Title

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Abstract

This is the abstract.

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We thank...

I. Modelling "Steel and Guns" in a Global Setting: Presenting the GVAR Methodology

I. GVAR: Country-specific Equations and Granger-causality Tests

Global vector auto-regressive models (GVAR) are a special category of vector auto-regressive models (VAR). Following Box-Steffensmeier et al. (2014, 164), define a VAR model as follows,

$$\mathbf{x}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\Phi}_i \mathbf{x}_{i,t-p} + \mathbf{u}_{it} \tag{1}$$

where $\mathbf{x}_{it}$ is a $k_i \times 1$ vector of endogenous variables which are lagged p times on the right-hand side, and where $E(\mathbf{u}_{it}) = 0$. Now, following Mauro and Pesaran (2013, 14), define a GVAR model with p lags for country i as follows,

$$\mathbf{x}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\Phi}_i \mathbf{x}_{i,t-p} + \boldsymbol{\Lambda}_{1i}\mathbf{W}_t + \boldsymbol{\Lambda}_{2i}\mathbf{W}_{t-p} + \mathbf{u}_{it} \tag{2}$$

where $\mathbf{x}_{it}$ is a $k_i \times 1$ vector of domestic (i.e. endogenous) variables, $\mathbf{W}_t$ is a $k_i \times 1$ vector of weakly-exogenous foreign variables, and $\mathbf{u}_{it}$ is a serially uncorrelated and cross-sectionally weakly dependent process. As it becomes apparent, the inclusion of foreign variables $\mathbf{W}_t$ in Equation 2 is one of the main characteristics of the GVAR approach, and the main difference with the VAR equation described in Equation 1. In simple, the Global vector autoregressive GVAR model in Equation 2 explains $\mathbf{x}_{i,t}$ as a function of past values $\mathbf{x}_{i,t-p}$ lagged p times, at the same time that it weights these dynamics by weakly-exogenous foreign variables $\mathbf{W}_{t-p}$ (weights which are captured by parameters $\boldsymbol{\Lambda}_{ni}$).

Since we are substantively interested in weather "guns" *cause* "steel" or the other way around, in this paper we estimate country-specific bivariate Granger-causality tests within the GVAR framework.[1] The Granger-causality method was introduced in Granger (1969) and it seeks to investigate if some variable X Granger-causes another variable Y, or the other way around. A variable X is said to Granger-cause Y if predictions of Y based on lagged values of Y and lagged values of X perform better than explaining Y just with its own past values. Since Granger-causality

1. We acknowledge that without proper experimentation and randomization there cannot be proper causation. Consequently, and following the Granger methodology, we employ a rather lose definition of "causation" and explore if lagged values of a variable *forecast* another variable.

tests are usually estimated by fitting VAR equations (Equation 1) we now derive the Granger-causality test within the GVAR framework. The substantive advantage of GVAR Granger-causality tests over regular Granger-causality tests is that estimates are weighted by the global economy, situating the domestic dynamics within the global context. More formally, we estimate the following GVAR Granger-causality system for every country i with p lags as follows:

$$\mathbf{x}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\Phi}_{1i}\mathbf{y}_{i,t-p} + \boldsymbol{\Phi}_{2i}\mathbf{x}_{i,t-p} + \boldsymbol{\Lambda}_{1i}\mathbf{W}_t + \boldsymbol{\Lambda}_{2i}\mathbf{W}_{t-p} + \boldsymbol{\Lambda}_{3i}\mathbf{W}_t + \boldsymbol{\Lambda}_{4i}\mathbf{W}_{t-p} + \mathbf{u}_{it} \tag{3}$$

$$\mathbf{y}_{it} = \boldsymbol{\alpha}_i + \boldsymbol{\Phi}_{1i}\mathbf{x}_{i,t-p} + \boldsymbol{\Phi}_{2i}\mathbf{y}_{i,t-p} + \boldsymbol{\Lambda}_{1i}\mathbf{W}_t + \boldsymbol{\Lambda}_{2i}\mathbf{W}_{t-p} + \boldsymbol{\Lambda}_{3i}\mathbf{W}_t + \boldsymbol{\Lambda}_{4i}\mathbf{W}_{t-p} + \mathbf{u}_{it} \tag{4}$$

In our case, the vector $\mathbf{x}_{it}$ contains country-year levels of "military personnel," while vector $\mathbf{y}_{it}$ contains country-year levels of "iron and steel production." Both variables were systematized by the Correlates of War Project, particularly, the National Material Capabilities dataset (Singer, Bremer, and Stuckey 1972).[2] The dataset covers all countries in the world between 1816-2012.

Also, the vector of foreign variables is the single variable "dyadic trade" which measures bilateral trade flows between two countries. This variable was constructed by the same project but in the Trade dataset (Barbieri, Keshk, and Pollins 2009; Barbieri and Keshk 2016)[3] and was used to construct the weight matrix $\mathbf{W}$. The matrix is a square matrix which has all K countries in both its columns and rows with zeros as diagonal elements. The matrix represents bilateral trade among two countries measured by the *flow1* and the *flow2* variables. The former measures imports from a country (*importer1*) to another country (*importer2*), and the latter measures the reverse dyad, i.e. imports from *importer2* to *importer1*. More formally, $\mathbf{W}$ contains t sub-matrices (one sub-matrix per year) with dimensions $k \times k$ for a total of $\mathbf{K}$ countries such that,

$$\mathbf{W}_t = \begin{array}{cc} & \begin{matrix} \mathbf{i}_1 & \mathbf{i}_2 & \mathbf{i}_3 & \dots & \mathbf{i}_K \end{matrix} \\ \begin{matrix} \mathbf{i}_1 \\ \mathbf{i}_2 \\ \mathbf{i}_3 \\ \vdots \\ \mathbf{i}_K \end{matrix} & \begin{bmatrix} 0 & f_{21} & f_{31} & \dots & i_{K1} \\ f_{12} & 0 & f_{32} & \dots & i_{K2} \\ f_{13} & f_{23} & 0 & \dots & i_{K3} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ f_{1K} & f_{2K} & f_{3K} & \dots & i_{KK} \end{bmatrix} \end{array}$$

2. Version 5.0.
3. Version 4.0.

Every W_t matrix weights all K country-specific Granger regressions described in Equation 3. Every K system is weighted by the other $K-1$ countries. And as Equation 3 shows, the GVAR methodology also considers p lags of the $\mathbf{W}$ matrix. Following the literature on Granger-causality tests we focus our attention model-specific f-tests (one per country) which tests if all variables in the model are jointly significant. Then null is that there is no Granger causality.

add Deterministic variables to table (trend, constant)

II. Results

Table 1: *Bivariate Gobal Granger Causality Tests of the World Political Economy,* 1871-1913

	Granger Relationship	F-Test	P-Value	DF	Adjusted R-sq	Lags
Austria-Hungary	steel → guns	2.16	0.017	8,31	0.192	1
	guns → steel	2.48	0.238	8,31	0.233	
Belgium	steel → guns	1.781	0.001	16,19	0.263	5
	guns → steel	2.339	0.017	16,19	0.38	
France	steel → guns	1.27	0.257	8,31	0.052	1
	guns → steel	2.72	0.095	8,31	0.261	
Germany	steel → guns	1.844	0.003	8,31	0.148	1
	guns → steel	7.891	0.022	8,31	0.586	
Italy	steel → guns	2.777	0.004	16,19	0.448	5
	guns → steel	6.801	0	16,19	0.726	
Russia	steel → guns	8.725	0	16,19	0.779	5
	guns → steel	3.595	0.034	16,19	0.543	
Spain	steel → guns	1.454	0.126	8,31	0.085	1
	guns → steel	0.554	0.214	8,31	-0.101	
United Kingdom	steel → guns	1.85	0.023	16,19	0.28	5
	guns → steel	0.966	0.284	16,19	-0.016	
United States	steel → guns	2.942	0.044	8,31	0.285	1
	guns → steel	8.608	0	8,31	0.609	

Table shows country-specific Granger-causality F-tests. Last column shows number of domestic lags used per every country-specific Granger model. Number of lags for endogenous variables = 2. Number of lags for foreign variables = 2. Max number of lags for estimating the country-specific VAR model = 5. Information criteria for optimal lag length = AIC. Deterministic variables: Trend and constant.

Table 2: *Bivariate Gobal Granger Causality Tests of the World Political Economy,* 1955-2012 *(A)*

	Granger Relationship	F-Test	P-Value	DF	Adjusted R-sq	Lags
Argentina	steel → guns	0.422	0.568	10,44	-0.12	1
	guns → steel	7.765	0	10,44	0.556	
Australia	steel → guns	0.629	0.649	12,41	-0.092	2
	guns → steel	5.618	0	12,41	0.511	
Austria	steel → guns	0.656	0.726	12,41	-0.084	2
	guns → steel	7.305	0.024	12,41	0.588	
Belgium	steel → guns	3.842	0.002	12,41	0.392	2
	guns → steel	3.001	0.005	12,41	0.312	
Brazil	steel → guns	0.237	0.91	12,41	-0.209	2
	guns → steel	9.498	0	12,41	0.658	
Bulgaria	steel → guns	1.269	0.58	12,41	0.057	2
	guns → steel	4.286	0	12,41	0.427	
Canada	steel → guns	1.69	0.22	10,44	0.113	1
	guns → steel	5.055	0.019	10,44	0.429	
Chile	steel → guns	0.561	0.969	10,44	-0.088	1
	guns → steel	7.313	0	10,44	0.539	
Colombia	steel → guns	4.855	0.001	18,32	0.581	5
	guns → steel	1.737	0.004	18,32	0.21	
Egypt	steel → guns	0.219	0.955	10,44	-0.169	1
	guns → steel	5.471	0.013	10,44	0.453	
Finland	steel → guns	1.428	0.093	12,41	0.088	2
	guns → steel	5.041	0	12,41	0.478	
France	steel → guns	8.235	0.343	16,35	0.694	4
	guns → steel	1.442	0.116	16,35	0.122	
Greece	steel → guns	1.344	0.023	18,32	0.11	5
	guns → steel	2.39	0.006	18,32	0.334	
Hungary	steel → guns	3.363	0.011	12,41	0.349	2
	guns → steel	3.711	0.002	12,41	0.38	
India	steel → guns	1.287	0.847	14,38	0.072	3
	guns → steel	6.048	0	14,38	0.576	
Israel	steel → guns	0.702	0.622	10,44	-0.058	1
	guns → steel	0.63	0.588	10,44	-0.073	
Italy	steel → guns	2.151	0.169	10,44	0.176	1
	guns → steel	11.365	0.001	10,44	0.657	
Japan	steel → guns	1.876	0.015	16,35	0.216	4
	guns → steel	4.079	0.001	16,35	0.491	
Luxembourg	steel → guns	2.296	0.003	10,44	0.194	1
	guns → steel	0.925	0.541	10,44	-0.014	
Mexico	steel → guns	1.436	0.262	16,35	0.12	4
	guns → steel	8.525	0	16,35	0.702	
Netherlands	steel → guns	2.483	0.001	10,44	0.216	1
	guns → steel	3.73	0.001	10,44	0.336	
North Korea	steel → guns	2.875	0.006	18,32	0.403	5
	guns → steel	2.143	0.013	18,32	0.292	
Norway	steel → guns	1.02	0.178	10,44	0.004	1
	guns → steel	1.122	0.704	10,44	0.022	
Poland	steel → guns	1.57	0.734	12,41	0.114	2
	guns → steel	2.745	0.005	12,41	0.283	
Portugal	steel → guns	0.749	0.404	10,44	-0.049	1
	guns → steel	3.265	0.004	10,44	0.296	
Romania	steel → guns	1.019	0.464	10,44	0.004	1
	guns → steel	2.878	0.001	10,44	0.258	
South Africa	steel → guns	0.686	0.912	10,44	-0.062	1
	guns → steel	1.102	0.547	10,44	0.019	
South Korea	steel → guns	0.448	0.924	10,44	-0.114	1
	guns → steel	9.019	0	10,44	0.598	
Spain	steel → guns	4.66	0.001	10,44	0.404	1
	guns → steel	4.92	0.002	10,44	0.421	
Taiwan	steel → guns	1.382	0.064	12,41	0.08	2
	guns → steel	5.667	0	12,41	0.514	
Turkey	steel → guns	1.696	0.157	14,38	0.158	3
	guns → steel	25.426	0	14,38	0.868	
United Kingdom	steel → guns	9.085	0	10,44	0.6	1
	guns → steel	1.139	0.404	10,44	0.025	

Table shows country-specific Granger-causality F-tests. Last column shows number of domestic lags used per every country-specific Granger model. Number of lags for endogenous variables = 3. Number of lags for foreign variables = 3. Max number of lags for estimating the country-specific VAR model = 5. Information criteria for optimal lag length = AIC. Deterministic variables: Trend.

Table 3: *Bivariate Gobal Granger Causality Tests of the World Political Economy,* 1955-2012 *(B)*

	Granger Relationship	F-Test	P-Value	DF	Adjusted R-sq	Lags
China	steel → guns	0.252	0.996	9,45	-0.142	2
	guns → steel	83.191	0	9,45	0.932	
Russia	steel → guns	3.663	0.003	7,48	0.253	1
	guns → steel	1.775	0.031	7,48	0.09	
United States	steel → guns	1.821	0.1	7,48	0.095	1
	guns → steel	1.961	0.063	7,48	0.109	

Table shows country-specific Granger-causality F-tests. Last column shows number of domestic lags used per every country-specific Granger model. Number of lags for endogenous variables = 2. Number of lags for foreign variables = 2. Max number of lags for estimating the country-specific VAR model = 5. Information criteria for optimal lag length = AIC. Deterministic variables: NA.

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II. Appendix

I. Info that goes into the Appendix