The Global Arms Trade Network 1950-2007*

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Abstract

Using SIPRI data on all international transfers of major conventional weapons 1950-2007, we study the relationship between differences in polity and arms trade. To study whether states tend to trade arms within their political vicinity we estimate gravity models of the likelihood of trade at the bilateral level and study the evolution of the global network over time. We find a stable negative relationship between differences in polity and the likelihood of arms trade for the duration of the Cold War, but not in recent years. In line with these results, the global arms trade network changes drastically over the sample period in several respects: it grows more dense, clustered and decentralized over time. The differences between the NATO and Warsaw Pact sub-networks that we find corroborate the common perception that the Warsaw Pact was more strongly centralized around the USSR than NATO around the UK, the US and France.

Keywords: Arms Trade, Network Formation, Polity, Cold War

JEL-classification: F19, F51, F59, P51

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1 Introduction

The arms trade is surrounded by great controversy. The nature of arms and the possibility to hold governments accountable for irresponsible trades makes the issue politically charged. In recent years, the propensity of many democratic governments to sell arms to autocracies and human-rights violators has stirred great public discontent. Yet, little empirical research has been devoted to the political economics of arms trade.

In this paper we focus on the relationship between political regimes and arms trade and study whether countries tend to trade arms within their political vicinity. We study the choices of key arms exporters, provide evidence on the determinants of arms trade at the bilateral level, study the evolution of the global arms trade network 1950-2007 and document key differences between the NATO and Warsaw Pact sub-networks during the Cold-War era.

The issue of polity as a potential determinant of arms trade is of great policy relevance. The post Cold-War era has been characterized by a self-proclaimed shift towards more ethical arms trade policies on the part of Western leaders, but proponents of international regulation have questioned the ability of states to act responsibly. The issue has been hotly debated in recent years and in April 2013, the UN passed its long-awaited but controversial Arms Trade Treaty (ATT). In addition to the prevention of arms flows to unstable regions and the objective to curb illicit trades, the respect for human rights is among the key principles of the treaty. Understanding how arms contracts are established and the structure of the global network may help us identify which features to emphasize in future ATT:s and other regulatory measures.

There are several reasons countries would prefer to trade arms with states with similar polity. To fix ideas, we focus on the perspective of democracies in what follows, but similar arguments may be applied to autocracies.\textsuperscript{1}

First, democracies may favour other democracies for reasons of security. The literature on arms races, comprising Schelling (1960), Aumann, Maschler, and Stearns (1968), Intriligator (1975), Brito and Intriligator (1981), Ayanian (1986), Levine and Smith (1995) and Baliga and Sjöström (2004), suggests that the possibility of reciprocity may be a strong deterrent when exporting arms. Moreover, the vast literature on the Democratic Peace Theory suggests that, while democracies are roughly as prone as non-democracies to go to war, they are unlikely to engage in violent conflict with other democracies, see for instance Maoz and Russett (1993) and references therein. This implies that a strategy of trading with kindred states is unlikely to

\textsuperscript{1} Throughout the analysis, we classify states as democratic or autocratic but an ideological distinction between left- and right-wing governments within each polity is beyond the scope of the paper. Comola (2012) studies how changes in political conditions affect the quantity of major conventional weapons exported by democracies and finds that right-wing governments tend to export more.
Second, governments may choose to trade with states with similar polity because it generates various types of political rents. Such rents may arise domestically, if ethical arms trade policies are rewarded by the electorate so that trading with other democracies helps governments stay in power. As noted by Perkins and Neumayer (2002), many Western governments have pledged to take human rights and democratic conditions into account in their arms trade decisions, but whether this is empty rhetoric is an open question. Blanton (2005) notes that in the post-Cold-War era, the US has claimed human rights and democratic conditions to be key determinants of US arms export eligibility. Estimating a two-stage model of US arms exports to developing countries over the period 1981-2001, she finds that democracies are more prone to receive arms and, in addition, more likely to receive large amounts of arms. This result is, however, contested by Perkins and Neumayer (2002), who study the export decisions of France, Germany, the UK and the US over the period 1992-2004, and find that these states have not discriminated against human-rights abusing or autocratic countries during this period. Indeed, Perkins and Neumayer claim to expose the "organized hypocrisy" of these supplier states and argue that arms have been exported to countries serving their economic and security interests.

Political rents may also arise internationally, if selling arms to similar states is a way to maintain strong international relations. Arms trade linkages may then be viewed as proxies for political ties and the global arms trade network should reflect constellations of political allies.

While security and political rents are likely to motivate democratic states to trade with other democracies, the lure of economic rents may render these objectives mute. The large fixed costs and technological constraints involved in the production of arms imply that exporting may be essential for rents to arise and for the survival of the weapons industry in many economies. If economic rents are a key driving force, governments may choose to export to any market where there is excess demand.

A challenge when trying to uncover the determinants of arms trade, is that the aforementioned mechanisms may yield similar outcomes. If we find evidence that democracies prefer other democracies, we would like to know whether this is for reasons of security or for reasons of political rents. However, it is not obvious how to gauge these factors, and even if they were directly observable, they are likely to be endogenously affected by arms transfers and therefore difficult to incorporate in a statistical model. This raises the question of whether there is some

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2 It is of course also possible that governments are altruistic and choose other democracies for this reason, rather than to remain in office.

3 On a related note, Antrás and i Miquel (2011) and Berger, Easterly, Nunn, and Satyanath (2010) argue that political influence leads to more trade bilaterally. If exporting arms is conducive to political influence in the receiving country and this leads to more intensive trade, economic rents from other trades may thus increase as well.
research design that can help us reveal the underlying preferences of governments.

One idea is to exploit the fact that the political landscape has changed drastically in the last 25 years. The end of the Cold War, marked by the collapse of the Soviet Union in 1991, caused substantial shifts in the global market for arms and changed the incentives for arms trade. This exogenous shock may be used to discriminate between different hypotheses about the underlying incentives for arms trade. While the literature on arms races suggests that, if democracies were to discriminate against autocracies during the Cold War, they would do so for reasons of security, Perkins and Neumayer (2002) and others suggest that, if democracies were to choose other democracies in recent years, they would do so to gain political rents. Evidence that polity mattered during the Cold War, is thus consistent with the hypothesis that the security motive dominated the prospect of economic rents in that period while evidence that polity has mattered after the Cold War, is an indication that political rents have dominated economic rents in recent years.

We address the relationship between polity and arms trade from several perspectives. First, we provide some indicative evidence by documenting the polities of the export destinations of six key economies. Second, we formalize the argument by estimating the relationship between differences in polity and the likelihood of arms trade in a bilateral specification of the gravity type. Third, we approach the subject from a novel perspective by studying the evolution of the global arms trade network over time. In addition to looking for clusters of political allies in the network graphs, we document how the network’s characteristics have changed over time. Fourth, we exploit the fact that the two main defence alliances during the Cold War, NATO and the Warsaw Pact, mainly comprised democratic and autocratic states, respectively. Comparing the properties of these two sub-networks, may shed some light on whether there are any differences in how democratic and autocratic arms trade networks function.

Throughout the analysis, we contrast the Cold-War era to the post-Cold-War subsample in an attempt to unveil whether governments are motivated by security, political rents or economic rents. We use an extensive dataset from the Swedish Institute for Peace Research (SIPRI), covering all trade in military equipment over the period 1950-2007. The dataset is of high quality and the richest dataset available on arms trade. We focus on trade in major conventional weapons and exclude trade in small arms from the dataset.4

Our main results are as follows. There is a stable, negative relationship between differences in polity and the likelihood of arms trade for the duration of the Cold War but not in recent years. This finding is corroborated by the network analysis: the network graphs suggest a clear

4 Since illegal trade is very difficult for larger types of military equipment, the exclusion of small arms reduces the risk of measurement error.
divide between the East and West throughout the Cold War era. The analysis also shows that the network has become more dense, clustered and decentralized over time and that it displays some similarities with other empirical networks, such as Small World Properties and dissorativity. Consistent with common perceptions about the hierarchy within NATO and the Warsaw Pact, we find that the latter network was more centralized than the former.

The recent economic literature on arms trade is limited. Our analysis is related to Levine and Smith (1995), who study the optimal design of arms control and to Levine, Smith, Reichlin, and Rey (1997), who provide a thorough discussion of the economic fundamentals of arms trade in a paper with empirical features.

The arms trade has, however, received more attention from political scientists. Kinsella (2011) provides an overview and notes that since intrastate conflict has become more common after the end of the Cold War, much of the recent literature focuses on small arms. Earlier discussions of the general characteristics and security issues involved in the global arms trade appear in Brzoska and Pearson (1994) and Buzan and Herring (1998).

We do not know of any published paper that applies network analysis to data on arms trade linkages. However, we were recently made aware of an unpublished study by Kinsella (2003), who documents properties of the arms trade network using SIPRI data. Our study digs deeper than Kinsella’s by addressing link formation at the bilateral level, by emphasizing the role of differences in polity and by studying the NATO and Warsaw Pact sub-networks separately.

Our paper also speaks to the literature on military alliances pioneered by Olson and Zeckhauser (1966). This strand has mainly addressed issues such as the optimal size and efficiency of alliances, see Sandler and Hartley (2001) for an overview.

In addition, our paper is somewhat related to the literature on trade and conflict. Martin, Mayer, and Thoenig (2008) dissect the conventional wisdom that trade deters conflict by distinguishing between bilateral and multilateral openness. They find that two countries trading with each other have a lower probability of bilateral conflict while multilateral openness has the opposite effect: more open economies are less dependent on bilateral relationships and therefore exhibit a greater probability of bilateral war. Finally, Glick and Taylor (2010) study the effects of belligerent conflict on international trade 1870-1997 and find very strong, persistent effects of war on trade. It is however doubtful whether these results can be applied to arms trade due to the strategic concerns involved.

The paper is organized as follows. Section 2 describes the data. Section 3 studies the behaviour of six key exporters. Section 4 presents the results from estimating a gravity model of arms trade and polity. Section 5 discusses the evolution of the global arms trade network.
1950-2007. Section 6 is devoted to the NATO and Warsaw-Pact sub-networks. Section 7 concludes.

2 Data

Data on arms trade is obtained from the Stockholm International Peace Research Institute (SIPRI). We use data from the SIPRI Arms Transfers Database, holding information on all international transfers of eleven categories of Major Conventional Weapons (MCWs): aircraft, air defence systems, anti-submarine warfare weapons, armoured vehicles, artillery, engines (for military aircraft, combat ships and most armoured vehicles), missiles, sensors, satellites and other MCWs (mainly turrets for armoured vehicles and ships). Our measure of arms trade is total bilateral exports (imports) of MCWs over the period 1950-2007. In order to minimize the noise in the data, we eliminate rebel groups from the sample. Representatives of SIPRI have assured us of the high quality of the dataset and informed us that, since the rules and surveillance pertaining to arms are so strict and since equipment of this nature and size is difficult to hide from observation, the arms trade not captured by the dataset is negligible.

The population of traders remains connected throughout the sample period with the exception of one trade between Cap Verde and Malawi in 2000. Dropping these two countries (the only isolates) from the sample results in a negligible loss of 22 out of 14,343 observations in the sample.

We merge the data with complementary information from different sources. Data on GDP per capita is from Maddison. Data on distance between countries, common language, common borders and common colonization history is retrieved from Centre D’Etudes Prospectives et D’Informations Internationales (CEPII). Data on the degree of democracy is from the POLITY IV database hosted by the Center for Systemic Peace and George Mason University. In order to compare our findings on arms trade to results for aggregate trade, we finally add data from the United Nations Comtrade database over the period 1962-2000.

As discussed in the introduction, in Section 6 we will study two subsets of countries comprising: (i) countries trading arms with at least one full member of NATO, henceforth the NATO network; and (ii) countries trading arms with at least one full member of the Warsaw Pact.

5 The standard dataset for international trade, the United Nations’ Comtrade dataset, also includes trade in arms, specifically “Arms and ammunitions” (sector 891 under SITC Rev. 4). However, we find the SIPRI data more suitable for this analysis for mainly two reasons. First, the UN data is collected by national customs authorities and therefore susceptible to manipulation. SIPRI collects data from a wide range of sources and is completely transparent as regards the exact content of any trade. Second, the UN data contains many “dual use” goods, which are suitable for both civilian and military use. An example would be optical equipment that can be used either as binoculars or mounted on rifles. The SIPRI data comprises larger goods and items intended exclusively for military use.
henceforth the Warsaw Pact network. The member countries of NATO and the Warsaw Pact are listed in Table A1 in the Appendix.

To verify that the NATO network was mainly democratic while the Warsaw-Pact network was mainly autocratic, we plot the sample size along with the evolution of the average POLITY-scores in the network as a whole and in the NATO and Warsaw Pact subgroups, in Figure 1. The solid black line in panel (a), depicting the population of countries trading arms, shows that the population of traders is roughly doubling between 1950-1970 and peaks in 1982. The pattern is similar for the NATO- and Warsaw Pact subgroups.

The POLITY-score ranges from $-10$ to $+10$, where a positive POLITY-score indicates that the sample is democratic on average, while a negative value indicates that the sample is non-democratic. The solid black line in panel (b), depicting the POLITY-score of the entire sample of countries, displays a decreasing trend at the beginning of the sample but a tendency towards democratic consolidation from the mid-1980s onwards. The plots suggest that the NATO network is, on average, indeed democratic in the beginning of the 1950s, becomes less democratic in the 1960s and 1970s, but displays a positive trend again in the 1980s. The trend for the Warsaw Pact is increasing, but the average POLITY-score remains clearly negative throughout its existence. These results suggest that countries trading arms with members of the Warsaw Pact, were autocratic on average.
3 The Choices of Six Key Players

To investigate whether polity matters for arms trade linkages, a naive approach is to study the POLITY-scores of the export destinations of key players. Figure 2 displays the POLITY-scores of the export destinations of the US, the UK, France, Sweden, the USSR and China over the period 1950-2007. Each dot represents the POLITY-score of each export destination in a given year and the black line indicates the annual average.

The top left graph of the US shows that, on average, the world’s oldest democracy tends to export arms to other democracies. However, the US has also consistently exported arms to autocracies throughout the sample period. There is a positive trend in the plot for the US, indicating that the US has become increasingly prone to export arms to other democracies over time. However, this could just reflect the global tendency towards democratization visible in Figure 1, rather than the US becoming increasingly selective. The patterns for the UK, France and Sweden are more erratic. The UK and France have been prone to export arms to other democracies except for in the 1970s and, in the case of France, in the early 1980s, when the average export destination of these countries was autocratic. Sweden, the only democracy in the group that maintained a neutral stance in the postwar-era, has mainly stayed on the democratic side of the horizontal axis except for in a few years in the late 1970s, when there was a tendency to export arms to non-democracies, albeit with average POLITY-scores close to zero.

Conversely, the USSR and China have typically exported arms to other autocracies. Figure 2 reveals that these countries have exported arms to democracies as well, but the average trading
partner has been non-democratic. There is some evidence that China started exporting arms to democratic countries to a greater extent in the beginning of the 21st century, but the trend has been reversed in recent years. The results also suggest that the USSR and China have been relatively more prone to export arms to countries with similar POLITY-scores, than the US, the UK, France and Sweden. In this small sample, the autocracies thus have an even stronger bias towards other autocracies than the democracies towards other democracies.

Figure 2 is consistent with the view that, historically, polity has been of some importance when choosing arms trade partners. Next, we look for statistical support for this conjecture.

4 A Gravity Model of Arms Trade

4.1 Econometric Specification

Our econometric strategy is to include distance in POLITY-scores as an explanatory variable in a gravity specification, controlling for a range of factors that may influence the likelihood of trade.\(^6\) Suppose that we have \(i = 1, \ldots, n\) countries in the sample. Let \(a_{ijt}\) and \(\overline{a}_{ijt}\) be dichotomous variables such that

\[
a_{ijt} = \begin{cases} 
1 & \text{if countries } i \text{ and } j \text{ trade in arms at time } t \\
0 & \text{otherwise}
\end{cases}
\]

and

\[
\overline{a}_{ijt} = \begin{cases} 
1 & \text{if country } i \text{ exports arms to country } j \text{ at time } t \\
0 & \text{otherwise}
\end{cases}
\]

Letting \(p_{it}\) be the POLITY-score of country \(i\) at time \(t\), we estimate the following linear probability models:

\[
a_{ijt} = \alpha (p_{it} - p_{jt})^2 + X_{ijt}\beta + \epsilon_{ijt}
\]

\(\forall i < j\) and

\[
\overline{a}_{ijt} = \alpha (p_{it} - p_{jt})^2 + X_{ijt}\beta + \sum_{i=1}^{n} (\gamma_{Xi}d_{Xi} + \gamma_{Mi}d_{Mi}) + \epsilon_{ijt}
\]

\(\forall i \neq j\) where \(\beta\) is a vector of parameters and \(X_{ijt}\) is a vector of controls comprising the following variables: \(B_{ijt}\), assuming the value 1 if \(i\) and \(j\) share the same border (contiguity); \(L_{ijt}\), assuming the value 1 if \(i\) and \(j\) share the same official language; \(CR_{ijt}\), assuming the value 1 if \(i\) and \(j\) were ever in a colonial relationship; \(CC_{45}^{ijt}\), assuming the value 1 if the countries were colonized by the same country post-1945; \(CR_{45}^{ijt}\), assuming the value 1 if the countries were in a colonial relationship post-1945; \(SC_{ijt}\), assuming the value 1 if the countries were the same country

\(^6\) Throughout the analysis, we estimate linear probability models. An alternative would be to assume a more structural approach based on firm heterogeneity as in Helpman, Melitz, and Rubinstein (2008). However, we do not believe firm heterogeneity to be a driving force behind arms trade and find a linear probability approach better suited for our purposes.
historically; \( \text{dist}_{ijt} \), denoting the distance between \( i \) and \( j \); \( y_{ijt} \), denoting the product of GDP in countries \( i \) and \( j \); \( y_{ijt}^C \), denoting the product of GDP per capita in countries \( i \) and \( j \); and \( r y_{ijt}^C \), denoting the relative GDP per capita between \( i \) and \( j \), i.e. \( r y_{ijt}^C = y_{it}^C - y_{jt}^C \).

A significant, negative estimate of \( \alpha \) thus suggests that the more different \( i \) and \( j \) are in terms of polity, the less likely they are to trade in arms. The dummy variables \( d_Xi \), and \( d_Mi \), are exporter and importer fixed effects, assuming the value 1 if country \( i \) is the exporter or importer, respectively, and 0 otherwise.\(^7\) It is not obvious whether fixed effects should be included as in (3). Fixed effects will capture country-specific differences that are constant over time, some of which may be of great importance to arms trade. Model (2), without fixed effects, measures the general correlation between differences in polity and the likelihood of arms trade, but disregards fixed country-specific characteristics. Some countries, such as the US or the UK, may, for instance, be exporting more arms due to the magnitude of their domestic arms trade industries. Other countries, such as the Ukraine after the breakup of the USSR, may be trading extensively due to large stocks of military equipment. The model without fixed effects also fails to take into account whether countries exhibiting a high risk of military conflict, such as the Koreas or Turkey, are more prone to import arms. When fixed effects are included, as in (3), \( \alpha \) captures the effect of differences in polity on the likelihood of arms trade taking such country-specific effects into account. For these reasons, we estimate models both with and without fixed effects and interpret them accordingly.

Since not all countries trade in arms and since the POLITY-score varies substantially with \( \max (p_{it} - p_{jt})^2 = 400 \), our estimates of \( \alpha \) will be quantitatively small. In order to provide meaningful interpretations of the estimated \( \alpha \)-coefficients, we convert them into implied relative probabilities, by taking into account the maximum variation of the POLITY-score and by relating the probability that two countries with different polities trade in arms to the probability that any two countries trade in arms. For the estimations without fixed effects we compute the implied relative likelihood, \( \theta \), as follows:

\[
\theta = \frac{(p_{\max} - p_{\min})^2 \hat{\alpha}}{\rho_{\text{arms}}} \tag{4}
\]

where \( p_{\max} \) and \( p_{\min} \) are the maximum and minimum POLITY-scores, respectively, \( \hat{\alpha} \) is the estimate from (2) and \( \rho_{\text{arms}} \) is the empirical probability that arms trade occurs in the sample.

At each point in time, the probability of arms trade is given by

\[
\rho_{\text{arms}} = \sum_i \sum_{i<j} \frac{a_{ij}}{n (n-1) / 2}
\]

\(^7\) We do not include country-pair fixed effects in the gravity equation since our outcome variable is binary and therefore contains limited variation.
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Notes: Standard errors within parenthesis. Significance codes: ** significant at the 1 percent level; * significant at the 5 percent level. The coefficient and standard error for distance in polity is multiplied by 1000. $\theta$ is the implied relative likelihood of arms trade in percent and measures how much less likely it is that two countries with the maximum distance in polity trade arms, compared to two countries with the same polity. FE indicates the inclusion of exporter and importer fixed effects.
where $n$ is the number of countries. For the fixed effects estimations, the implied relative probability is computed in the same way, but the average probability is slightly modified since the sample size increases when the direction of trade is taken into account. $\theta$ thus measures how much less likely two countries with the maximum distance in polity are to trade in arms, than two countries with the minimum distance in polity, when the overall probability of arms trade is taken into account.

### 4.2 Results

The results from estimating (2) and (3) using pooled OLS on the full sample 1962-2000 are displayed in Table 1, columns (1)-(6). Columns (1)-(3) display the results without fixed effects, i.e. model (2), and columns (4)-(6) the results when exporter and importer fixed effects are included as in model (3). Columns (7)-(10) report results from estimating these models on the Cold-War and post-Cold-War subsamples.

The results suggest that two states are more likely to trade arms if they share a border and if they were ever in a colonial relationship with one another. These results are robust across all specifications. Most specifications also suggest that countries at close geographical proximity from one another are more likely to trade arms, as are countries where the same language is spoken. The effects of the other variables are more sensitive to the inclusion of exporter- and importer- fixed effects and the sample period considered.

Turning to our main variable of interest, the results in columns (1)-(3) suggest that distance in polity has a negative effect on the likelihood of arms trade. The implied relative likelihood, computed according to (4), indicates that the effects are large. A country with the highest possible POLITY-score, i.e. a stable democracy such as the US, is approximately 60 percent less likely to trade with a country with the lowest possible polity score than with another country with the highest polity rating. Columns (4)-(6) indicate that these findings are robust to the inclusion of importer and exporter fixed effects. Even when taking into account fixed country characteristics such as the size of the arms industry and proximity to war zones, countries are thus more likely to trade with states within their political vicinity.

In light of the dramatic changes in the political landscape during the sample period, it is of great interest to study whether the effect of polity on the likelihood of arms trade is stable over time. Figure 3 displays $\theta$, the implied relative likelihood derived from the $\alpha$-coefficients obtained when estimating (2) and (3), and the associated 95-percent confidence interval in each

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8 The results are not sensitive to excluding trades of small volume. Additional results, available on request, show that the results are scarcely affected by redefining the occurrence of trade as meaning a transfer larger than a threshold value.
year. The left panel shows the results without fixed effects and the right panel the results when fixed effects are included. The figure shows that the estimate obtained when fixed effects are excluded is negative and significantly different from zero almost every year in the sample. The magnitude of the estimate decreases somewhat over time but remains negative throughout the sample period. When including fixed effects in the right panel, the effect of distance in polity remains negative for the duration of the Cold War but tends to zero after 1990.

How can we reconcile these findings? Recall that fixed effects allow us to control for country-specific characteristics such as the size of the arms trade industry and the technology available and that the fixed effects therefore are likely to proxy for the extent of trade. Excluding fixed effects implies that any effect of polity that we observe may be due to selection: perhaps democratic countries happen to trade with democratic countries simply because the latter group has access to better technology and therefore tends to produce arms. Including fixed effects, however, allows us to purge the estimates of such factors. The results in the right panel in Figure 3 thus suggest that, even when controlling for country characteristics, arms traders chose to trade with states with similar polity throughout the Cold War. After the Cold War, however, any negative correlation between distance in polity and the likelihood of arms trade that we find, is entirely absorbed by the country-specific fixed effects. The political regime, it seems, therefore played an important role prior to dissolution of the Soviet Union but has been of no importance in recent years. This is a key finding.

Figure 3: The effect of polity divergence on arms trade. Implied relative likelihood ($\theta$).
The results in columns (7) and (8), obtained when estimating (2) and (3) on the Cold War sub-sample, corroborate the pattern in Figure 3. Differences in polity had a significant, negative effect on the likelihood of arms trade prior to 1990. The results in columns (9) and (10), displaying the estimates on the post-1990 sample, confirm our previous findings that any effects of distance in polity that we find can be accounted for by exporter and importer fixed effects.

As a robustness check, we estimate (2) and (3) for aggregate trade to see whether distance in polity has any impact on the likelihood of trade in non-military goods. To be able to compare the two, we plot the results for arms trade along with the corresponding implied likelihood for trade in other goods in Figure 4. We find no negative effects of distance in polity on the likelihood of aggregate trade: the correlation is positive before 1990 and then tends to zero. The positive correlation found for aggregate trade may be driven by factors unrelated to polity, such as comparative advantage and natural resource endowments.\(^9\)

\(^9\) This could, for instance, reflect democracies not being able to discriminate against autocracies when importing goods that are largely produced in such economies. Oil is an example of a resource that, to a large extent, is held by non-democracies such as Saudi Arabia and the United Arab Emirates.
5 The Global Arms Trade Network

Having established that polity is likely to have played a key role in arms trade link formation during the Cold War but not in recent years, we now turn to our study of the global network. In addition to looking for constellations of political allies in the graphs, we study how the properties of the network have evolved over time.

5.1 Definitions and Graphs

To fix ideas, let $N = \{1, ..., n\}$ be the set of countries trading arms in a given year. Let $a$ represent an $n \times n$ matrix where $a_{ij}$ is defined as in (1) and represents a link between $i$ and $j$. The degree of each country, $d_i(a)$, is the number of links involving that node so that $d_i(a) = \# \{j : a_{ji} = 1\}$. The density of the network measures the number of trades as a share of all possible trades, and may be written as

$$D(a) = \frac{\sum_i d_i(a)}{n(n - 1)}$$

To be able to graph the evolution of the network over time, we plot five-year averages of bilateral

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure5.png}
\caption{The global arms trade network, 1950-1954.}
\end{figure}
Figure 6: The global arms trade network, 1970-1974.

trades. Figures 5-7 display the arms trade network over the periods 1950-54, 1970-74 and 2000-04, respectively. Since we are interested in the occurrence of trade (the extensive margin), rather than the volume of trade (the intensive margin), we treat the network as unweighted. The arrows run from exporter to importer and their lengths are unrelated to trading volumes.

Figure 5 shows that in 1950-54, arms were essentially traded within two distinct networks. The first network is centered around the US and the other around the USSR. To some extent, the sharp divide between the two networks is likely to reflect the agreement of the Coordinating Committee for Multilateral Export Controls (COCOM), initiated by western countries in 1949, to stop transfers of arms and technologies to the Soviet Union and its Eastern allies. A similar pattern, albeit more complex, can be detected in the 1970-74 network in Figure 6. A comparison of the graphs suggests that the arms trade network has become more dense and involved over time as more countries have started to trade and to form more links. Moreover, the East-West division that characterized the network in the 1950s in particular, is preserved throughout the Cold War but becomes less significant over time and dissolves completely in recent years as can be seen in Figure 7, showing the 2000-04 network.

Due to space constraints we only include a selection of graphs in the paper. All omitted plots are available on request.
These graphs thus corroborate our previous finding that polity was a key factor behind arms trade decisions during the Cold War, but has been of no importance since. Since the Cold War stemmed from ideological differences, the arms trade network of that era closely reflects the military alliances at the time: the democracies within NATO traded with each other, as did the autocracies within the Warsaw Pact. By contrast, the post-Cold-War network does not appear to be driven by such homophily in terms of political regimes.

5.2 Network Characteristics

Since the graphs suggest that the network has become more complex over time, we would like to know what has driven the disintegration of the east-west division. It could be that there are still political constellations in the network but that these are concealed by the network’s complexity. We next report a set of network statistics that help shed some light on this issue. In the process, we report network statistics not directly related to the issue of homophily in terms of polity. Since the global arms trade network has largely been unexplored in the previous literature, such analysis seems warranted. In this part of the analysis, we make no distinction between exporters and importers and treat the network as undirected.

Figure 8 plots the evolution of key network statistics. Consistent with our previous findings,
Figure 8: Network statistics.

Panel (a), displaying sample size, suggests that the number of countries trading arms has increased. The increasing density, displayed in panel (b), implies that the ratio of actual trades to the number of possible trades has gone up. Panel (c) suggests that the diameter, i.e. the largest distance between any two nodes in the network, increases slightly over time but remains low throughout the sample period. The diameter peaks at a value of 6 in the early 1990s, when 150 countries participate in the network. The low diameter is one of the Small World Properties discussed by, for instance, Goyal, Leij, and Moraga-González (2006).

One shortcoming of the gravity model in Section 4, is that it fails to take into account how each economy’s position in the network affects the likelihood of trade. To assess whether countries with many trading partners prefer to trade with other high-degree countries, we compute the degree of assortativity of the network:

\[ A(a) = \frac{\sum_{ij \in g} (d_i - m) (d_j - m)}{\sum_{i \in N} (d_i - m)^2}. \]

where \( m \) is the average degree of the network as a whole. Panel (d) reveals that the network displays dissorativity, a typical feature of many other trade- and technological networks. This suggests that the arms trade network consists of a set of important players, trading with peripheral low-degree countries. The decreasing trend in this statistic suggests that the relative importance of the key players in the arms market has diminished somewhat in recent years.

\[ Formally, \text{there is a path between countries } i \text{ and } j \text{ if there exists a sequence of distinct links } i_1 i_2, i_2 i_3, \ldots, i_{K-1} i_K \text{ such that } i_k i_{k+1} \in g \forall k \in \{1, \ldots, K-1\} \text{ with } i_1 = i \text{ and } i_K = j, \text{ between them. The distance between } i \text{ and } j, l(i,j), \text{ is the number of links in the shortest path between them.} \]
To quantify how connected nodes in the network are, we next report clustering coefficients. The overall clustering coefficient in panel (e) measures how common it is that, if countries \( j \) and \( k \) are both trading with country \( i \), they are also trading with each other. The average clustering coefficient in panel (f) is related to the overall clustering coefficient but gives more weight to low-degree nodes than the latter.\(^{12}\) The graph suggests that overall clustering has increased so that countries have started forming more links with trading partners of existing ones. This confirms that the network has grown more dense and connected over time. In particular, minor trading partners of key players have become more likely to trade with each other as well, which has reduced the relative importance of the major traders. Contrary to overall clustering, average clustering has decreased over time. The fall in average clustering results from the entrance of small countries, who only trade with a few countries who, in turn, do not trade with each other.

Panels (g)-(i) in Figure 8 display the degree centrality, betweenness centrality and closeness centrality of the network, respectively. At the country level, the degree centrality measures country \( i \)’s degree relative to the maximum degree, betweenness centrality measures the extent to which country \( i \) lies on the shortest paths between other nodes in the network, and closeness centrality measures how close country \( i \) is to any other node \( j \) in the network. At the network level, the centrality measures are based on individual countries’ deviations from the maximum value of these statistics and thus capture the dispersion of these measures.\(^{13}\) All three centrality measures remain relatively high throughout the sample period but decrease over time. This suggests that degree, betweenness and closeness centrality have become more evenly distributed in recent years. While a set of key countries have been able to maintain their central positions in the network throughout the period, they have thus become less influential over time. This impression is corroborated by the negative trends in maximum degree, betweenness and closeness in panels (i)-(l).

Figure 9 displays the degree distribution of the network in 1950, 1965, 1980 and 2000. The degree distribution, \( P(d) \), captures the fractions of nodes of different degrees \( d \). Many empirical

\(^{12}\) The overall clustering coefficient is defined as 
\[ Cl(g) = \frac{\sum_{i,j,k,l} g_{ij} g_{jk} g_{lk}}{\sum_{i,j,k,l} g_{ij} g_{jk} g_{lk}}. \]

The average clustering coefficient is based on the concept of individual clustering defined as 
\[ Cl_i(g) = \frac{\sum_{j,k,l \neq i} g_{ij} g_{jk} g_{lk}}{\sum_{j,k,l \neq i} g_{ij} g_{jk} g_{lk}}. \]

The individual clustering coefficient of country \( i \) therefore considers all pairs of countries that it is linked to, and then registers how many of them are linked to each other. The average clustering coefficient is then the average of all individual clustering coefficients, i.e. 
\[ \text{Cl}^{Avg}(g) = \frac{\sum_i Cl_i(g)}{n}. \]

\(^{13}\) The degree centrality of the network is defined as 
\[ Ce^D(g) = \frac{\sum_i \left| Ce_i^D - Ce^D \right|}{((n-2)(n-1))} \]

where \( Ce_i^D(g) = d_i/(n-1) \) and \( Ce^D \) denotes the maximum degree centrality in the network.

The betweenness centrality of the network is defined as 
\[ Ce^B(g) = \frac{\sum_i \left| Ce_i^B - Ce^B \right|}{((n-2)(n-1)/2)}, \]

where \( Ce_i^B = \sum_{j,k \neq i} P_i(jk)/P(jk)/((n-1)(n-2)/2) \), \( Ce^B \) denotes the maximum betweenness centrality in the network, \( P_i(jk) \) denotes the number of shortest paths between nodes \( j \) and \( k \) that \( i \) lies on and \( P(jk) \) denotes the total number of shortest paths between \( j \) and \( k \).

Closeness centrality of the network is defined as 
\[ Ce^C(g) = \frac{\sum_i \left| Ce_i^C - Ce^C \right|}{((n-2)(n-1)/(2n-3))}, \]

where \( Ce_i^C = \sum_{j \neq i} d(i,j) \) and \( Ce^C \) denotes the maximum closeness centrality of the network.
networks follow a (scale-free) power distribution:
\[ P(d) = cd^{-\gamma}, \]
where \( c > 0 \) normalizes the support of \( P \) to 1. Taking logs we obtain:
\[ \log P(d) = \log c - \gamma \log d. \] (5)
Figure 9 suggest that a scale-free distribution, of the Pareto type described by (5), describes the network fairly well. We estimate the value of \( \gamma \) in (5) to approximately .9.

To address the centralization and shape of the network, we finally plot average clustering against the degree distribution for the years 1950, 1965, 1980 and 2000 in Figure 10. In a highly centralized network, countries with a high degree tend to trade with countries that are unlikely to trade with each other and thus display low clustering coefficients. The negative correlation in the graph suggests that the majority of the trading partners of the most active arms traders do not trade with each other, a typical feature of star networks.

We may summarize our findings as follows: (i) the number of countries in the network is strictly increasing until 1990; (ii) the network becomes increasingly dense over time; (iii) the diameter remains low throughout the sample; (iv) the network is fairly centralized around a set of key players, but becomes increasingly decentralized over time.
Figure 10: Average clustering and degree distribution, 1950, 1965, 1980 and 2000.

5.3 The East-West Divide

The network graphs are consistent with our findings from the gravity equations: ideological differences appear to have mattered for link formation during the Cold War but have been of no importance in recent years. However, given that the network has become more dense and involved over time, the dissolution of the divide between East and West that we see in the network graphs may be due to increasing noise rather than some fundamental change in attitude on the part of governments. To address whether the increasing density originates from the entry of new traders or from a shift in the behaviour of old players, we purge the sample of new entrants and pursue a counterfactual study of the subsample of countries that were trading already in 1950.

Figure A1 in the Appendix plots the sample size along with the average polity within this sub-network. While the sample size is decreasing as some countries vanish from the set, average polity displays a positive trend. The original traders of 1950 thus also tend to become more democratic over time.

Graphs of this subnetwork over the years 1970-74 and 2000-04, respectively, are displayed in Figures A2 and A3 in the Appendix. Figure A2 suggests that the gap between the two alliances is indeed preserved in the 1970s. While an increasing number of countries are trading with both parties, there is a clear divide between two clusters. The USSR has now lost some of its importance in the Warsaw Pact as Czechoslovakia in particular has become an important player in the East bloc. The graph in Figure A3 corroborates the conclusions drawn from Figure 7: in
recent years the East-West division has vanished completely.

Figure A4 displays the network characteristics of this subset. The graph suggests that the properties of the network are similar to those of the network as a whole.

6 The NATO and Warsaw Pact Sub-Networks

To shed additional light on the relationship between polity and arms trade, we next report a range of network statistics for the NATO and Warsaw Pact networks. As shown in Figure 1 in Section 3, the Warsaw-Pact network was, on average, autocratic throughout its existence while NATO was mainly democratic throughout the sample period.

Network statistics for the two alliances are displayed in Figure 11. The plots in panels (a) and (c) reveal positive trends in the sample size and diameter for both networks. The fact that the diameter is almost the same for the two networks, despite NATO being larger, suggests that NATO is internally better connected than the Warsaw Pact. While the NATO network is becoming more dense over time, panel (b) suggests that the density for the Warsaw Pact is falling sharply prior to its disestablishment in 1991.

Panel (j) shows that the maximum degree is substantially higher for NATO than for the Warsaw Pact, indicating that the US sustained more links than the USSR during the Cold War. This is not surprising given that NATO is larger. The centrality measures in panels (g)-(i) are all relatively stable over time but show that the Warsaw Pact is a more centralized network than NATO. This can also be seen in the network graphs in Figure 5, where the Warsaw Pact
network resembles a star network with the USSR as a central node, surrounded by peripheral trading partners who, as a rule, do not trade with each other. The conjecture that the Warsaw Pact was more centralized than NATO is supported by the overall clustering statistic in panel (d) being substantially lower for the Warsaw Pact than for NATO throughout the sample. A defining property of a star network is precisely that while the central country trades with many other countries, these are unlikely to trade with each other. The result that maximum centrality is higher for the Warsaw Pact than for NATO supports the notion that the USSR was more important for the former than the US for the latter. These findings are in line with a common perception about the two defense alliances, namely that NATO membership was largely voluntary, while membership in the Warsaw Pact largely resulted from coercion by the USSR.

The main differences between the NATO and the Warsaw Pact networks can be summarized as follows: (i) the NATO network was larger than the Warsaw Pact network throughout the sample period; (ii) density fell sharply over time for the Warsaw Pact but not for the NATO network; (iii) the Warsaw Pact was more centralized than NATO; (iv) the USSR was relatively more important to the Warsaw-Pact network than the United States to the NATO network; (v) NATO was internally better connected than the Warsaw Pact and the United States was more clustered than the USSR.

Do these findings say anything about differences in the way that arms are transferred between autocratic and democratic states? The results do suggest a more hierarchical structure within the Warsaw Pact than within NATO. The external validity of this result is admittedly low, but the finding fits the historical narrative well and is in line with common perceptions about the organization of the two alliances. These results are thus also interesting from the viewpoint of network methodology. The fact that statistics commonly used to describe the properties of networks so accurately reflect the way scholars of the Cold War view the organization of the two alliances should lend credibility to these statistical measures.

7 Concluding Remarks

Using data on all international transfers of Major Conventional Weapons 1950-2007, we study the relationship between polity and arms trade from different perspectives. We study the export destinations of six key economies, estimate models of the likelihood of trade as a function of institutional variables and a measure of differences in polity, study how the global arms trade network has evolved over time and investigate the properties of the NATO and Warsaw-Pact sub-networks.
Our results suggest a stable negative relationship between differences in polity and the likelihood of arms trade for the duration of the Cold War. In the last two decades, however, we find no convincing evidence that states have traded within their political vicinity.

To interpret these results, we may exploit the shift in the incentives for arms trade implied by the end of the Cold War. The results are consistent with the conjecture that the security concerns during the Cold War were sufficiently strong to deter states from trading with states with differing polity. The finding that polity has not mattered after the Cold War suggests that democracies have not been as altruistic or ethical as they have claimed in recent years. This finding is consistent with Perkins and Neumayer (2002) and others.

The network analysis corroborates the findings from the econometric analysis. There was a clear divide between the eastern and western blocs during the Cold War, but the division has dissolved after 1990. The analysis also shows that the network has become more dense, clustered and decentralized over time. The network displays some similarities with other empirical networks, such as Small World Properties. Similar to other trade networks, the arms trade network also displays dissortativity, meaning that very active states tend not to trade with each other.

Consistent with common perceptions about the hierarchy within NATO and the Warsaw Pact, we find that the USSR was more important to the latter than the US to the former. The Warsaw Pact was therefore a more centralized alliance than NATO. This result is consistent with the historical view that NATO membership was voluntary, while membership in the Warsaw Pact to some extent resulted from coercion by the USSR.
References


### Appendix

Table A1: Members of NATO and the Warsaw Pact.

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Figure A1: Arms trade participation and average polity, 1950-2007: the subset of countries trading in 1950.

Figure A2: The arms trade subnetwork of countries trading in 1950, 1970-1974.
Figure A3: The arms trade subnetwork of countries trading in 1950, 2000-2004.

Figure A4: Network statistics for the subset of countries trading in 1950.

Note: All years and all countries in the sample are included.