# Title

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**Abstract**

This is the abstract.

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# 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 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 countries in both its columns and rows with zeros as diagonal elements. The matrix represents bilateral trade among two countries. Every country is weighted by the other remaining countries. As Equation 3 shows, the GVAR methodology also considers $p$ lags for the $\mathbf{W}$ matrix. More formally, $\mathbf{W}$ contains $t$ sub-matrices (one matrix per year) with dimensions $k \times k$ for a total of $\mathbf{K}$ countries such that,

$$\mathbf{W}_t = \begin{array}{c} \\ \mathbf{i}_1 \\ \mathbf{i}_2 \\ \mathbf{i}_3 \\ \vdots \\ \mathbf{i}_K \end{array} \begin{array}{c} \begin{array}{ccccc} \mathbf{i}_1 & \mathbf{i}_2 & \mathbf{i}_3 & \dots & \mathbf{i}_K \end{array} \\ \begin{bmatrix} 0 & |i_1 - i_2| & |i_1 - i_3| & \dots & i_{1K} \\ |i_2 - i_1| & 0 & |i_2 - i_3| & \dots & i_{2K} \\ |i_3 - i_1| & |i_3 - i_2| & 0 & \dots & \vdots \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \vdots & \vdots & \vdots & \dots & i_{KK} \end{bmatrix} \end{array}$$

This means that the dynamics of every $i$ country-specific systems of equations are weighted $t$ times. Also note that bilateral trade is the geometric distance (i.e. the absolute value) between countries $i$ for all $K$ countries. Following the literature on Granger-causality, we focus our attention on the joint hypothesis

inflows out-flows?

f tests

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 | 2.834 | 0.017 | 8,31 | 0.273 | 1 |
| | guns → steel | 1.393 | 0.238 | 8,31 | 0.075 | |
| Belgium | steel → guns | 4.216 | 0.001 | 10,28 | 0.458 | 2 |
| | guns → steel | 2.759 | 0.017 | 10,28 | 0.316 | |
| France | steel → guns | 1.35 | 0.257 | 8,31 | 0.067 | 1 |
| | guns → steel | 1.907 | 0.095 | 8,31 | 0.157 | |
| Germany | steel → guns | 3.827 | 0.003 | 8,31 | 0.367 | 1 |
| | guns → steel | 2.694 | 0.022 | 8,31 | 0.258 | |
| Italy | steel → guns | 3.61 | 0.004 | 10,28 | 0.407 | 2 |
| | guns → steel | 5.039 | 0 | 10,28 | 0.515 | |
| Russia | steel → guns | 10.499 | 0 | 16,19 | 0.813 | 5 |
| | guns → steel | 2.423 | 0.034 | 16,19 | 0.394 | |
| Spain | steel → guns | 1.749 | 0.126 | 8,31 | 0.133 | 1 |
| | guns → steel | 1.454 | 0.214 | 8,31 | 0.085 | |
| United Kingdom | steel → guns | 2.674 | 0.023 | 8,31 | 0.256 | 1 |
| | guns → steel | 1.29 | 0.284 | 8,31 | 0.056 | |
| United States | steel → guns | 2.254 | 0.044 | 10,28 | 0.248 | 2 |
| | guns → steel | 5.528 | 0 | 10,28 | 0.544 | |

**Table 2:** *Bivariate Gobal Granger Causality Tests of the World Political Economy, 1955-2014*

| | Granger Relationship | F-Test | P-Value | DF | Adjusted R-sq | Lags |
|---|---|---|---|---|---|---|
| Argentina | steel → guns | 1.072 | 0.402 | 9,45 | 0.012 | 1 |
| | guns → steel | 6.222 | 0 | 9,45 | 0.465 | |
| Australia | steel → guns | 0.996 | 0.466 | 11,42 | -0.001 | 2 |
| | guns → steel | 3.564 | 0.001 | 11,42 | 0.347 | |
| Austria | steel → guns | 0.694 | 0.736 | 11,42 | -0.068 | 2 |
| | guns → steel | 2.526 | 0.015 | 11,42 | 0.24 | |
| Belgium | steel → guns | 4.525 | 0 | 13,39 | 0.468 | 3 |
| | guns → steel | 1.012 | 0.459 | 13,39 | 0.003 | |
| Brazil | steel → guns | 0.19 | 0.997 | 11,42 | -0.202 | 2 |
| | guns → steel | 5.779 | 0 | 11,42 | 0.498 | |
| Bulgaria | steel → guns | 0.606 | 0.813 | 11,42 | -0.089 | 2 |
| | guns → steel | 3.202 | 0.003 | 11,42 | 0.314 | |
| Canada | steel → guns | 1.531 | 0.157 | 11,42 | 0.099 | 2 |
| | guns → steel | 3.517 | 0.002 | 11,42 | 0.343 | |
| Chile | steel → guns | 0.294 | 0.973 | 9,45 | -0.133 | 1 |
| | guns → steel | 5.678 | 0 | 9,45 | 0.438 | |
| China | steel → guns | 0.13 | 0.999 | 9,45 | -0.17 | 1 |
| | guns → steel | 25.707 | 0 | 9,45 | 0.805 | |
| Colombia | steel → guns | 3.422 | 0.001 | 17,33 | 0.452 | 5 |
| | guns → steel | 1.719 | 0.089 | 17,33 | 0.196 | |
| Egypt | steel → guns | 0.19 | 0.994 | 9,45 | -0.156 | 1 |
| | guns → steel | 2.639 | 0.015 | 9,45 | 0.215 | |
| Finland | steel → guns | 1.504 | 0.154 | 17,33 | 0.146 | 5 |
| | guns → steel | 2.994 | 0.003 | 17,33 | 0.404 | |
| France | steel → guns | 1.456 | 0.194 | 9,45 | 0.071 | 1 |
| | guns → steel | 2.438 | 0.024 | 9,45 | 0.193 | |
| Greece | steel → guns | 1.35 | 0.232 | 11,42 | 0.068 | 2 |
| | guns → steel | 1.917 | 0.064 | 11,42 | 0.16 | |
| Hungary | steel → guns | 3.568 | 0.001 | 11,42 | 0.348 | 2 |
| | guns → steel | 4.868 | 0 | 11,42 | 0.445 | |
| India | steel → guns | 0.45 | 0.9 | 9,45 | -0.101 | 1 |
| | guns → steel | 7.349 | 0 | 9,45 | 0.514 | |
| Israel | steel → guns | 1.405 | 0.201 | 13,39 | 0.092 | 3 |
| | guns → steel | 1.291 | 0.259 | 13,39 | 0.068 | |
| Italy | steel → guns | 0.386 | 0.936 | 9,45 | -0.114 | 1 |
| | guns → steel | 1.142 | 0.355 | 9,45 | 0.023 | |
| Japan | steel → guns | 2.783 | 0.006 | 17,33 | 0.377 | 5 |
| | guns → steel | 2.074 | 0.036 | 17,33 | 0.267 | |
| Luxembourg | steel → guns | 5.861 | 0 | 17,33 | 0.623 | 5 |
| | guns → steel | 1.483 | 0.162 | 17,33 | 0.141 | |
| Mexico | steel → guns | 2.421 | 0.014 | 17,33 | 0.326 | 5 |
| | guns → steel | 4.269 | 0 | 17,33 | 0.526 | |
| Netherlands | steel → guns | 4.03 | 0 | 13,39 | 0.431 | 3 |
| | guns → steel | 1.771 | 0.084 | 13,39 | 0.162 | |
| North Korea | steel → guns | 3.9 | 0.001 | 11,42 | 0.376 | 2 |
| | guns → steel | 5.135 | 0 | 11,42 | 0.462 | |
| Norway | steel → guns | 0.786 | 0.684 | 15,36 | -0.067 | 4 |
| | guns → steel | 1.26 | 0.276 | 15,36 | 0.071 | |
| Poland | steel → guns | 0.597 | 0.792 | 9,45 | -0.072 | 1 |
| | guns → steel | 1.487 | 0.182 | 9,45 | 0.075 | |
| Portugal | steel → guns | 0.678 | 0.724 | 9,45 | -0.057 | 1 |
| | guns → steel | 1.59 | 0.147 | 9,45 | 0.089 | |
| Romania | steel → guns | 0.753 | 0.659 | 9,45 | -0.043 | 1 |
| | guns → steel | 2.089 | 0.051 | 9,45 | 0.154 | |
| Russia | steel → guns | 2.955 | 0.008 | 9,45 | 0.246 | 1 |
| | guns → steel | 1.032 | 0.43 | 9,45 | 0.005 | |
| South.Africa | steel → guns | 0.323 | 0.963 | 9,45 | -0.127 | 1 |
| | guns → steel | 1.282 | 0.273 | 9,45 | 0.045 | |
| South Korea | steel → guns | 0.306 | 0.969 | 9,45 | -0.131 | 1 |
| | guns → steel | 7.079 | 0 | 9,45 | 0.503 | |
| Spain | steel → guns | 3.799 | 0.001 | 13,39 | 0.412 | 3 |
| | guns → steel | 1.347 | 0.229 | 13,39 | 0.08 | |
| Taiwan | steel → guns | 2.099 | 0.05 | 9,45 | 0.155 | 1 |
| | guns → steel | 2.644 | 0.015 | 9,45 | 0.215 | |
| Turkey | steel → guns | 1.617 | 0.139 | 9,45 | 0.093 | 1 |
| | guns → steel | 10.103 | 0 | 9,45 | 0.603 | |
| United Kingdom | steel → guns | 10.371 | 0 | 9,45 | 0.61 | 1 |
| | guns → steel | 0.994 | 0.459 | 9,45 | -0.001 | |
| United States | steel → guns | 1.527 | 0.168 | 9,45 | 0.081 | 1 |
| | guns → steel | 2.986 | 0.007 | 9,45 | 0.249 | |

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# II. Appendix

## I. Info that goes into the Appendix