Exploring free riding among NATO member states: A spatiotemporal approach*

Ringailė Kuokštytė[†] Vytautas Kuokštis[‡]

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Abstract

Concerns over free riding are wide-spread in alliances, including NATO. Spatial interdependence between allies has been a common approach to analyzing free-riding patterns: How does a country's defense spending react to changes in its allies' military expenditures? Recent literature finds a significant negative response for NATO allies and concludes that the alliance suffers from systematic free riding. However, this research remains silent on the substantive implications of the concerned effect. Furthermore, it does not adequately account for temporal dependence, which risks a biased estimate of spatial interdependence and inaccurate effects of covariates' coefficient-estimates. Better accounting for temporal dependence provides a different picture of the within-alliance dynamics. We show that while the previously found immediate free-riding effect has been inflated, in the long run, this effect is even more substantial. We discuss the relevant practical and theoretical implications and highlight the steps to improve the efforts of modeling defense spending interdependence.

Keywords: Free riding, NATO member states, spatial interdependence, long-run effects

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[†]General Jonas Žemaitis Military Academy of Lithuania, ringailekuokstyte@gmail.com

[‡]Institute of IR and Political Science, Vilnius University, kuokstis@gmail.com

1 Introduction

Does alliance membership induce free riding? More concretely, do NATO members free ride, and if so – to what extent? The relevance of these questions extends beyond the academic arena. They are also of obvious real-world importance, in particular in the context of heightened military threats from Russia. US President Trump was perhaps the most explicit and vocal in blaming allies for free riding and in calling for substantially ramping-up military spending. Though he was by no means an exception (Duchin 1992).

One of the most common ways to analyze free riding consists in modeling spatial interdependence between allies, whereby an average NATO member tends to decrease its own defense spending in response to other allies' increased military expenditures. This negative interdependence is consistent with the expectation of free-riding behavior. The spatial aspect refers to the distance between the allies, which does not have to be geographical (e.g., alliance contiguity). Importantly, it defines a weights-based network of relationships that is assumed to structure the free-riding dynamics. For instance, in case the geographical logic applies, it may be commonly expected that a closer ally's defense spending matters more than that of a more distant ally (George and Sandler 2018).

Notwithstanding the ample literature on NATO, it remains silent on the quantitative magnitude of free riding. This is ever more surprising, considering that the effect estimation associated with spillovers in the outcome variable presents unique challenges (Whitten et al. 2019; Cook et al. 2020). Spatial effects of interdependence are largely directly non-interpretable. There is therefore a missed opportunity in the defense economics literature to extract useful and, in fact, pertinent information from the statistical results (King et al. 2000). Furthermore, due to the omission of temporal dependence, the implied free-riding behavior between the allies risks mischaracterization. The neglect of the temporally autoregressive nature of the data-generating process (DGP) of interest may be expected to produce an inflation bias in the parameters' coefficient-estimates and invalid inferences.

Using the latest methodological insights from the TSCS literature, we show that the immediate spatial effect of interdependence, once we account for temporal dependence, is still present but the previous research, with its direct focus on space at the expense of time, has much inflated this effect. In the long run, however, spatial interdependence in defense expenditures of NATO allies is not only present but is indeed substantial. This offers a meaningfully different version of the phenomenon (Cook et al. 2022), as there is an over-time pattern and therefore a more complex free-riding dynamics, which has important implications for policy discussions and academic research.

2 Existing findings

The core idea of free riding is related to the concept of public goods. To the extent that security created by alliances is non-excludable and non-rival in consumption, we might expect members to free ride on others' expenditures (Olson and Zeckhauser 1966).

Theoretically, the concept of free riding is quite clear; yet it turns out that its operationalization is not so simple.[1] Empirically, researchers have tried to capture free riding in different ways by looking at whether smaller members spend less on defense in proportion to GDP (Alley 2021; Kim and Sandler 2020); how countries respond to increasing military expenditure on behalf of the US (Spangler 2018); or whether and how NATO allies react to increased threats from potential adversaries, such as the Soviet Union and Russia (Plümper and Neumayer 2015).

One of the most common ways to capture free riding is to analyze the spatial interdependence between allies' military expenditures. If the free-riding hypothesis is correct, we

[1]E.g., Lanoszka (2015) offers an enlightening discussion of different ways to understand free riding.

would expect spillovers in defense spending to be negative – when other members increase their military expenditures, a given country is likely to decrease its own. The primarily cross-sectional and strategic nature of such dynamics suggests the existence of spatial interdependence (Cook et al. 2020).

Studies on NATO allies' defense spending have improved dramatically, with researchers now able to account for a wide specter of influences. While a negative correlation between allies' defense expenditures was already observed by Murdoch and Sandler (1984), such pioneering studies did not, in fact, consider spatial interdependence of the dependent variable, which implies global spillovers (Cook et al. 2020; Whitten t al. 2019) and simultaneity.[2] Recently, George and Sandler (2018, 2022) have published two important studies which address spatial interdependence between NATO allies' defense spending, using spatial econometric techniques that also deal with simultaneity. This research represents an important step forward insofar as it specifically focuses on modeling spatial spillovers in NATO members' military expenditures. In George and Sandler's (2018, 223) own words, they "present the first spatial-based estimates of NATO allies' demand for defense spending."

The core takeaway from this research is that spatial interdependence among NATO allies' defense expenditures is negative and significant, as the authors point to the (negative) sign and statistical significance of the spatial interdependence parameter. While the implied substantive interpretation is that free riding is prevalent and substantial, the effect derived from the parameter itself, – that is, the extent of free riding –, is not interpreted in quantitative and easily understandable terms. This constitutes a "missed opportunity" (Drolc et al. 2019, 24), as it limits our knowledge about the inferential scope of free riding and therefore the political but also the theoretical relevance of this phenomenon (De Boef and Keele 2008). It precludes us from learning from the research (King et al. 2000, 348). Another important

[2]See also their similar analysis on EU military expenditure (George and Sandler 2021).

limitation of this research, as already mentioned, is the omission of temporal dependence, which can lead to biased estimates and inaccurate effect estimation, thus compromising, overall, the validity of inferences.

3 The need to control for temporal dependence

Analyses using time-series cross-section (TSCS) data tend to focus either on the temporal dimension or the spatial one. In fact, as noted by Cook et al. (2022, 1), during the period of 2012–2019, only a meager percentage (less than 6 per cent) of TSCS-based articles in the top journals of political science "model[ed] both temporal and spatial dependence directly." The time series literature being more established, applied researchers are well aware of the important consequences if one fails to incorporate the temporal dimension – in the form of temporal lags, notably the lagged dependent variable –, where it belongs (Keele and Kelly 2006; Williams and Whitten 2012).

Only recently, however, the relevant implications from this literature have been systematically and meaningfully explored by those mainly concerned with spatial dependence (Cook et al. 2022). Their methodological effort cautions against modeling only one dimension when, in fact, both space and time matter. The failure of considering space-time co-dependence results in a wide array of issues. Inadequate attention to modeling spatiotemporal dimensions "jointly simultaneously" leads to biased estimates of the dependence parameters (overestimation of the included parameter) and also biases the covariates' coefficients, as well as their effects, be they dynamic, spatial, or total (Cook et al. 2022, 2–4).

The popular use of one-way or two-way fixed effects models, accompanied by the assumption that dependence is present in only one of the spatiotemporal dimensions, has largely comforted scholars in applying methods either from time series or cross-unit research (Cook et al. 2022). The treatment of the underspecified dimension, in this scenario, is largely equated with the correction of either within-country (across time) or within-period (across units) correlation. Other statistical fixes, first and foremost the method of panel-corrected standard errors (PCSE) (Beck and Katz 1995), do not resolve the distinctive challenges of two-dimensional data analysis either. The PSCE method, for instance, assumes a specific type of cross-sectional dependence (based on unit pairs).[3] Substantively, it does not match the ambition of modeling more complex spatial relationships, which are the focus of spatial econometrics and more consistent with real-world situations. Furthermore, the very logic of correcting standard errors (the PCSE case) prevents us from any theoretical insight into how space and time interact to define the outcome of interest.

The lack of attention to spatiotemporal dependence, in fact, weakens the very substance of political science (Cook et al. 2022). Beyond the relevant methodological concerns, researchers are also interested in providing a substantive interpretation of the phenomenon of interest. This challenges them to identify the exact mechanism that underlies the spatially- and temporally-correlated data they observe (what makes the data manifest the spatiotemporal patterns they do?). While both spatial econometrics and time series analyses have their fair share of recommendations on how to try to distinguish between theoretically competing mechanisms, omitting one of the dimensions mitigates if not compromises beforehand this ambition (Cook et al. 2022; Elhorst 2001).

There are strong reasons to expect that military spending has considerable persistence over time. Therefore, even if a researcher is only interested in accurately modeling instantaneous spatial interdependence (for whatever curious reason this may be[4]), neglecting the temporal dimension is likely to result in a biased coefficient of the spatial parameter, as

[3] This is also the case with fixed unit and period effects.

[4] As reminded by Cook et al. (2022, 3), "in the presence of spatiotemporal lags of outcomes and/or covariates, the coefficients on x alone are not the sought effect of x on y."

well as inaccurate covariates' estimates, thus impairing the validity of inferences and the theoretical scope of the analysis. These considerations have not systematically featured the defense economics literature. They have been largely overlooked in spatial analysis of free riding.

4 Empirics

We integrate both dimensions in our analysis of 27 NATO allies' defense expenditures.[5] We follow an empirical strategy motivated by George and Sandler's (2018, 2022) work and, specifically, by their finding of an actual free-riding effect. We update defense spending (total spending in millions of constant 2020 USD) data up to 2021 based on SIPRI (2022) and proceed with a parsimonious model which includes logged GDP (World Bank, 2022; measured in absolute value in constant 2015 USD) and logged population (World Bank, 2022). We also adjust for country fixed effects, which, at least partially, equally accounts for time-invariant external threats. We consider spatial interdependence by estimating the spatial autoregressive (SAR; also, spatial lag) model.

Similarly to George and Sandler (2018), furthermore, we look at several periods – from 1975 to 2021, from 1991 to 2021, and from 1999 to 2021, in order to test whether there were differences in free riding across these periods, or, alternatively, the relevant dynamics appear as a consistent feature of NATO's organizational existence. We submit our findings based on the weights matrix representing inverse distances (in hundreds of kilometers) between the capital cities. Providing such a structure to NATO allies' network system is common in the literature. Substantively, its relevance rests on the notion that geographically closer allies may be expected to assist militarily in the case of a conventional conflict (George and Sandler 2018); furthermore, closer allies may be expected to perceive similar threats and acquire (or develop) similar defense capabilities, thus making a given country count on its

[5] From the current NATO member states, we exclude Iceland, Montenegro, and North Macedonia.

ally-neighbors and proceed with reducing its defense expenditures.

Table 1 represents the results of our spatial models without the lagged dependent variable (LDV). In Table 2, the latter is included. We find that, when the temporal (autoregressive) dynamics are present (Table 2), our models improve considerably in terms of model fit (e.g., log likelihood improves by a factor of almost four for the period of 1975–2021). Relative to the static spatial model (Table 1), the estimated spatial parameter (ρ) continues to point to free riding, as it remains negative and significant. However, in terms of the actual extent of free riding, the approach to understanding the relevant dynamics across time and space substantively changes.

Table 1: Spatial Autoregressive (SAR) Models Excluding the LDV. Defense Spending (Logged) as the Dependent Variable

	Dependent variable:					
	Defense spending (log)					
	(1975-2021)	Spatial effect (short-run)	(1991-2021)	Spatial effect (SR)	(1999-2021)	Spatial effect (SR)
ρ	−0.033***	−0.076	−0.030***	−0.070	−0.033***	−0.076
	(0.003)		(0.003)		(0.004)	
lngdp	0.755***		1.124***		1.271***	
	(0.050)		(0.061)		(0.068)	
lnpop	−0.313**		−0.842***		−0.846***	
	(0.138)		(0.146)		(0.163)	
Constant	−3.233*		−4.175*		−8.565***	
	(1.765)		(2.251)		(2.988)	
Observations	897		680		566	
Country FE	Yes		Yes		Yes	
Log Likelihood	244.967		285.810		229.802	
σ^2	0.034		0.025		0.026	
Akaike Inf. Crit.	−427.933		−509.620		−397.604	
Note:						*p<0.1; **p<0.05; ***p<0.01

One should be careful about directly interpreting the spatial parameter, as, oftentimes, it is hardly informative. In spatial models, the estimated parameters "contain a wealth of information on relationships between the observations" (LeSage and Pace 2009, 33; see also Whitten et al. 2019) but are not themselves directly interpretable or easy to understand.

Table 2: Spatial Autoregressive (SAR) Models Including the LDV. Defense Spending (Logged) as the Dependent Variable

	Dependent variable:					
	Defense spending (log)					
	1975-2021	Spatial effect (SR & long-run)	1991-2021	Spatial effect (SR & LR)	1999-2021	Spatial effect (SR & LR)
ρ	-0.006^{***}	-0.014 (SR)	-0.009^{***}	-0.022 (SR)	-0.012^{***}	-0.030 (SR)
	(0.001)	-0.588 (LR)	(0.002)	-0.458 (LR)	(0.002)	-0.557 (LR)
lnmilsp_lag	0.887^{***}		0.824^{***}		0.808^{***}	
	(0.016)		(0.020)		(0.023)	
lngdp	0.171^{***}		0.379^{***}		0.441^{***}	
	(0.026)		(0.038)		(0.045)	
lnpop	-0.270^{***}		-0.420^{***}		-0.394^{***}	
	(0.064)		(0.080)		(0.093)	
Constant	1.623^{**}		-0.906		-3.091^{*}	
	(0.824)		(1.216)		(1.698)	
Observations	897		680		566	
Country FE	Yes		Yes		Yes	
Log Likelihood	931.574		704.407		551.767	
σ^2	0.007		0.007		0.008	
Akaike Inf. Crit.	$-1{,}799.148$		$-1{,}344.815$		$-1{,}039.534$	
Note:						*p<0.1; **p<0.05; ***p<0.01

Instead, we believe that the goal of quantitative research should be to "convey numerically precise estimates of the quantities of greatest substantive interest" and "require little specialized knowledge to understand" (King et al. 2000, 347).

Interpreting free riding makes sense if we try to answer the following question: what is the expected effect of a one-unit shock (in our case, of 1 per cent) in military expenditures of a given country's neighbors on that same country's defense spending? This counterfactual appeals to the SAR model's core idea of the relationship between a country's expected outcome and those of its neighbors (Ward and Gleditsch 2019, 61). To quantitatively respond to the question posed, when the LDV is not included, we derive the average spatial effect from considering the relevant off-diagonal elements of the spatial multiplier in its basic form (Franzese and Hays 2006), which is based on a full cross-sectional weights matrix (that is, representing NATO's membership of 27 allies).[6] In case the LDV is present, the average effect is derived from the spatiotemporal multiplier, the dimensions of which are those of our respective period-based unbalanced panels.

The non-dynamic models (Table 1) suggest an instantaneous spatial effect of magnitude which is several times larger compared to the short-run effect that we obtain based on the spatiotemporal models (Table 2). It is, for example, greater by a factor of 2.5 for the period of 1999–2021 (–0.076 vs. –0.030) and greater by more than five times for the 1975–2021 period (–0.076 vs. –0.014).

In the spatiotemporal scenario, however, the effect of a 1 per cent shock in defense spending of a country's neighbors reverberates forward not only across space but also across time. The estimated long-run spatial effect, over time, ends up being ultimately larger than suggested by the temporally static spatial models. The results are generally similar across different time periods. An increase of 1 per cent in defense spending of a country's allies, as specified by the weights matrix, may be expected to lead to a decrease of 0.46–0.59 per cent in its own military expenditures in the long run.[7] We also observe that other covariates' coefficient-estimates also appear to be significantly reduced in magnitude, when we directly account for spatiotemporal dependence.

5 Conclusion

In this article we suggest two principal contributions. First, we quantify the estimated effect of free riding within NATO. Second, we present the first study that models directly

[6]The cross-sectional matrix is created by isolating the last diagonal (of 27 by 27 dimensions) from the overall weights matrix with the dimensions corresponding to the number of observations in our unbalanced panel. We are interested in what is known as indirect spatial effects, which do not include feedback from country x's own impulse of increased defense spending on this same country x.

[7]Similar results (not reported) are also obtained with the spatial autocorrelation (SAC) model, which, on top of spatial dependence in the outcomes, also adjusts for remaining spatial correlation in the residuals.

both temporal and spatial dependence of military expenditures for NATO members. Based on the state-of-the-art methodological knowledge in TSCS analysis, we argue that accurate derivation of spatial interdependence, which is used in the defense economics literature as a proxy measure for free riding, cannot be modeled appropriately if temporal dependence is present but unaccounted for.

We empirically show that the inclusion of the LDV substantially reduces – although does not render insignificant – the spatial interdependence parameter. We therefore corroborate the earlier research's findings that free riding, defined as negative spatial spillovers in allies' military expenditures, exists within NATO during the periods analyzed. Yet, at the same time, we show that the short run effect is markedly lower than the one that can be derived from one-dimensional spatial models. More importantly still, in the long run the spatial effect is substantially more profound. As already noted, these are meaningfully different versions of the phenomenon in terms of their dynamics and therefore their inferences. These findings have a few important implications. On the policy (or practical) level, they suggest that some of the concerns over free riding may not have been overblown, as the phenomenon appears to manifest itself in a more significant manner than previously thought. Our evidence suggests that additional efforts are necessary to mitigate free riding in NATO, especially given the prospect of new members joining the alliance, as well as the actual need to increase NATO defense spending in the context of support for Ukraine and Russia's aggression more generally. Our analysis also points to the complexity of free riding, which does not lend itself to a yearly-based appreciation but requires a longer-term perspective. This thus brings forth the importance of the allies' strategic commitment, with free riding potentially serving as an actual liability.

It needs, however, reminding that spatial interdependence is only one measure of other possible free riding dimensions (Lanoszka 2015). Being able to quantify different aspects of these alliance dynamics constitutes a promising and, indeed, a crucial venue for further research. Another implication for researchers is that scholarship investigating free riding in NATO and other alliances, or modeling interdependence in military expenditures more generally, needs to also directly model the temporal dependence, at least as a sensitivity check. In fact, this implication has a broader bearing – while the use of TSCS analysis has grown very substantially in social science, still only the minority of studies address both time and spatial dependence directly (Cook et al. 2022).

Finally, the bias stemming from the neglect of temporal dependence is not limited to the overestimation of spatial parameters. Covariates' coefficient-estimates will also suffer from bias, while the effects of interest will be estimated inaccurately,including by omitting their meaningfully diverse dynamics (short vs. long run effects). All this speaks directly to the researcher's efforts of uncovering the true DGP of any given phenomenon and therefore provides an indispensable basis for future research motivated by TSCS data.

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