# Online Appendix: Data, Method, & Robustness Checks

# "Beyond Threats: How Allies and Bureaucratic Competition Shape the Initial Development of Military Cyber Capabilities"

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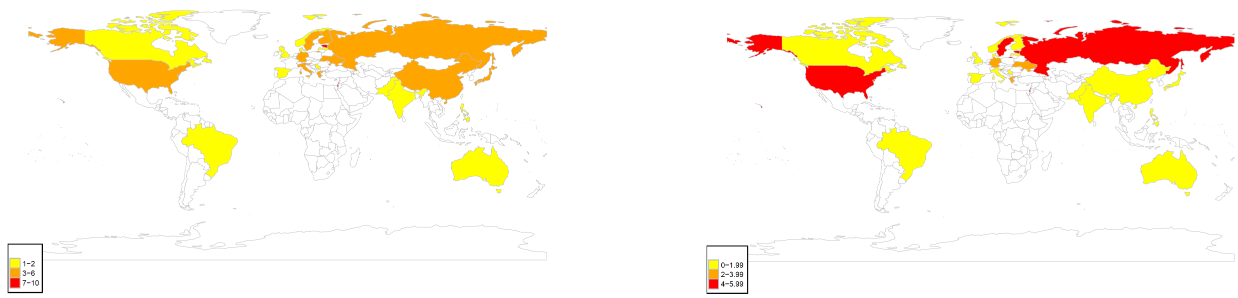
## Contents

# 1 Elite Interviews: Causes of Military Cybercapability

To investigate the factors that drive a country's decision to start integrating military technologies, I conducted sixty-four interviews with cybersecurity experts from twenty-five countries in 2018.[1] Most of these experts either have a current or past government affiliation. I personally conducted these interviews in person or via Skype or email. Figure 1a displays the number of interviews I conducted in each country. The most interviews I conducted in a given country was nine (in Estonia and Israel). Figure 1b displays the total duration of my interviews by country. My interviews, on average, lasted for about an hour, with the shortest interviews lasting for fifteen or thirty minutes.

Figure 1: Summary of the Interviews




(a) Total Number of Interviews by Country

(b) Total Duration by Country (in hours)

# 2 Summary Statistics and Correlation Plots

Figure 2 depicts the correlation plot for the main explanatory variables and controls. Table 1 shows the summary statistics for the main explanatory variables and controls.

Table 1: Summary Statistics

| | *Minimum* | *Median* | *Mean* | *Maximum* |
|---|---|---|---|---|
| Adversaries Integrating Cyber via Existing Agencies (lasg, sc) | -0.38 | -0.38 | 0.00 | 5.54 |
| Adversaries Integrating Cyber via New Agencies (lag, sc) | -0.22 | -0.22 | 0.00 | 8.25 |
| Allies Integrating Cyber via Existing Agencies (lasg, sc) | -18.91 | -0.17 | 0.00 | 5.61 |
| Allies Integrating Cyber via New Agencies (lasg, sc) | -5.97 | -0.16 | 0.00 | 4.79 |
| Bureaucratic Dominance | 0.00 | 0.53 | 0.52 | 1.00 |
| GDP per Capita (log, sc) | -2.09 | -0.06 | 0.00 | 2.46 |

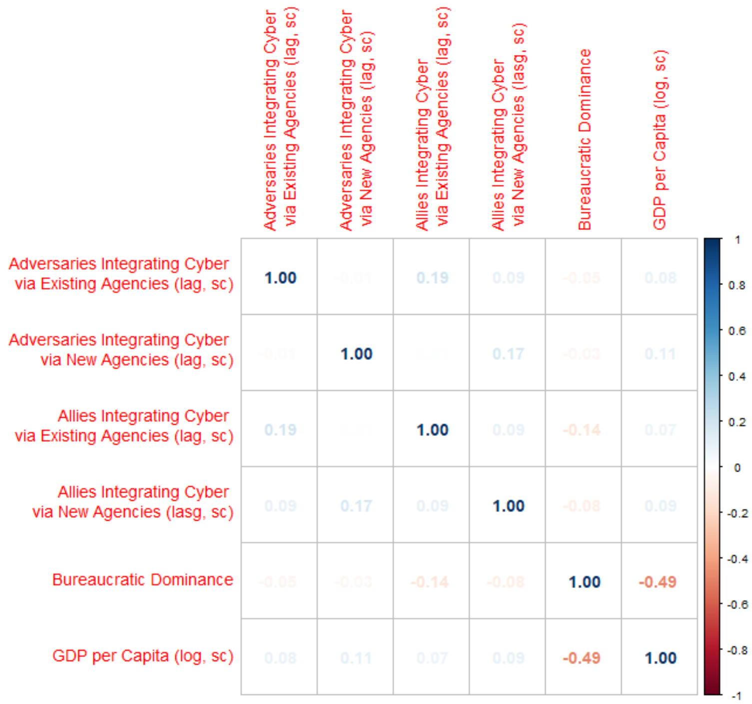
# 3 Empirical Strategy

## 3.1 Lagged network-weighted effects

To identify the effect of the agencies developed by a country's adversaries and allies, I create lagged network-weighted effects. Instead of lagging the value of the dependent unit one variable at a time

[1] The IRB approval is #HUM00127749 (February 14, 2018).

Figure 2: Correlation Plot




and, as a result, adding a significant number of regressors to my model, I use lagged network-weighted effects that capture the “weighted average of the dependent variable in the actor's ‘neighborhood”’ (Simmons and Elkins, 2004, 178). I define such effects for a country $i$ as:

$$W_i * y_{-i}(t) := \sum_{j \neq i} W_{i,j}(t) y_j(t), \tag{1}$$

where, $W_{i,j}(t)$ is an $N \times N$ spatial weights matrix that capture's country $i$'s allies/adversaries. Each element in $W_{i,j}$ measures a country $i$'s allies/adversaries. $\sum_{j \neq i} W_{i,j}$ captures the weight of the relationship between any two nations (either any two allies or any two neighbors) relative to the nation's total relationships with other allies/adversaries. This weight captures the importance of an ally/adversary's influence on this country. For instance, if a nation has only one ally, then their relationship has a weight of 100%; consequently, the ally will most likely have a significant influence on this country's decision to start developing its military cyber capabilities. On the other hand, if a nation has twenty allies and each relationship has a weight of 5%, then the influence of an individual ally on the country's decision to start developing its military cyber capabilities will most likely be limited. $y_{-i}(t)$ represents whether a country's ally/adversary $-i$ assigned a new responsibility to an existing military agency or created a new unit. Combined, $W_i * y_{-i}(t)$ captures the total effect of the country's ally/adversary that started developing its military cyber capabilities.

## 3.2 Competing Risks Cox Proportional Hazard Model

I fit the following competing risks Cox proportional hazard models, which examines the effect of time-varying and time-invariant covariates on the country's decision to start integrating cyber technologies within its military. Equation 2 presents the log hazard that stands for the relative risk of the country starting developing cyber capabilities by assigning a new responsibility to an existing military agency.

$$log(H_y(t; X_i, y, z)) = W_i * y_{-i}([t-1])\beta_1 + W_i([t-1])z([t-1])\beta_2 + X_i([t-1])\beta_3 + log\lambda_y(t), \quad (2)$$

where: $log(H_y(t; X_i([t-1]), y_i([t-1])))$ is the log hazard that stands for the relative risk of country $i$ assigning a new responsibility to an existing military agency at time $t$; $W_i y_{-i}([t-1])$ is an $n \times n$ spatial weights matrix, as explained in Section 3.1, that represents a dispersion variable which stands for a convolution of the country's allies/adversaries that started developing cyber capabilities by assigning new responsibilities to existing military agencies; $W_i z_{-i}([t-1])$ is an $n \times n$ spatial weights matrix, as explained in Section 3.1, that represents a dispersion variable which stands for a convolution of the country's allies/adversaries that started developing cyber capabilities by creating new military units; $X_i([t-1]) = [x_{1i}([t-1]), \ldots, x_{ki}([t-1])]'$ is a matrix of $k$ exogenous variables; $\beta_3$ is a three-dimensional vector of coefficients; and $log\lambda(t)$ is baseline hazard. As described in main manuscript, I control for the country's GDP per capita (logged) in a given year, taken from the World Bank (`GDP_PerCapita`). I also use robust standard errors with clustering on the countries to account for time-varying coefficients.

Equation 3 presents the log hazard that stands for the relative risk of the country starting developing cyber capabilities by creating a new military unit.

$$log(H_z(t; X_i, y, z)) = W_i([t-1])y([t-1])\beta_1 + W_i([t-1])z([t-1])\beta_2 + X_i([t-1])\beta_3 + log\lambda_z(t), \quad (3)$$

where: $log(H_z(t; X_i([t-1]), y_i([t-1])))$ is the log hazard that stands for the relative risk of country $i$ creating a new military agency at time $t$; $W_i y_{-i}([t-1])$ is an $n \times n$ spatial weights matrix, as explained in Section 3.1, that represents a dispersion variable which stands for a convolution of the country's allies/adversaries that started developing cyber capabilities by assigning new responsibilities to existing military agencies; $W_i z_{-i}([t-1])$ is an $n \times n$ spatial weights matrix, as explained in Section 3.1, that represents a dispersion variable which stands for a convolution of the country's allies/adversaries that started developing cyber capabilities by creating new military military units; $X_i([t-1]) = [x_{1i}([t-1]), \ldots, x_{ki}([t-1])]'$ is a matrix of $k$ exogenous variables; $\beta_3$ is a on-dimensional vector of coefficients; and $log\lambda(t)$ is baseline hazard.

One assumption of the Cox proportional hazard model is that no two countries can integrate cyber technologies at the same time. To "break" possible ties, I use the Efron approximation in my model as it is a tighter approximation to the exact marginal. Another assumption of the Cox proportional hazard model is that the hazard ratios do not vary over time. I use the Therneau and Grambsch nonproportionality test, which uses scaled Schoenfeld residuals, to test this assumption (Grambsch and Therneau, 1994). If variables violate this assumption, I interact these variables with `tstart` to address this issue (Therneau, Crowson and Atkinson, 2020). Despite following this recommendation by the authors of the R package, the effect of these variables should be generally understood as an average effect over the entire studied period and not as a conditional effect over a particular period of time. Moreover, while the Therneau and Grambsch nonproportionality test detects a number of specification errors in addition to nonproportionality, it may yield a false-positive test if the model is misspecified (Therneau, Grambsch and Fleming, 1990; Grambsch and Therneau, 1994; Therneau and Grambsch, 2000). I ran robustness checks that use the inverse hyperbolic sine function for continuous covariates to address that possibility.

# 4 Robustness checks

My results are robust to the following checks:

1. *Alternative measure of alliances:* Section 4.1 considers an alternative measure of alliances, using Gibler (2008)'s The Correlates of War (COW) Project's data on formal alliances (v4.1));
2. *Alternative network specification:* Section 4.2 considers diffusion via geographic neighbors and socio-culturally similar nations.
3. *Alternative functional form:* Section 4.3 uses the inverse hyperbolic sine function for continuous covariates to investigate whether I employ the correct functional form of the covariates.

## 4.1 Alternative measure of alliances

This section considers an alternative measure of alliances, using Gibler (2008)'s The Correlates of War (COW) Project's data on formal alliances (v4.1)). Model 1 in Table 2 confirmed the replication dynamics that exists within alliances.

Table 2: Robustness Checks: Influence of adversaries, allies, and bureaucratic competition on a country's decision to start developing military cyber capabilities (hazard ratios and confidence intervals)

| | *Model 1* | | *Model 2* | |
|---|---|---|---|---|
| | E: Existing | E: New | E: Existing | E: New |
| | (COW Alliances) | | (Diffusion after Neighbors) | |
| *Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.336***(1.14;1.57) | 0.976 (0.67;1.42) | 1.479***(1.24;1.76) | 1.435**(1.13;1.82) |
| *Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | 1.000 (0.81;1.23) | 1.213*(1.01;1.46) | 0.960 (0.78;1.18) | 1.134 (0.74;1.73) |
| *Neighbors Integrating Cyber Technologies within Existing Agencies (lag, sc)* | —— | —— | 1.033 (0.89;1.19) | 0.945 (0.75;1.20) |
| *Neighbors Integrating Cyber Technologies within New Agencies (lag, sc)* | —— | —— | 0.880*(0.78;1.00) | 1.070 (0.91;1.26) |
| *Adversaries Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.80 (0.92;1.26) | 1.179 (0.95;1.46) | 1.078 (0.92;1.26) | 1.098 (0.88;1.36) |
| *Adversaries Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.955 (0.81;1.12) | 0.959 (0.72;1.27) | 0.962 (0.79;1.17) | 0.946 (0.73;1.23) |
| *Bureaucratic Dominance* | 1.002(0.44;2.26) | 0.380 (0.09;1.65) | 0.797 (0.35;1.81) | 0.310 (0.07;1.31) |
| *GDP_PerCapita (log)* | 2.079***(1.62;2.67) | 2.644***(1.62;4.31) | 2.002***(1.55;2.58) | 2.327***(1.47;3.69) |
| Clustering by country | ✓ | | ✓ | |
| Concordance | 0.727 | | 0.753 | |

*Note:* Results are from a Cox Proportional-Hazards model, a competing risk model in particular. The reported values are the hazard ratios and confidence intervals. Hazard ratios larger than 1 identify positive correlation and those smaller than 1 identify negative correlation. There are 2,470 observations and 94 events. All results are based on two-tailed tests. *E:* event; `Existing` identifies integration of cyber technologies within an existing military agency; `New` identifies integration of cyber technologies within a new military cyber agency; `log:` logarithmized; `lag:` lagged; `sc:` standardized. ^p<0.1; *p<0.05; **p<0.01; ***p<0.001

## 4.2 Alternative Network Specification

In addition to examining the influence of allies, I also explore an alternative network specification: diffusion through geographic neighbors. Countries often develop their military cyber capabilities with warfare in mind. Most international conflicts occur between a limited set of dyads, known as "interstate rivals" (Goertz and Diehl, 1993; Lemke and Reed, 2001). These enduring rivalries frequently involve contiguous states. Factors such as contiguity (Diehl, 1985; Senese, 2005; Boulding, 1962; Bremer, 1992; Hensel et al., 2000) and territorial claims (Hensel et al., 2000; Vasquez, 2009; Huth, 2009; Vasquez, 1995, 2001) are key drivers of escalating conflicts. Additionally, conflicts over territory between neighboring states are more likely to re-emerge (Hensel, 1994; Stinnett and Diehl, 2001). Some scholars argue that changes in relative capabilities over time are critical to understanding the breakdown of peace (Werner, 1997, 1999). Based on this reasoning, it is plausible that a country might emulate its neighbors in structuring its military cyber capabilities. To identify geographic neighbors, I use a dummy variable that indicates whether two countries share a land border or are separated by at most 400 miles of water (`Neighbors`) (Stinnett et al., 2002). The results presented in Model 2 of Table 2 show that the organization of military cyber capabilities by a country's allies is a more consistent predictor of the country's own choices than geographic proximity alone.

Table 3: Robustness Checks: Influence of adversaries, allies, and bureaucratic competition on a country's decision to start developing military cyber capabilities (continued) (hazard ratios and confidence intervals)

| | *Model 3* | | *Model 4* | |
|---|---|---|---|---|
| | E: Existing | E: New | E: Existing | E: New |
| | (Diffusion after Linguistic Partners) | | (Functional Form | |
| *Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.485***(1.25;1.77) | 1.363*(1.05;1.76) | 2.044***(1.5; 2.79) | 1.961**(1.25;3.09) |
| *Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.952 (0.78;1.16) | 1.124 (0.74;1.71) | 0.862 (0.61;1.22) | 1.251 (0.57;2.76) |
| *Linguistic Partners Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.017 (0.83;1.25) | 0.869*(0.78;0.97) | | |
| *Linguistic Partners Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.952^(0.9;1.00) | 1.164*(1.01;1.34) | — | — |
| *Adversaries Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.074 (0.92;1.26) | 1.152 (0.94;1.41) | 1.187 (0.89;1.59) | 1.129 (0.75;1.69) |
| *Adversaries Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.960 (0.78;1.17) | 0.819 (0.5;1.33) | 0.863 (0.57;1.32) | 0.958 (0.55;1.67) |
| *Bureaucratic Dominance* | 0.784 (0.34;1.79) | 0.412 (0.1;1.76) | 0.808 (0.33;2.00) | 0.326 (0.07;1.63) |
| *GDP_PerCapita (log)* | 2.013***(1.57;2.58) | 2.239***(1.39;3.60) | 2.319***(1.64;3.27) | 2.977**(1.50; 5.90) |
| Clustering by country | ✓ | | ✓ | |
| Concordance | 0.755 | | | |

*Note:* Results are from a Cox Proportional-Hazards model, a competing risk model in particular. The reported values are the hazard ratios and confidence intervals. Hazard ratios larger than 1 identify positive correlation and those smaller than 1 identify negative correlation. There are 2,470 observations and 94 events. All results are based on two-tailed tests. *E:* event; `Existing` identifies integration of cyber technologies within an existing military agency; `New` identifies integration of cyber technologies within a new military cyber agency; `log:` logarithmized; `lag:` lagged; `sc:` standardized. ^p<0.1; *p<0.05; **p<0.01; ***p<0.001

In addition to geographic neighbors, I also examine the influence of linguistic partners. Given that cybersecurity is a relatively new field, national leaders often operate under conditions of limited information when developing their military cybersecurity strategies. In such contexts, leaders are likely to seek guidance from countries with similar cultural and linguistic backgrounds (Simmons and Elkins, 2004, 175). To investigate this, I use Graham and Tucker (2019)'s World Economics and

Politics Dataverse (WEPD) to create a dummy variable indicating whether two nations share the same official language. By combining this with Kostyuk (2022)'s State Cybersecurity Organizations (SCO) dataset, I calculate a weighted average effect of the cybersecurity organizations adopted by a country's linguistic partners in the period preceding the country's decision on cyber militarization. The results presented in Model 3 of Table 3 indicate that the organization of military cyber capabilities by a country's allies is a more consistent predictor of the country's own choices than the influence of linguistic partners.

### 4.3 Functional Form

To investigate whether I employ the correct functional form of the covariates, I run robustness checks using the inverse hyperbolic sine function for continuous covariates. Model 4 in Table 3 demonstrates that the earlier obtained results generally hold.

# 5 Additional Analyses: Explaining the influence of allies

Table 4: Influence of adversaries, allies, and bureaucratic competition on a country's decision to start developing military cyber capabilities, broken by alliance types (hazard ratios and confidence intervals)

| | *Model 5* | | *Model 6* | |
|---|---|---|---|---|
| | E: Existing | E: New | E: Existing | E: New |
| *Defensive Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.271**(1.08;1.49) | 1.216 (0.95;1.56) | —— | —— |
| *Defensive Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.905 (0.73;1.12) | 1.455*(1.07;1.99) | —— | —— |
| *Neutrality Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | —— | —— | 1.264*(1.10;1.46) | 1.067 (0.78;1.46) |
| *Neutrality Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | —— | —— | 1.127^(0.99; 1.28) | 1.215 (0.94;1.56) |
| *Adversaries Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.09 (0.94;1.28) | 1.125 (0.92;1.37) | 1.104 (0.95;1.28) | 1.155 (0.94;1.41) |
| *Adversaries Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.952 (0.81;1.13) | 0.911 (0.70;1.20) | 0.920 (0.75;1.14) | 0.918 (0.65;1.28) |
| *Bureaucratic Dominance* | 0.988 (0.43;2.26) | 0.473 (0.15;1.94) | 0.884(0.38;2.04) | 0.274(0.056;1.34) |
| *GDP_ PerCapita (log)* | 2.189***(1.70;2.82) | 2.423***(1.46;4.04) | 2.148***(1.67;2.76) | 2.585***(1.61;4.17) |
| Clustering by country | ✓ | | ✓ | |
| Concordance | 0.723 | | 0.732 | |

*Note:* Results are from a Cox Proportional-Hazards model, a competing risk model in particular. The reported values are the hazard ratios and confidence intervals. Hazard ratios larger than 1 identify positive correlation and those smaller than 1 identify negative correlation. There are 2,470 observations and 94 events. All results are based on two-tailed tests. *E:* event; `Existing` identifies integration of cyber technologies within an existing military agency; `New` identifies integration of cyber technologies within a new military cyber agency; `log:` logarithmized; `lag:` lagged; `sc:` standardized. ^p<0.1; *p<0.05; **p<0.01; ***p<0.001

Table 5: Influence of adversaries, allies, and bureaucratic competition on a country's decision to start ideveloping military cyber capabilities, broken by alliance types (continued) (hazard ratios and confidence intervals)

| | *Model 7* | | *Model 8* | |
|---|---|---|---|---|
| | E: Existing | E: New | E: Existing | E: New |
| *Nonaggression Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.24*(1.02;1.52) | 1.46**(1.12;1.91) | —— | —— |
| *Nonaggression Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.96 (0.76;1.22) | 1.43^(0.99;2.08) | —— | —— |
| *Consultation Allies Integrating Cyber Technologies within Existing Agencies (lag, sc)* | —— | —— | 1.15 (0.93;1.42) | 1.236(0.88;1.75) |
| *Consultation Allies Integrating Cyber Technologies within New Agencies (lag, sc)* | —— | —— | 0.987(0.77;1.26) | 1.240*(1.00;1.53) |
| *Adversaries Integrating Cyber Technologies within Existing Agencies (lag, sc)* | 1.12 (0.97;1.30) | 1.08 (0.88;1.33) | 1.125 (0.97;1.31) | 1.134 (0.93;1.39) |
| *Adversaries Integrating Cyber Technologies within New Agencies (lag, sc)* | 0.94 (0.78;1.13) | 0.90 (0.70;1.16) | 0.954(0.81;1.13) | 1.00 (0.80;1.25) |
| *Bureaucratic Dominance* | 0.92 (0.41;2.06) | 0.321(0.07;1.52) | 1.012 (0.45;2.30) | 0.345 (0.07;1.63) |
| *GDP_PerCapita (log)* | 2.125***(1.66;2.72) | 2.574***(1.57;4.21) | 2.151***(1.70;2.74) | 2.688***(1.64;4.41) |
| Clustering by country | ✓ | | ✓ | |
| Concordance | 0.731 | | 0.721 | |

*Note:* Results are from a Cox Proportional-Hazards model, a competing risk model in particular. The reported values are the hazard ratios and confidence intervals. Hazard ratios larger than 1 identify positive correlation and those smaller than 1 identify negative correlation. There are 2,470 observations and 94 events. All results are based on two-tailed tests. *E:* event; `Existing` identifies integration of cyber technologies within an existing military agency; `New` identifies integration of cyber technologies within a new military cyber agency; `log:` logarithmized; `lag:` lagged; `sc:` standardized. ^p<0.1; *p<0.05; **p<0.01; ***p<0.001

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