       | 11      | 11      | Netherlands | 3       | 2.0      | 1.9      |

Source: SIPRI (2011, 2016, 2021)
manufactured by countries observing the trade embargoes (Johnson, 2022; Watling & Reynolds, 2022). The firing of Russian Kalibr cruise missile and its Iskander-M short-range ballistic missile (SRBM) was scaled back in April 2022 as Russia ran low on precision-guided systems, manufactured abroad (Johnson, 2022). In fact, some high-precision Russian cruise missiles depend on computer components made by US companies (Watling & Reynolds, 2022, p. 11)! Even a main Russian air-defense system – TOR-M2 – requires a key British-produced component. Russia will need a long time to recapture its arms-producing and arms-exporting capacity. As Russian defense exports are curtailed, NATO and Chinese defense industries will gain customers.

8 Concluding remarks

Our unmistakable message is that NATO allies relied or free rode on the defense spending of other allies under a rich array of alternative defense-spillover representations despite a looming Russian threat. The associated free-riding dependency is most acute for nearer and frontline allies (contiguous to Russia). For 2010–2020, NATO allies spent surprisingly less on ME as Russia increased its defense outlays. Those reactions came despite NATO allies’ commitment in 2014 to allocate a larger portion of their GDP to defense spending and to raise their weapon procurement investments. The ME behavior of NATO allies signaled to Putin that NATO would likely not unite against a Russian invasion of Ukraine. That signal is even more poignant given many European NATO allies’ reliance on Russian oil and gas, which should have made such allies hesitant to irritate Moscow. Thus far, many NATO allies appear to be taking steps to allocate a greater share of their GDP to defense and to augment new weapon procurement. A clear case is German Chancellor Scholz’s proposal to allocate at least 2% of German GDP to defense and to spend 100 billion euros on military procurement over the next five years (SIPRI, 2022b). Given the size of the German economy, this huge defense commitment will catapult Germany into the top five of defense spenders. During the summer of 2022, France and the United Kingdom made much smaller pledges to raise their ME/GDP (Machi, 2022; Muvija & Ravikumar, 2022). The associated reduction in free riding from major NATO allies is motivated by the perceived threat posed by Russia. Perhaps, this seismic shift in threat perception is best illustrated by NATO’s announced plans during the Madrid Summit in June 2022 to increase NATO’s Rapid Reaction Force from 40,000 to 300,000 soldiers to be stationed strategically throughout NATO territory (Murphy, 2022). The enlarged force will allow for greater EU cooperation in deterring future Russian aggression, especially in eastern allies such as Poland or the Baltic states. Such enhanced forces would be complementary to the announced stationing of more US troops in eastern NATO allies. NATO allies have acted in unison to sever Russia from world markets despite Russian threats and the concomitant economic consequences of the allies’ actions.

Notably, Finland and Sweden, two historically neutral countries, applied for NATO membership. For their application to reduce free riding, our counterfactual exercise indicates that they must increase their defense spending and that NATO
members must not then cut back on their own ME. The enhanced Russian threat that NATO allies now perceive will limit future free riding.

With new weapon procurement in NATO, defense industries in the United States, France, Germany, and the United Kingdom are anticipated to increase substantially. Other European arms-producing countries – Italy, the Netherlands, Spain, Sweden, and Turkey – will likely see increased defense exports and defense sector growth. By contrast, Russian defense industries are anticipated to relinquish their second rank as arms suppliers to the world as they struggle to restock lost Russian arms in light of the trade embargo that adversely affects required computer chip availability.

Five years from now, a re-examination of NATO free riding may uncover stark changes if the alliance stays the course regarding renewed pledges to spend more of allies’ GDP on ME.

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Declarations

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References

Cornes, R., & Sandler, T. (1996). The theory of externalities, public goods, and club goods (2nd ed.). Cambridge University Press
Correlates of War Project (2006). Direct Contiguity Data, 1816–2006, Version 3.1. Retrieved from https://correlatesofwar.org/
Dudley, L., & Montmarquette, C. (1981). The demand for military expenditures: An international comparison. Public Choice, 37(1), 5–31
Dunne, J. P., & Perlo-Freeman, S. (2003). The demand for military spending in developing countries. International Review of Applied Economics, 17(1), 23–48
Elhorst, J. P. (2003). Specification and estimation of spatial panel data models. International Regional Science Review, 26(3), 244–268
Flores, A. Q. (2011). Alliances as contiguity in spatial models of military expenditures. Conflict Management and Peace Science, 28(4), 402–418
Franzese, R., & Hays, J. C. (2007). Spatial-econometric models of cross-sectional interdependence in political-science panel and time-series-cross-section data. *Political Analysis, 15*(2), 140–164

Gaibulloev, K., & Sandler, T. (2019). What we have learned about terrorism since 9/11. *Journal of Economic Literature, 57*(2), 275–328

George, J., & Sandler, T. (2018). Demand for military spending in NATO, 1968–2015: A spatial panel approach. *European Journal of Political Economy, 52*, 222–236

George, J., & Sandler, T. (2021). EU demand for defense, 1990–2019: A strategic spatial approach, *Games, 12*(13), 1–18. Retrieved from http://www.mdpi.com/journal/games

Gleditsch, K. S., & Ward, M. D. (2001). Measuring space: A minimum-distance database and applications to international studies. *Journal of Peace Research, 38*(6), 739–758

Gompert, D. C., & Larrabee, F. S. (Eds.). (1997). *American and Europe*. Cambridge University Press

Goldsmith, B. E. (2007). Arms racing in “space”: Spatial modelling of military spending around the world. *Australian Journal of Political Science, 42*(3), 419–440

Hartley, K. (2014). *The political economy of aerospace industries*. Edward Elgar

Hartley, K. (2017). *The economics of arms*. Agenda Publishing

Hilton, B., & Vu, A. (1991). The McGuire model and the economics of the NATO alliance. *Defence Economics, 2*(2), 105–121

International Monetary Fund (IMF) (2021). Direction of Trade Statistics. Washington DC. Retrieved from https://data.imf.org/regular.aspx?key=61013712

Johnson, R. (2022). Russian Attempts to Restock Its Military May Be Doomed to Failure, *Breaking Defense*. Retrieved from https://breakingdefense.com/2022/05/russian-attempts-to-restock-its-military-may-be-doomed-to-failure/

Kelejian, H. H., & Prucha, I. R. (1998). A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive disturbance model with autoregressive disturbances. *Journal of Real Estate Finance and Economics, 17*(1), 99–121

Kim, W., & Sandler, T. (2020). NATO at 70: Pledges, free riding and benefit-burden concordance. *Defense and Peace Economics, 31*(4), 400–413

Machi, V. (2022). France to request multibillion-dollar defense boost in 2023, *Defense News*. Retrieved from https://www.defensenews.com/global/europe/2022/07/08/france-to-request-multibillion-dollar-defense-budget-boost-in-2023/

Muvija, M., & Ravikumar, S. (2022). Britain to boost defence spending to 2.5% of GDP by end of decade, *Reuters*. Retrieved from https://www.reuters.com/world/uk/ukraine-wars-russia-britain-defence-spending-reach-2-5-gdp-by-end-decade-johnson-2022-06-30/

McGuire, M. C., & Groth, C. H. (1985). A method for identifying the public good allocation process within a group. *Quarterly Journal of Economics, 100*(Supplement), 915–934

Mickolus, E. F., Sandler, T., Murdock, J. M., & Flemming, P. (2022). *International terrorism: Attributes of terrorist events, 1968–2020 (ITERATE)*. Vinyard Software

Murdock, J. C. (1995). Military alliances: Theory and empirics. In K. Hartley, & T. Sandler (Eds.), *Handbook of defense economics* (vol. 1). North-Holland

Murdock, J. C., & Sandler, T. (1982). A theoretical and empirical analysis of NATO. *Journal of Conflict Resolution, 26*(2), 237–263

Murdock, J. C., & Sandler, T. (1984). Complementarity, free riding and the military expenditure of NATO allies. *Journal of Public Economics, 25*(1–2), 83–101

Murphy, M. (2022). NATO plans huge upgrade in rapid reaction force, *BBC News*. Retrieved from https://www.bbc.com/news/world/europe-61954516

NATO Information Service. (1989). *NATO facts and figures*. NATO

NATO Office of Information and Press. (1995). *NATO handbook*. NATO

NATO (2014). Wales Summit Declaration, Press Release (2014) 120. Retrieved from https://www.nato.int/cps/en/natohtml/official_texts_112964.htm

Neumayer, E., & Plümper, T. (2016). W, Political Science Research and Methods, 4(1), 175–193

Olson, M., & Zeckhauser, R. (1966). An economic theory of alliances. *Review of Economics and Statistics, 48*(3), 165–179

Plümper, T., & Neumayer, E. (2010). Model specification in the analysis of spatial dependence. *European Journal of Political Research, 49*(3), 418–442

Sandler, T. (1977). Impurity of defense: An application to the economics of alliances. *Kyklos, 30*(3), 443–460

Sandler, T. (1993). The economic theory of alliances: A survey. *Journal of Conflict Resolution, 37*(3), 446–483
Sandler, T., & Forbes, J. F. (1980). Burden sharing, strategy, and the design of NATO. *Economic Inquiry, 18*(3), 425–444.

Sandler, T., & Hartley, K. (1999). *The political economy of NATO: Past, present, and into the 21st century*. Cambridge University Press.

Sandler, T., & Hartley, K. (2001). Economics of alliances: The lessons for collective action. *Journal of Economic Literature, 39*(3), 869–896.

Sandler, T., & Murdoch, J. C. (1990). Nash-Cournot or Lindahl behavior? An empirical test for the NATO allies. *Quarterly Journal of Economics, 105*(4), 875–894.

Sandler, T., & Murdoch, J. C. (2000). On sharing NATO defence burdens in the 1990s and beyond. *Fiscal Studies, 21*(3), 297–327.

Shimizu, H., & Sandler, T. (2010). Recent peacekeeping burden sharing, *Applied Economic Letters, 17*(15), 1479–1484.

Skogstad, K. (2016). Defence budgets in the post-Cold War era: A Spatial econometrics approach. *Defence and Peace Economics, 27*(3), 323–352.

Smith, R. (1980). The demand for military expenditure. *Economic Journal, 90*(4), 811–820.

Smith, R. (1990). Defence spending in the United Kingdom. In K. Hartley, & T. Sandler (Eds.), *The economics of defence spending: An international survey*. Routledge.

Smith, R. (1995). The demand for military expenditure. In K. Hartley, & T. Sandler (Eds.), *Handbook of defense economics* (vol. 1). North-Holland.

Stinnet, D. M., Tir, J., Schafer, P., Paul, F., Diehl, P. F., & Gochman, C. (2002). The Correlates of War project direct contiguity data, Version 3. *Conflict Management and Peace Science, 19*(2), 58–66.

Stockholm International Peace Research Institute (SIPRI). (2011). *SIPRI yearbook 2011*. Oxford University Press.

Stockholm International Peace Research Institute (SIPRI). (2016). *SIPRI yearbook 2016*. Oxford University Press.

Stockholm International Peace Research Institute (SIPRI). (2021). *SIPRI yearbook 2021*. Oxford University Press.

Stockholm International Peace Research Institute (SIPRI) (2022a). *SIPRI extended military expenditure database*. Retrieved from https://www.sipri.org/databases/milex.

Stockholm International Peace Research Institute (SIPRI) (2022b). SIPRI explainer: The proposed hike in German military spending. Retrieved from https://www.sipri.org/commentary/blog/2022/explainer-proposed-hike-german-military-spending.

The *Economist* (2022a). Sorrow in battalions, *The Economist, 443*(9394), 30 April, 15–18.

The *Economist*. (2022b). Finland and NATO: Stretching the border. *The Economist, 443*(9292), 16.

United Nations (2021). UN Comtrade database. New York. Retrieved from https://comtrade.un.org/data/

van Ypersele de Strihou, J. (1967). Sharing the defense burden among Western allies. *Review of Economics and Statistics, 49*(4), 527–536.

Watling, J., & Reynolds, N. (2022). Operation Z: The death throes of an imperial delusion, RUSI Special Report, 22 April. Retrieved from https://static.rusi.org/special-report-202204-operation-z-web.pdf.

Wikipedia (2022). Russo-Ukrainian War. Retrieved from https://en.wikipedia.org/wiki/Russo-Ukrainian_War.

World Bank (2022). *World Development Indicators (WDI)*. Retrieved from http://data.worldbank.org/data-catalog/world-development-indicators.

Xiaoxin, Y., & Bo, C. (2021). Defense burden and the effect of others: From neighbors to allies. *Defence and Peace Economics, 32*(8), 927–940.

Yesilyurt, M. E., & Elhorst, J. P. (2017). Impacts of neighboring countries on military expenditures: A dynamic spatial panel approach. *Journal of Peace Research, 54*(6), 770–790.

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