

# Two-stage Modelling of Arms Trade: Applying Inferential Network Analysis on the Cold War Period

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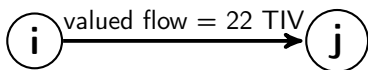
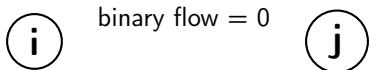
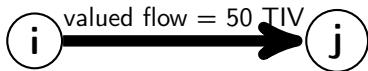
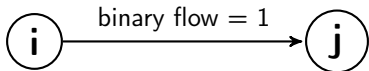
# Outline

1. Situating the Problem of IAT Research
2. Data
3. Empirical Strategy
4. Results
5. Summary
6. References



## International Arms Trade (IAT) - Motivation

1. Modelling for endogenous processes in IAT was neglected.
2. Conceiving IAT in a networked context is paramount.
  - ▷ Interdependencies of one trade being dependent on other trades.
3. So far only binary flows have been analysed, never valued flows.



## International Trade & Network Analysis

Squartini et al. (2011a) & (2011b):

- ▶ Binary as well as valued networks carry significant amounts of information.
- ▶ Derive need to first estimate binary flows before turning to valued flows.



# Outline

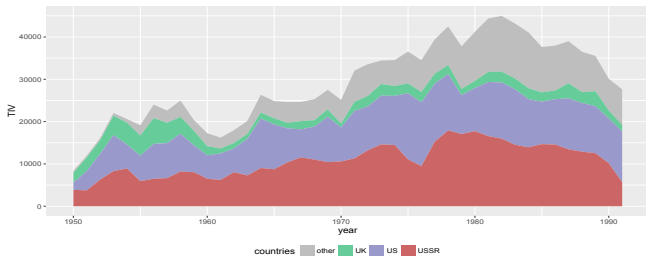
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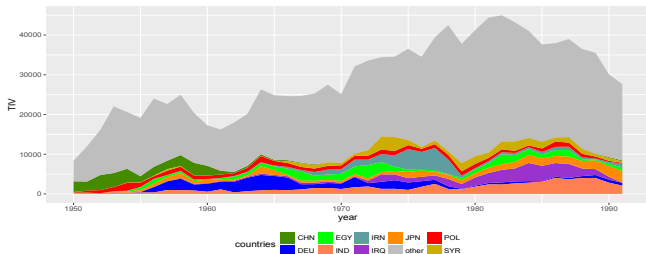
## Data

- ▶ SIPRI Arms Transfers Database
- ▶ All major conventional arms (MCW) trade from 1950 to 1991
- ▶ Measured in "Trend Indicator Values" (TIV), equals to transfer of military resources (not financial value)





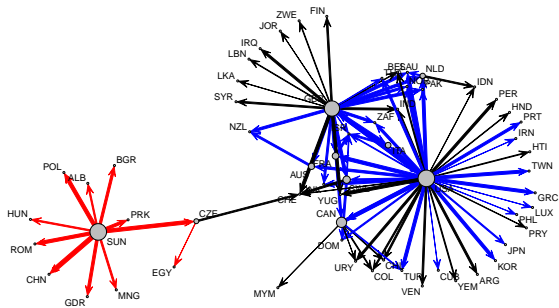
## Export



## Import



## Arms trade network in 1952







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## 1. Stage: ERGM - Binary decision to trade

- ▶ Exponential Random Graph Models (ERGMs) can model the structural generation of networks.
- ▶ Contains statistics which captures endogenous structures.
- ▶ Exogenous covariates that can be sender-specific, receiver-specific or dyad-specific.

$$P(\tilde{Y}_t | X_t = x_t) = \frac{\exp\{\theta^T s(\tilde{Y}_t, x_t)\}}{z(\theta)}$$

⇒ Probability of a given network over all networks one could have observed.



## Specifying the binary model - network statistics

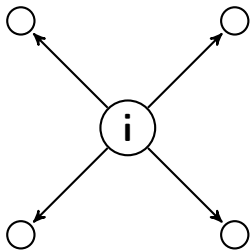


Figure 2: Geometrically weighted outdegree (GWO).

Endogenous Exporter Effect.

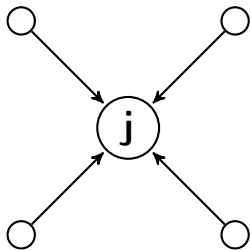


Figure 3: Geometrically weighted indegree (GWI).

Endogenous Importer Effect



## Specifying the binary model - network statistics

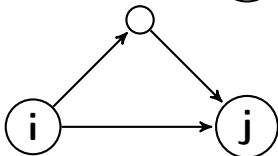
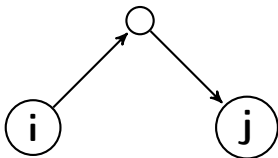


Figure 4: Geometrically weighted dyad wise shared partner (GWDSP)

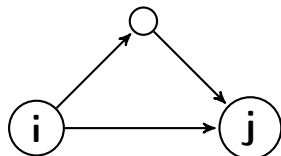


Figure 5: Geometrically weighted edge wise shared partner (GWESP)



## Specifying the binary model - ERGM exogenous covariates

Variable	Description	Source
<b>Economic Quantities</b>		
Log GDP, Sender	Logarithmic GDP of Exporter, 2 year lag	Gleditsch 2013
Log GDP, Receiver	Logarithmic GDP of Importer, 2 year lag	Gleditsch 2013
Log Military expenditure, Receiver	Logarithmic Military expenditure of Importer, 2 year lag	COW Project (2017)
Lagged log Arms Trade	Logarithmic Arms Trade, 1 year lag	SIPRI
Lagged log Goods Trade	Logarithmic Volume of Goods Trade, 1 year lag	Gleditsch 2013
<b>Political Quantities</b>		
Western Bloc	NATO, and US client states	See Paper Annex
Eastern Bloc	Warsaw Pact, and Soviet Union client states	See Paper Annex
Absolute Difference Polity Score	Difference between Scores (-10 to 10)	Polity IV series



## 2. Stage: Mixed Model - valued flows

- ▶ Usually employed in spatial statistics.
- ▶ Is conditional on given, binary network.
- ▶ Contains both fixed and random effects.
- ▶ Delegates network dependencies into the random effects.



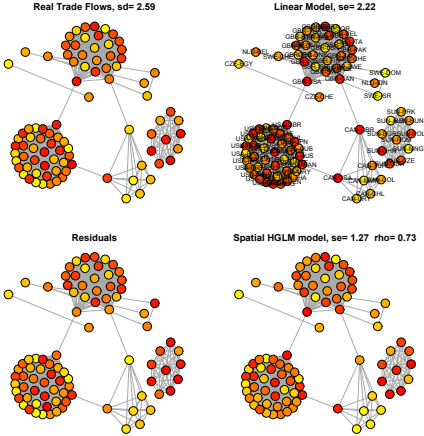


Figure 6: Tradecorrelation in 1952. Colours range from yellow (low values of  $\log(y_{t,ij})$ ) to red (high values of  $\log(y_{t,ij})$ ).





## Flowchart

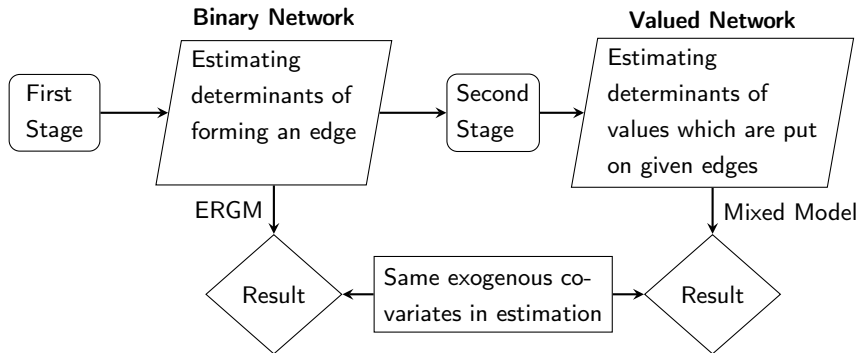


Figure 7: Depiction of the two stage process for estimating the IAT.



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## ERGM Results

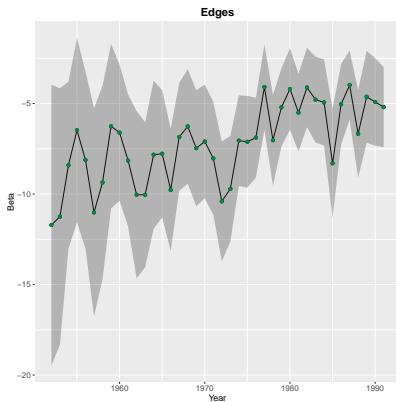


Figure 8: Negative Value represents a not very dense network.



## ERGM Results

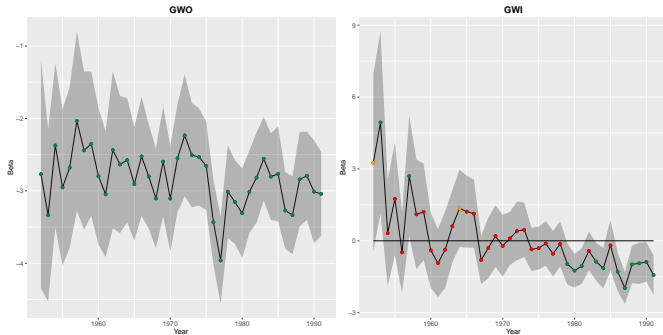


Figure 9: Significant & negative outdegree (GWO). From 1980ies significant & negative indegree (GWI).



## ERGM Results



Figure 10: Significant & negative GWDSP. Significant & positive GWESP from 1970ies on.



## Network statistics

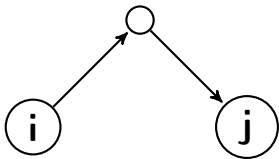


Figure 11: Negative GWDSP equals to not many indirect trades.

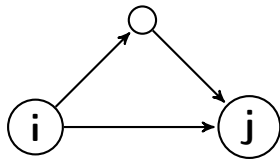


Figure 12: Positive GWESP means triangles defining feature of network.



## ERGM Results - exogenous covariates



Figure 13: Log GDP sender  $i$  and Log GDP receiver  $j$



## ERGM Results - exogenous covariates



Figure 14: Trade within Western Bloc results mixed.  
Trade within Eastern Bloc significant & positive





## ERGM Results - exogenous covariates

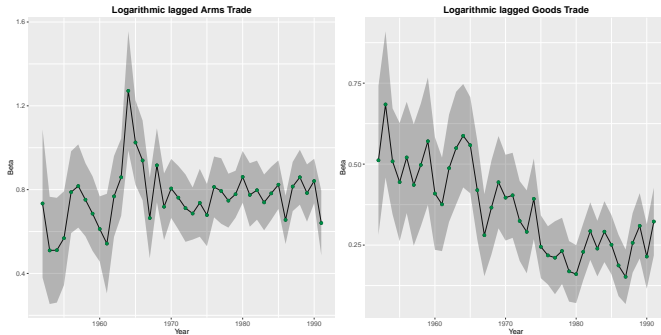


Figure 15: Lagged logarithmic Arms and Goods Trade positive and significant influence.



## ERGM Results

To summarize:

The selection into trade is defined by network dependencies and strategic, political motives.



## Mixed Model results, fixed effects



Figure 16: Log GDP sender  $i$  and Log GDP receiver  $j$



## Mixed Model results, fixed effects

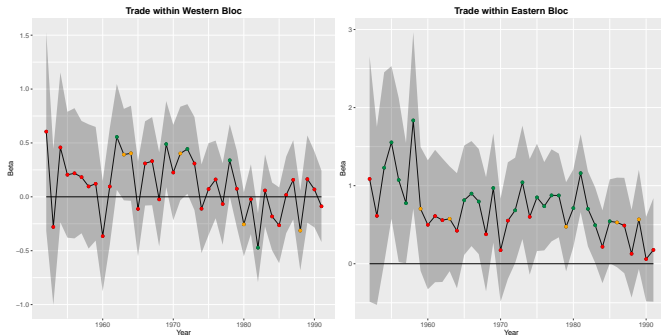


Figure 17: Within Western Bloc trade, within Eastern Bloc trade



## Mixed Model results, Joint estimation

Summary of the fixed effects estimates:

$\log(Y_{t,ij})$	Estimate	Std. Error	t-value	$\Pr(> t )$
Aircraft/Airdefence	-1.729	0.257	-6.718	0.0000
Armoured Vehicles	-1.635	0.257	-6.348	0.0000
Artillery	-2.120	0.264	-8.040	0.0000
Ships	-0.708	0.259	-2.729	0.0064
Other Equipment	-2.440	0.261	-9.343	0.0000
$\log(GDP_i)$	0.115	0.013	9.128	0.0000
$\log(GDP_j)$	0.155	0.011	13.767	0.0000
$\log(\text{Military Exp.}_j)$	0.033	0.005	6.494	0.0000
Western Bloc	0.096	0.032	2.997	0.0027
Eastern Bloc	0.651	0.052	12.640	0.0000
$\log(Y_{t-1,ij})$	0.511	0.007	73.361	0.0000
$\log(\text{Trade}_{t-1,ij})$	0.004	0.008	0.464	0.6425
$ \text{polity}_i - \text{polity}_j $	-0.011	0.002	-5.653	0.0000

Table 1: Result for the Linear Mixed Model, Estimated jointly for 1952-1991.



## Mixed Model Results, fixed effects

To summarize:

On the amount stage strategic, political motives compete with the supplier's economic motives.



## Mixed Model results, random effects

Summary of the random effects estimates:

		Estimate
Trade correlation	$\rho$	0.2430
Dispersion	$\tau^2$	0.6458
Time effects	included as dummy variables	
Observations		10,115
$R^2$		0.86
h-likelihood		-21,717.61
conditional AIC		32,954.44
marginal AIC		34,226.80

Table 2: Result for the Linear Mixed Model, Estimated jointly for 1952-1991.



## Trade correlation attributed to sender

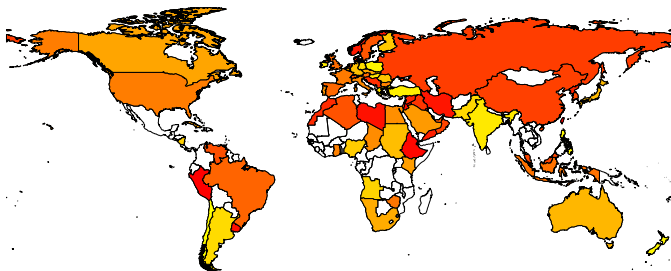


Figure 18: Random effects by countries, range from yellow (low) to red (high)





## Trade correlation attributed to receiver

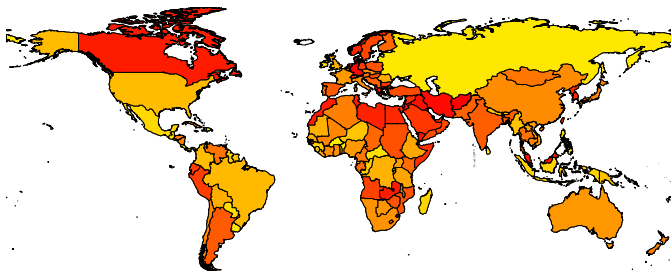


Figure 19: Random effects by countries, range from yellow (low) to red (high)



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## Flowchart

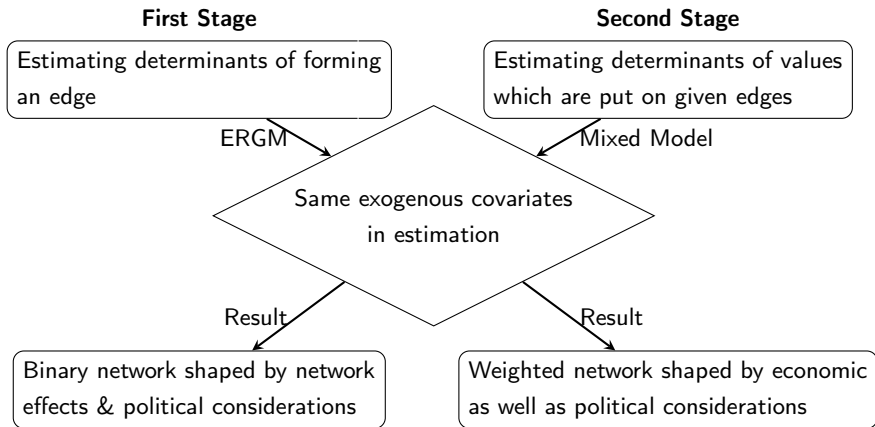


Figure 20: Depiction of the two stage process for estimating the IAT.



## Main results

1. The binary decision to trade is strongly driven by network effects and shows political considerations (strategic motive).
2. The amount stage suggests that economic considerations then play a bigger role for the decision of how much to trade (economic motive).
3. Flows in Eastern Bloc are higher than expected and in the Western Bloc lower than expected.



## Relevant points of the paper

- ▶ **Idea:** Take a network-based approach to analyse IAT.
- ▶ **Innovation:** Use a new approach to estimate the binary as well as valued flows.
- ▶ **Contribution to IAT literature:** Can disentangle between different motives on each stage.



## Future research

- ▶ A formal economic model to explain decision making on each stage.
- ▶ Deeper investigation of dependency structure of trade flows.
- ▶ Valued Network model with degree and transitivity measures in valued versions next step.
- ▶ Separate Investigation on binary and trade flows.
- ▶ Additional research on post Cold War period and Small Arms & light weapons.



## References

- ▶ Gleditsch, K. S. Expanded trade and GDP data 2013
- ▶ Singer, J. David, Stuart Bremer, and John Stuckey. (1972). "Capability Distribution, Uncertainty, and Major Power War, 1820-1965." in Bruce Russett (ed) Peace, War, and Numbers, Beverly Hills: Sage, 19-48., Version 5
- ▶ SIPRI Arms Transfers Database 2017
- ▶ Squartini, T., Fagiolo, G., Garlaschelli, D. (2011). Randomizing world trade. I. A binary network analysis. Physical Review E, 84(4), 046117.
- ▶ Squartini, T., Fagiolo, G., Garlaschelli, D. (2011). Randomizing world trade. II. A weighted network analysis. Physical Review E, 84(4), 046118.

