The Global Arms Trade Network 1950-2007*

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Abstract

We study the evolution of the global arms trade network using a unique dataset on all international transfers of major conventional weapons over the period 1950-2007. First, we provide a careful description of the characteristics of global arms trade using tools from social network analysis. Second, we relate our findings to political regimes by studying whether differences in polity scores affect the likelihood of arms trade by estimating an augmented gravity equation. Our findings from the network analysis are much in line with common views of the Cold War. We see a clear division between the Warsaw Pact and NATO, with the Soviet Union being more central to the former than the United States to the latter. We find that differences in polity has a significant, negative effect on the likelihood of arms trade between two countries. The relationship is remarkably robust throughout the sample period and does not hold for trade in any other good that we investigate. The result suggests that democracies are indeed more likely to trade arms with other democracies than with autocracies since the former are not perceived as potential adversaries. We view this finding as evidence in favour of the Democratic Peace Theory.

Keywords: Arms Trade, Networks, Democracy, Autocracy, NATO, The Warsaw Pact

JEL-classification: F19, F51, F59, P51

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1 Introduction

Armed conflict is arguably the single most important source of human suffering governed by mankind. Due to the high fixed costs and the extensive research and development involved in the production of military equipment, a global network of arms trade is a key catalyst for such conflicts. Given the security issues and moral considerations involved in arms trade, the lack of empirical evidence on the economics behind it, is striking. Who trades with whom? To what extent is arms trade strategic? Are governments concerned with the political regime of potential trading partners?

In this paper we study the evolution of the global arms trade network over the period 1950-2007. The analysis consists of two parts. First, we provide a careful description of the characteristics of global arms trade using tools from social network analysis. Second, we study the effect of differences in polity between states on the likelihood of arms trade between them, using methods from economic geography.

While the empirical evidence on arms trade is scarce, the Cold War inspired a theoretical literature on arms races, i.e. models of how two countries perceiving each other as threats react to increases in military expenditure or advancements in weapons technology from the perceived opponent. Contributions include Schelling (1960), Aumann et al (1968), Intriligator (1975), Brito and Intriligator (1981) Levine and Smith (1995) and, more recently, Baliga and Sjöström (2004). Ayanian (1986) provides some empirical tests of theoretical predictions from the earlier literature. Levin and Smith (1997) provide a thorough discussion of the economic fundamentals of arms trade in a paper with empirical features. The optimal design of arms control is modelled in Levin and Smith (1995).

A number of political scientists, and a growing group of economists, subscribe to what is known as the Democratic Peace Theory (DPT), see for instance Maoz and Russett (1993), Bueno de Mesquita et al (1999), Kadera et al (2003) and Levy and Razin (2004). According to this hypothesis, two democratic states are extremely unlikely to engage in militarised conflict with each other. The DPT thus suggests that a democratic state is more apt to sell arms to another democratic state than to a non-democratic state since the probability of an armed conflict is higher with the latter than the former.[1]

Social network analysis has supplied economists with an increasingly popular toolbox for analysing complex interaction between a large number of agents, see Jackson (2008) for an overview. While standard economic models typically consider a small group of agents or countries in isolation, the strength of network analysis lies in its ability to describe and analyse the interactions in a large system that would quickly become intractable using standard models. Recently, network analysis has therefore started to gain recognition among trade economists and applied macroeconomists, see for instance De Benedictis and Tajoli (2008), who study the global trade network and Flandreau and Jobst (2005, 2009), who study the existence of strategic externalities in the international currency system.

We argue that network analysis is particularly suited for the study of arms trade for the following reasons. First, the fact that arms trade is heavily regulated allows us to think of arms traders and governments as roughly the same entity. Second, the moral concerns and potential repercussions involved in arms trade suggest that decisions to trade in arms are strategic. Since governments are likely to choose its trading partners with great care, the arms trade network is therefore likely to reflect a network of political ties and alliances. Using network theory, we are able to identify key players with central positions in the network and study how their roles have changed over time. Specifically, we are able to identify important differences and similarities between the two intergovernmental military alliances dominating the post-war era, i.e. the North Atlantic Treaty Organization (NATO) and the Warsaw Pact.

Following the descriptive network analysis, we turn to factors governing the likelihood of an arms trade agreement between states. Specifically, we study the impact of differences in political regimes on the likelihood of arms trade by adding factors capturing distance in polity and institutional measures to a gravity equation.[2] In order to address the claim that political

[1] Mulligan et al (2004) find that military expenditures are typically higher in autocracies than in democracies, and suggest that democratic leaders have less reason to worry about foreign military threats than a dictator. As noted by Cowen (1990), a democratic leader is likely to go to war if he thinks that international victories will strengthen his probability of reelection and, as pointed out by Mulligan et al (2004), a democratic leader is more likely to attack a regime that his electorate resents.

[2] We are well aware of the fact that, when studying political regimes and arms trade, causality may run in both directions. In this paper, we therefore intepret our results with some caution but leave the issue of causality to a follow-up paper.

incentives are a major determinant of arms trading partners, we also estimate the same gravity equation for a large variety of non-military goods.

We use a unique dataset from the Swedish Institute for Peace Research (SIPRI), covering all trade in military equipment over the period 1950-2007. We feel confident that the dataset is the richest dataset available on arms trade and have been assured of its high quality.[3] To the best of our knowledge, our paper is the first to apply the aforementioned methodology on any dataset on arms trade and political regimes.

Our main findings are as follows. In the first part of the analysis, we find that while the global arms trade network possesses some characteristics typically found in empirical studies of other networks, we are also able to identify some important differences. Similar to other networks, we find that the global arms trade network exhibits a small-world property, negative correlation between degree and clustering coefficients and can be described by a scale-free degree distribution. The network is also characterised by negative assortativity, a feature found in other trade networks (De Benedictis and Tajoli, 2008). Our results suggest that the most central countries in the network are very influential. Moreover, there are large changes in key characteristics over time. The network as a whole becomes denser over time as an increasing number of countries start trading in arms and, additionally, form more links. In terms of network characteristics, there are substantial differences between NATO and the Warsaw Pact. Throughout the Cold War, the NATO network is more decentralised than the Warsaw Pact and the largest trader within NATO, the US, is less influential than the largest trader in the Warsaw Pact, the Soviet Union. We believe these findings to be in line with how most people have come to view the hierarchy within the two organisations during the Cold War.

In the second part of the analysis, we find that the largest arms exporters tend to trade arms with countries with similar political rule. The largest democracies export to democracies as well as autocracies but, with some exceptions, they tend to favour democracies. The largest autocracies have an even stronger bias towards other autocracies. To control for factors such as geographic proximity and colonial ties, we add distance in polity to a gravity-equation with

[3] Trade in small arms is excluded from the dataset. Since illegal trade is very difficult for larger types of military equipment, the exclusion of small arms implies that we face a very small risk of measurement error.

likelihood of arms trade as the dependent variable. We find that there is a stable negative relationship between differences in polity and the likelihood of arms trade. The relationship is stable over the entire sample period, i.e. throughout the Cold War but also over the period following the collapse of the Soviet Union in 1991. We find no such negative relationship for aggregate trade or trade in any other good studied. The results thus suggest that it is the politically charged nature of arms trade, and plausibly the fear of weapons being used against them, that causes governments to choose their trading partners wisely. The robust negative relationship between differences in polity and likelihood of arms trade may therefore be interpreted as evidence in favour of the Democratic Peace Theory.

The paper is organised as follows. Section 2 provides a descriptive analysis of the evolution of the global arms trade network using social network theory. Section 3 addresses the issue of polity and arms trade by reporting the results from estimating a gravity model. Section 4 concludes.

2 The Global Arms Trade Network

In this section we study the evolution of the global arms trade network over time. We begin with a thorough discussion of the SIPRI dataset in Section 2.1. We then aggregate arms trade between countries over five-year intervals and graph the global arms trade in section 2.2. We then define key centrality measures in Section 2.3. The evolution of these measures over time are reported in Section 2.4.

Throughout the section we study (i) all countries trading arms, (ii) countries trading arms with at least one full member of NATO (we call this set of countries *the NATO Network*) and (iii) countries trading arms with at least one full member of the Warsaw Pact (*the Warsaw Pact Network*).[4]

[4] During the decade following World War II, the majority of the industrialised world was roughly divided into two defense alliances. The North Atlantic Treaty Organization (NATO) was founded on April 4 1949. The Treaty of Friendship, Cooperation and Mutual Assistance, commonly referred to as the Warsaw Pact, was founded on May 17 in 1955 and disestablished on July 1 in 1991. The member countries of NATO and the Warsaw Pact are listed in Table A1 in the Appendix.

2.1 Data

SIPRI hosts 6 different databases related to international relations, military expenditure, production and arms trade. The data used in this study is obtained from the SIPRI Arms Transfers Database, holding information on all international transfers of seven categories of *Major Conventional Weapons* from 1950 onwards. The concept of Major Conventional Weapons comprises aircraft, armoured vehicles, artillery, sensors, air defence systems, missiles, ships, engines (for military aircraft, combat ships and most armoured vehicles) and other major conventional weapons (mainly turrets for armoured vehicles and ships).

Our measure of arms trade is total bilateral exports (imports) of Major Conventional Weapons over the period 1950-2007. In order to minimise the noise in the data, we have chosen to eliminate rebel groups from the sample. Discussions with representatives of SIPRI have ensured us of the high quality of the dataset. We have learned 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, arms trade not captured by the dataset is negligible.

2.2 Graphs of The Arms Trade Network

In order to be able to graph the evolution of the arms trade network over time, we first compute five-year averages of bilateral arms trade and plot them. Figure 1 displays the arms trade network over the period 1950-1954 and Figure 2, the network over the period 1955-1959.[5] For ease of exposition, plots of the network over the period 1960-2007 are displayed in Figures A1-A10 in the Appendix. In these graphs, each node represents a country and each link indicates that there is trade between the two countries in question. The length of each link is thus not proportional to the magnitude of the trade, they simply indicate whether trade has occurred during the period. The arrows run from exporter to importer.

Figure 1, covering the period 1950-1954, shows that during this period, global arms trade is roughly divided into two networks. The first network is centered around the US and the other around the USSR. The same holds for the 1955-1959 network in Figure 2. As can be seen from

[5] All network graphs are processed using the Pajek software. We use the Kamada-Kawai method of energising the data for the layouts as this seems to produce more stable results than for instance the Fruchterman Reingold energy command; see de Nooy et al (2007).

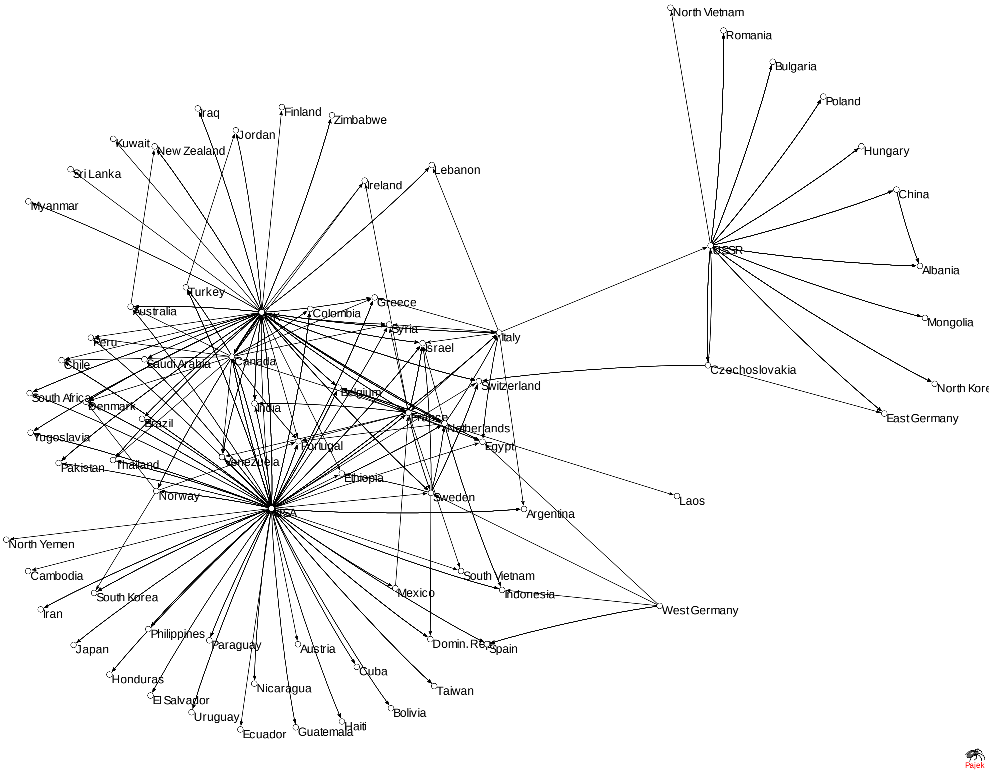

Figure 1: The global arms trade network, 1950-1954.

Figures A1-A10 in the Appendix, this pattern is preserved throughout the Cold War, but the divide between the two groups is particularly clear in the 1950s. The plots in the Appendix suggest that the arms trade network becomes much more dense and complex over time. After the collapse of the Cold War and the disestablishment of the Warsaw Pact, the divide between the two groups is much less distinct.

2.3 Network theory: Definitions and Key Concepts

We next describe some key statistics for characterising the evolution of the arms trade network over time. Let $N = \{1, ..., n\}$ denote the set of nodes in the network. Each node represents a country. Let g represent an $n \times n$ matrix where g_{ij} represents the link between countries i and

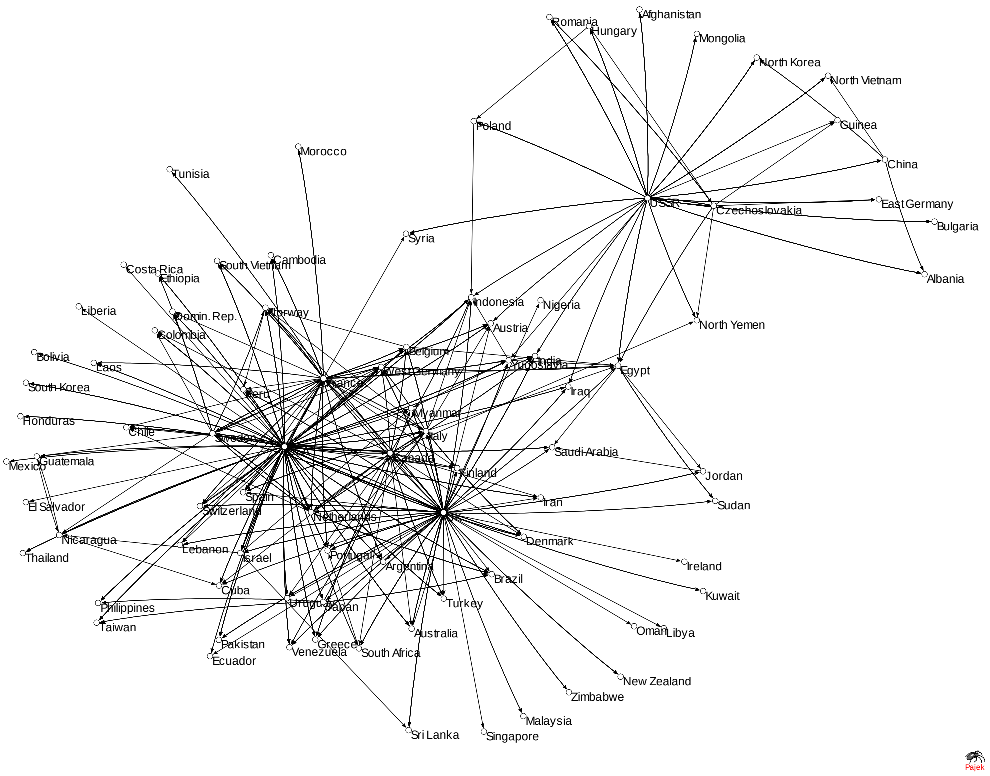

Figure 2: The global arms trade network, 1955-1959.

j. For our purposes, it is the existence of arms trade rather than the magnitude of the trade that matters, and we therefore think of each link as having equal strength. In other words, we think of the network as being unweighted and define

$$g_{ij} = \begin{cases} 1 \text{ if } i \text{ and } j \text{ are trading arms} \\ 0 \text{ otherwise} \end{cases}.$$

The neighbourhood of a node i in the network g is the set of nodes linked to i:

$$N_i(g) = \{j : g_{ij} = 1\}.$$

The degree of a node, $d_i(g)$, is the number of links that involve that node, i.e.

$$d_i(g) = \#\{j : g_{ji} = 1\} = \#N_i(g).$$

A path between nodes i and j is a sequence of links $i_1i_2, i_2i_3, ..., i_{K-1}i_K$ such that $i_ki_{k+1} \in g$ $\forall k \in \{1, ..., K-1\}$ with $i_1 = i$ and $i_K = j$, and such that each node in the sequence $i_1, ...i_K$

is distinct. A path never hits the same node twice. The distance between two nodes is the number of links in the shortest path (geodesic) between them. For future reference, denote the distance between i and j by $l(i,j)$.

We next define key micro statistics pertaining to individual nodes. These concepts are important in identifying and characterising important players in the network. It is useful to start with a description of these individual characteristics as some of the definitions are needed when describing the properties of the network at large.

Degree Centrality The degree centrality of country i is computed as

$$Ce_i^D(g) = \frac{d_i(g)}{n-1}. \tag{1}$$

A country with degree $n-1$ would be trading arms with every other country in the network. By contrast, a country with a low degree would be considered less central. Since the maximum degree is $n-1$, the measure of degree centrality is confined within the unit interval.

The degree centrality-measure has some shortcomings. While it does provide some indication of connectedness, it says nothing about how close each node is to other nodes or about the location in the network.

Closeness Centrality Closeness centrality tracks how close a node i is to any other node j in the network. Recall that $l(i,j)$ denotes the number of links in the shortest path between i and j. Closeness centrality is defined as

$$Ce_i^C = \frac{n-1}{\sum_{j \neq i} l(i,j)}. \tag{2}$$

Closeness centrality thus measures the inverse average distance between i and j.

Betweenness Centrality Let $P_i(jk)$ denote the number of shortest paths between nodes j and k that i lies on and let $P(jk)$ be the total number of shortest paths between j and k. The ratio $P_i(jk)/P(jk)$ captures the importance of i in connecting j and k. If $P_i(jk)/P(jk)$ is close to one, country i lies on most of the geodesics between j and k. If the ratio is close to zero, country i is less important in connecting j and k. Betweenness centrality is defined as

$$Ce_i^B = \sum_{j \neq k : i \notin \{j,k\}} \frac{P_i(jk)/P(jk)}{(n-1)(n-2)/2}. \tag{3}$$

Betweenness centrality is thus a measure of the ratio of $P_i(jk)/P(jk)$, averaged across all pairwise nodes j and k that meet the above criteria.

We next define some key statistics that are useful when attempting to characterise the network as a whole.

Diameter The diameter of the network is the largest distance between any two nodes in the network. It thus provides an upper-bound measure of the size of the network.

Density The density of the network is computed as the average degree divided by $n-1$, i.e.

$$D(g) = \frac{\sum_i d_i(g)}{n(n-1)}. \tag{4}$$

Degree Distribution The degree distribution, $P(d)$, of the network captures the relative frequencies, i.e. fractions of nodes that have different degrees, d. A power distribution (scale-free distribution) satisfies:

$$P(d) = cd^{-\gamma}$$

where $c > 0$ normalises the support of P to sum to 1. Taking logs we obtain:

$$\log(P(d)) = \log c - \gamma \log d. \tag{5}$$

Using actual data on the observed distribution of degrees, γ can be estimated from this formulation.

Overall Clustering Clustering coefficients describe how connected nodes in the network are. Overall clustering of the network is defined as

$$Cl(g) = \frac{\sum_i \#\{jk \in g | k \neq j, j \in N_i(g), k \in N_i(g)\}}{\sum_i \#\{jk | k \neq j, j \in N_i(g), k \in N_i(g)\}} = \frac{\sum_{i;j\neq i;k\neq j;k\neq i} g_{ij}g_{ik}g_{jk}}{\sum_{i;j\neq i;k\neq j;k\neq i} g_{ij}g_{ik}}. \tag{6}$$

To understand this concept, consider two nodes, ij and ik, sharing the common node i. The measure of average clustering measures how common it is that also the nodes j and k are linked to each other.

Average Clustering In order to compute the average clustering coefficient, we first need to define individual clustering. The individual clustering coefficient is given by:

$$Cl_i(g) = \frac{\#\{jk \in g | k \neq j, j \in N_i(g), k \in N_i(g)\}}{\#\{jk | k \neq j, j \in N_i(g), k \in N_i(g)\}} = \frac{\sum_{j\neq i;k\neq j;k\neq i} g_{ij}g_{ik}g_{jk}}{\sum_{j\neq i;k\neq j;k\neq i} g_{ij}g_{ik}}. \tag{7}$$

The individual clustering coefficient of node i therefore considers all pairs of nodes 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.

$$Cl^{Avg}(g) = \sum_i \frac{Cl_i(g)}{n}. \tag{8}$$

Average clustering gives more weight to low-degree nodes than the overall clustering coefficient.

Max Degree The Max Degree of the network, Ce_i^{D*}, is the degree of the node with the highest number of links.

Max Closeness The Max Closeness of the network, Ce_i^{C*}, is the value of Closeness Centrality of the node with the highest measure of this statistic.

Max Betweenness The Max Betweenness of the network, Ce_i^{B*}, is the value of Betweenness Centrality of the node with the highest measure of this statistic.

Degree Centrality The Degree Centrality of the network is given by:

$$Ce^D(g) = \frac{\sum_i \left|Ce_i^D - Ce_i^{D*}\right|}{(n-2)(n-1)}.$$

Closeness Centrality The Closeness Centrality of the network is given by:

$$Ce_i^C = \frac{\sum_i \left|Ce_i^C - Ce_i^{C*}\right|}{(n-2)(n-1)/(2n-3)}.$$

Betweenness Centrality The Betweenness Centrality of the network is given by:

$$Ce_i^B = \sum_i \left|Ce_i^B - Ce_i^{B*}\right|.$$

Assortativity Turning to the correlation patterns among high-degree nodes, we turn to the concept of assortativity. If high-degree nodes tend to be connected to other high-degree nodes, there is said to be positive assortativity. The degree of assortativity of the network g is computed as

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

2.4 Characteristics of the Arms Trade Network

Figure 3 plots the evolution of the statistics defined in Section 2.3 for the network including all countries. Starting with the aggregate properties of the network, Figure 3 suggests that the number of countries involved has increased along with the diameter and the density. This suggests that an increasing number of countries have started to trade in arms. This may be due to either an increase in the number of exporters (producers of arms) or an overall increase in import demand for arms. The graphs in Figures 1 and 2, but in particular in Figures A1-A10 in the appendix support the claim that the global arms trade network has become much more dense and complicated over time.

The number of countries that trade in arms increases rapidly during the sample period. The diameter increases as well but remains very low throughout the sample, a feature of many networks often referred to as *the small world property,* see for instance Goyal et al (2006).

We see that the country with the highest number of links, as measured by max degree, is increasing in the beginning of the sample but is starting to decrease at the end of the Cold War. While overall clustering has increased, average clustering has been falling over time. The fall in average clustering results from the entrance of small, new countries, who only trade with a few countries who, in turn, do not trade with each other. The fact that overall clustering increases, however, is the result of the network as a whole growing denser and more connected and in particular that the countries with the highest number of links have become more clustered, i.e. that their trading partners have become more likely to trade as well. All three centrality measures are also decreasing over time, suggesting that the most important countries have become less influential over time. However, the centrality measures remain relatively high throughout the sample period. This suggests that while a small set of key countries have

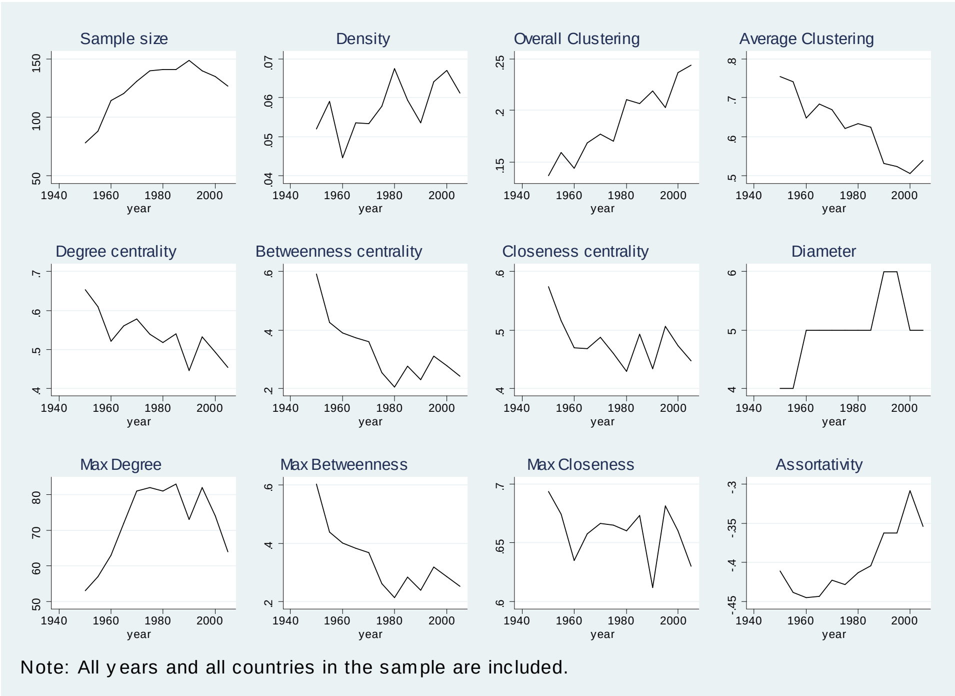

Figure 3: Network statistics for the global arms trade network.

been able to maintain their central positions in the network throughout the period, they have become less influential over time as the network has become increasingly decentralised.

Finally, assortativity is negative throughout the sample but less so in recent years. Negative assortativity is typical for many other trade and technological networks where countries (agents) with many connections are prone to trade with countries (agents) with fewer connections. Countries with few connections, on the other hand, are more likely to trade with countries with many trading partners.[6]

Figure 4 displays the degree distribution of the global arms trade network in 1950, 1965, 1980 and 2000. The results suggest that a scale-free distribution of the Pareto type, as described by (5), would indeed characterise the network fairly well. The estimated value of γ in (5) is around 0.9.

Figure 5 plots the degree distribution against average clustering for the years 1950, 1965,

[6] This property stands in contrast to many social networks where, for example, friends of individuals with many friends also tend to have many friends, see Newman (2002).

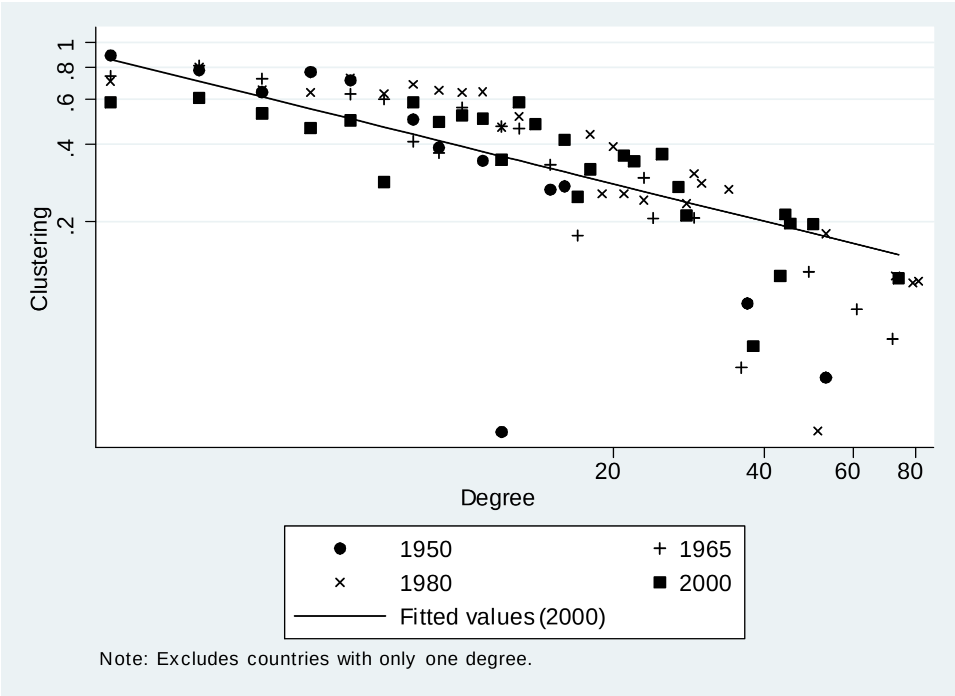

Figure 4: Average clustering and degree distribution, 1950, 1965, 1980 and 2000.

1980 and 2000 and the graph clearly reveals a negative relationship between the two. This 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 summarise our findings for the global arms trade network as follows.

(i) The number of countries in the network rises constantly until 1990;

(ii) The network is fairly centralised with some important central countries and a large number of peripheral countries (high centrality measures, a negative relation between average clustering and number of degrees, large differences between overall and average clustering and negative assortativity);

(iii) The network becomes increasingly decentralised over time (all centrality measures are falling over time, overall clustering increases while average clustering decreases and assortativity becomes less and less negative);

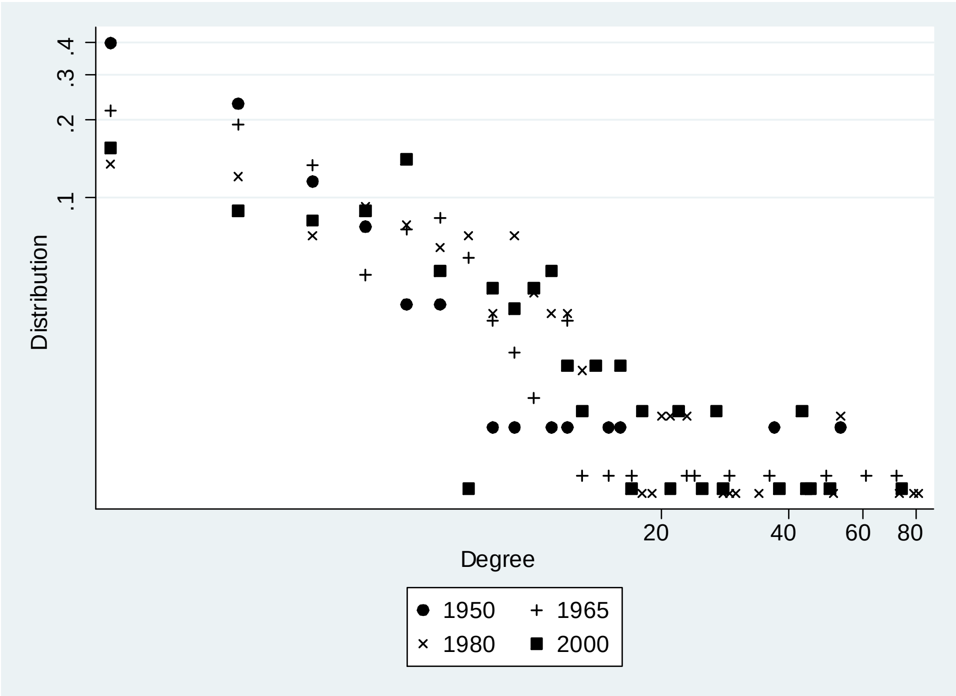

Figure 5: Degree distribution 1950, 1965, 1980 and 2000.

(iv) The diameter remains remarkably low throughout the sample, peaking at a value of 6, despite the fact that 150 countries participate in the network.

Figure 6 displays key network statistics for NATO and the Warsaw Pact. We see that the number of countries and the network diameter are displaying positive trends for both networks. The fact that the diameter is almost the same for the two networks despite the larger size of NATO suggests that NATO is better internally connected than the Warsaw Pact. While the NATO network is becoming more dense over time, the Warsaw Pact density is falling sharply up to its disestablishment in 1991. We also see that the max degree is much higher in NATO than in the Warsaw Pact, indicating that the US has more links than the USSR for the duration of the Cold War. This is hardly surprising given that NATO is larger. Regarding the centrality measures, they are all relatively stable over time but show that the Warsaw Pact was a much more centralised network than NATO. This can also be seen in the network graphs Figures 1, 2 and A1-A5 where the Warsaw Pact network most clearly resembles a "star" network with

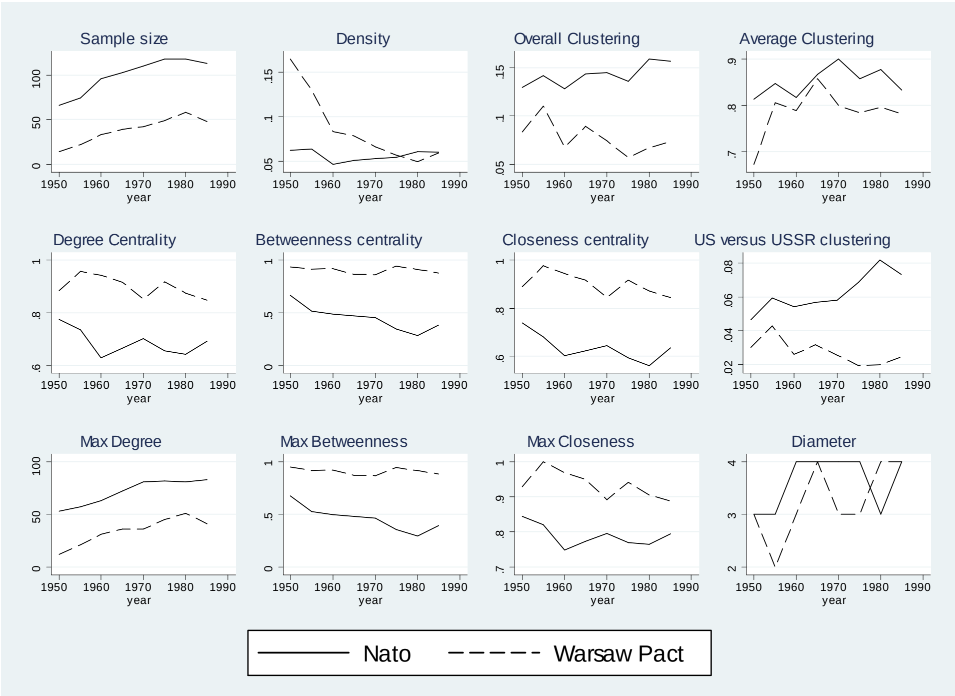

Figure 6: Network statistics for NATO and the Warsaw Pact.

one central node (the USSR) surrounded by peripheral trading partners who, as a rule, do not trade with each other. This property is also revealed by the fact that the overall clustering variable is substantially lower in the Warsaw Pact than in 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 fact that the USSR was more important for the Warsaw Pact than the United States was for NATO is shown by the measures of maximum centrality being higher for the Warsaw Pact than for NATO throughout the period.

The main differences between NATO and the Warsaw Pact can be summarised as follows.

(i) There is a distinct division between NATO and the Warsaw Pact during the Cold War, most clearly in the beginning. Towards the end of the sample, an increasing number of countries trade with both alliances (see graphs A1-A10 in the Appendix);

(ii) More countries participate in the NATO network than in the network of the Warsaw Pact;

(iii) The Warsaw Pact is substantially more centralised than NATO;

(iv) The role of the USSR in the Warsaw Pact is more important than that of the United States in NATO;

(v) NATO is internally better connected and the United States is much more clustered than the USSR;

(vi) Density falls sharply for the Warsaw Pact but not for NATO.

The graphic division between NATO and the Warsaw Pact is a naive but compelling indication that polity matters for arms trade ties. It is well known that throughout the post-war era, the conflict between the US and the Soviet Union was based on radically different ideological beliefs. While the constitution in the US is based on maximum freedom of individuals, the Soviet Union has come to represent the other extreme; a regime with limited freedom of individuals ruled by a highly centralised government. This ideological divide seems to be mirrored in the arms trade network. The results from the network analysis suggest that the Warsaw Pact network, centered around the Soviet Union, comprises mainly other autocratic states. Conversely, the NATO network consists mainly of democratic states and is centered around the world's oldest and largest democracies; the US, the UK and France. We look for statistical support for this conjecture in Section 3.2, below.

Clearly, the dichotomous division of the world's states into autocracies and democracies is a crude approximation of reality. Since democracies as well as autocracies can be either right-wing or left-wing, it would interesting to study a more detailed classification of countries. However, this is beyond the scope of the paper and left for future research.

3 Polity and Arms Trade

Having characterised the global arms trade network and how it evolves over time, we next turn to the empirical relationship between arms trade and political regimes. We therefore add data on political and economic characteristics and estimate a gravity equation where one of the independent variables is a measure of distance in polity. In order to address the specific nature of arms trade, i.e. the question of how arms trade differs from trade in other goods, we report estimates of the same gravity equation for trade in a wide range of other commodities.

3.1 Data

In order to compare our findings on arms trade to trade in other goods, we add data on trade from the United Nations Comtrade database over the period 1962-2000. In addition to studying aggregate trade between the countries in the sample, we study the subgroups textiles, oil, coffee, chemicals, leather, cars, wheat and rice. Data om GDP per capita is from Maddison and covers the full sample period 1950-2006. Data on distance between countries, common language, common borders and common origin of colonisation 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. The polity variable, henceforth denoted POLITY, is an index ranging from -10 to $+10$, where a negative value represents autocracy and a positive value represents democracy. The higher the value, the stronger the democratic regime in terms of a number of criteria specified within POLITY IV.

3.2 Trends in Democratisation

Before proceeding with the regressions, it is useful to take a first look at the data by studying trends in the variables and plotting key relationships. Figure 7 depicts the evolution of the sample size and the average polity over the sample period. The left graph shows that over the period 1950-2007, sample size displays a positive trend, implying that an increasing number of countries are trading arms. The trend is particularly strong until the beginning of the 1980s. During the 1980s, the trend is in fact decreasing but starts to increase again in the middle of the 1990s. This pattern holds for the NATO network as well as for the overall network. The trend for the Warsaw Pact is increasing until its disestablishment in 1991.

The right graph in Figure 7 captures the average POLITY-scores in the entire sample and

Figure 7: Arms trade participation and average polity, 1950-2007.

in the two subgroups. A positive POLITY index indicates that the sample is democratic on average, while a negative value indicates that the sample is non-democratic according to the POLITY IV criteria. The results suggest the NATO network was, on average, democratic in the beginning of the 1950s, but became less democratic in the 1960s and 1970s. In the early 1980s, democratisation picked up and the average POLITY-score of the NATO network again displayed a positive trend. The trend for the Warsaw Pact is increasing, but the average POLITY-score remains negative throughout the existence of this network. These results suggest that a country trading arms with members of the Warsaw Pact, was indeed non-democratic on average. The trend for the overall sample closely follows that of the NATO network since NATO comprised more countries.

We next address the question of whether countries are more likely to export arms to countries with the same polity. Figure 8 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

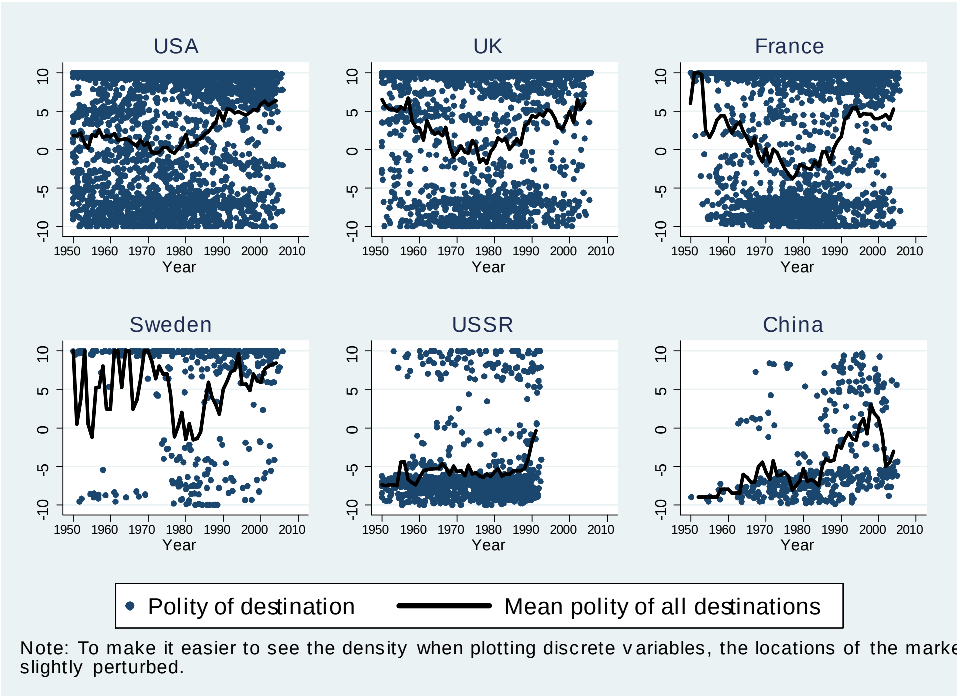

Figure 8: Polity of export destinations for six key players, 1950-2007.

dot represents the POLITY-score of each export destination in a given year and the black line indicates the per-year average. The top left graph of the US shows that the world's oldest democracy has consistently been prone to export arms to other democracies. However, as the graph shows, the US has also exported arms to autocratic countries throughout the sample period. There is a positive trend in the plot for the US, indicating that the US has chosen to export arms to countries that have become increasingly democratic. However, this could just be symptomatic of the overall tendency to world democratisation rather than of the US becoming increasingly choosy when deciding which countries to export to. 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 up to the mid-1980s. Sweden 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.

By contrast, the USSR and China have typically exported arms to other autocratic countries. The results suggest that they have exported arms to democracies as well, but the average trading partner has been non-democratic. There is some evidence that China started exporting more arms to democratic countries in the beginning of the 21th century, but the trend has been reversed in recent years.

The results also suggest that, compared to NATO members, the USSR and China have been relatively more prone to export arms to countries with similar POLITY-scores. This indicates that, in the sample, autocracies have an even stronger bias towards other autocracies than democracies vis-à-vis other democracies.

3.3 The Gravity Equation

As reported in the previous section, plotting the data suggests that there is a correlation between polity divergence and arms trade. In order to test this hypothesis controlling for several other variables that may influence export decisions, we specify and estimate a gravity equation containing these variables. Let Y_t^{ij} be a dichotomous variable capturing trade between countries i and j, such that

$$Y_t^{ij} = \begin{cases} 1 \text{ if countries } i \text{ and } j \text{ trade in } Y \text{ at time } t \\ 0 \text{ otherwise} \end{cases}.$$

In the same way we define the variable B_t^{ij}, assuming the value 1 if i and j share the same border (contiguity), L_t^{ij}, assuming the value 1 if i and j share the same official language, CR_t^{ij}, assuming the value 1 if i and j were ever in a colonial relationship, $CC_t^{45,ij}$, assuming the value 1 if the countries were colonised by the same country post-1945, $CR_t^{45,ij}$, assuming the value 1 if the countries were in a colonial relationship post-1945 and finally, SC_t^{ij}, assuming the value 1 if the countries were the same country historically. Let D_t^{ij} denote distance between i and j, let GDP_t^i denote GDP of country i, let $GDP_t^{C,i}$ denote GDP per capita and let $RGDP_t^{C,ij}$ be relative GDP per capita between i and j, i.e. $RGDP_t^{C,ij} = GDP_t^{C,i} - GDP_t^{C,j}$. Finally, let Pol_t^i be the POLITY-score of country i at time t. For notational convenience, let X_t^{ij} denote the vector of control variables:

$$X_t^{ij} = \left(B_t^{ij}, L_t^{ij}, CR_t^{ij}, CC_t^{45,ij}, CR_t^{45,ij}, SC_t^{ij}, \ln GDP_t^i, \ln GDP_t^{C,i}, \ln \left(RGDP_t^{C,ij} \right)^2, \ln D_t^{ij} \right).$$

We then estimate the following linear probability model:

$$Y_t^{ij} = \alpha \left(Pol_t^i - Pol_t^j \right)^2 + \overline{\beta} X_t^{ij} + \epsilon_t^{ij} \tag{9}$$

where $\overline{\beta}$ is a vector of parameters. Letting Y_t^{ij} denote arms trade, a significant negative estimate of α thus suggests that the more different i and j are in terms of polity, the less likely they are to trade in arms.[7]

As mentioned in the introduction, trade in arms is likely to exhibit some unique properties that separates it from trade in any other good. First, and perhaps most importantly, the sale of arms involves a risk of the traded weapons being used against the exporting country. Second, arms trade production involves long-term investments in research and development and large fixed costs, implying that arms producers may be forced to export their output to ensure profitability. Third, since arms are traded intergovernmentally, governments are likely to internalise the fact that the arms will be consumed by the receiving government rather than private agents in the importing country. Thus, if a government wants to signal its disapproval of the polity in the importing country, it is more likely to do so by imposing an embargo on arms trade than on trade in any other commodity. In an attempt to identify the effects of these unique features of arms trade, we additionally estimate (9) for a wide range of alternative commodities with diverse characteristics.

3.4 Results

Columns (1)-(3) in Table 1 display the results from estimating (9) on arms trade using pooled OLS. For the sake of comparison, columns (4), (5) and (6) report the results from estimating the same equation using data on aggregate trade, trade in cars and trade in coffee, respectively.

The results in columns (1)-(3) suggest that differences in polity has a negative effect on the likelihood of arms trade. If the difference in POLITY-scores between countries i and j

[7] We do not apply fixed effects to the gravity equation since our outcome variable is binary, i.e. measures whether trade occurs or not, and therefore does not contain enough variation for country-pair fixed effects to be applicable. Moreover, the empirical trade literature has recently paid attention to the absence of trade between many countries, even at the aggregate level. Helpman et al (2008) report that as many as half of all aggregate bilateral trade flows assume the value zero (these are often dropped from the sample by researchers using logarithmic values) and suggest a structural estimation procedure building on firm heterogeneity as in Melitz (2003). However, we do not believe firm heterogeneity to be the driving force behind arms trade. We therefore find a linear probability approach more appropriate.

Table 1: Results from estimating the gravity equation. Pooled OLS.

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Arms	Arms	Arms	All	Cars	Coffee
$(Pol_t^i - Pol_t^j)^2$	-1.31e-05**	-1.52e-05**	-1.27e-05**	.000566**	9.06e-05**	-3.97e-07
	(1.59e-06)	(1.58e-06)	(1.63e-06)	(6.84e-06)	(4.15e-06)	(3.81e-06)
$\ln(GDP_t^i)$	1.79e-08**	1.23e-08**	1.27e-08**	1.06e-07**	3.63e-08**	5.17e-08**
	(2.54e-10)	(2.65e-10)	(2.69e-10)	(1.14e-09)	(6.90e-10)	(6.32e-10)
$\ln(GDP_t^{C,i})$		.000273**	.000267**	.00275**	.00188**	.000720**
		(4.00e-06)	(4.08e-06)	(1.73e-05)	(1.05e-05)	(9.60e-06)
$\ln(RGDP_t^{C,ij})^2$			-.000499**	.0206**	.00734**	.00475**
			(7.11e-05)	(.000300)	(.000182)	(.000167)
$\ln D_t^{ij}$	-.00899**	-.00630**	.00623**	-.0544**	-.0568**	.00167*
	(.000278)	(.000279)	(.000279)	(.00118)	(.000717)	(.000656)
B_t^{ij}	.0170**	.0189**	.0184**	-.00138	.0453**	.0530**
	(.00139)	(.00138)	(.00139)	(.00586)	(.00356)	(.00326)
L_t^{ij}	-.00492**	-.00331**	-.00315**	.0623**	.0119**	.0171**
	(.000595)	(.000592)	(.000592)	(.00250)	(.00152)	(.00139)
CR_t^{ij}	.0556**	.0470**	.0466**	.260**	.164**	.273**
	(.00242)	(.00240)	(.00241)	(.0102)	(.00617)	(.00565)
$CC_t^{45.ij}$	-.00639**	-.00375**	-.00388**	-.0923**	-.0459**	.0200**
	(.000784)	(.000779)	(.000779)	(.00329)	(.00200)	(.00183)
$CR_t^{45.ij}$	-.0123**	-.00440	-.00284	-.0248	.255**	.00915
	(.00323)	(.00321)	(.00322)	(.0136)	(.00825)	(.00756)
SC_t^{ij}	-.0254**	-.0217**	-.0220**	.0359	.0119*	.0158**
	(.00199)	(.00197)	(.00197)	(.00834)	(.00506)	(.00464)
Observations	313925	313925	313925	313925	313925	313925
R^2	.025	.039	.040	.194	.187	.084

is high, they are less likely to engage in arms trade. As shown in columns (4)-(6), this is not true for trade in other goods. Column (4) indicates that differences in polity may in fact increase the probability of trade. This may seem odd at first, but could simply reflect that these countries trade for other reasons, such as comparative advantage. Since trade in other goods is not as constrained by policy as trade in arms, these results could simply capture that non-democracies may demand goods produced in democracies and that democracies choose to export these goods as there are no political barriers keeping them from doing so. Exporting chemicals or rice to a non-democracy is clearly less controversial than exporting arms to such a

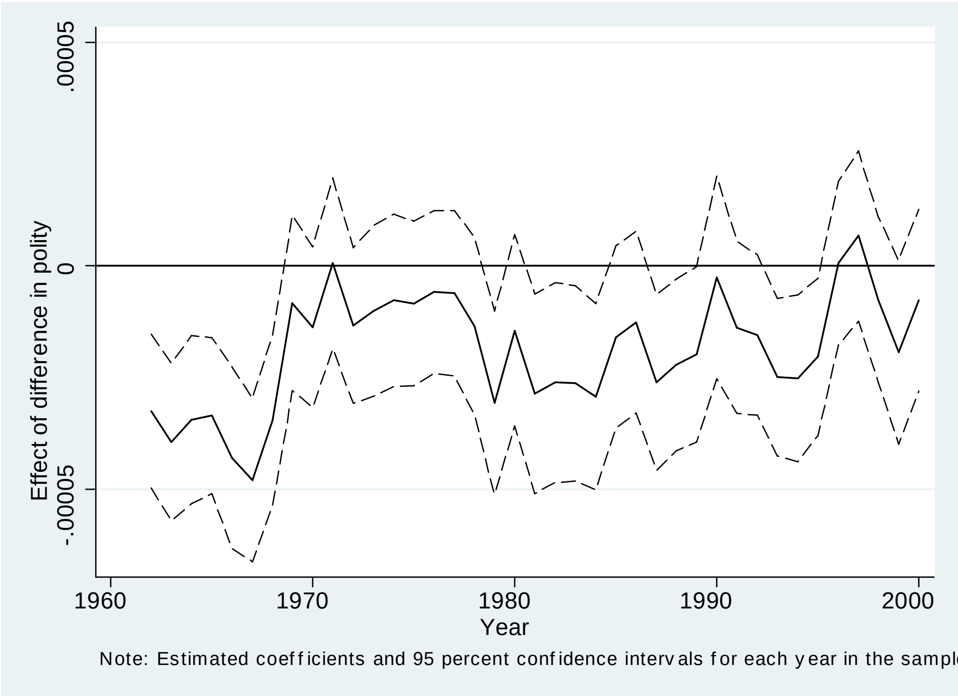

Figure 9: Polity divergence and arms trade.

country. The results for cars in column (5) are similar: differences in POLITY-scores indicate a higher likelihood of trade in cars. In 2007, the five largest producers of cars were Japan, China, Germany, the US and South Korea.[8] By necessity, a large share of the total number of cars exported from these countries will end up in countries with differing political views. Finally, the results for coffee in column (6) suggests that differences in polity have no effect on the propensity to trade as the estimated α is insignificant.

Figure 9 displays the estimated α-coefficient from estimating equation (9) on arms trade, and the associated 95-percent confidence interval in each year. The results suggest that the estimate is negative and significantly different from zero. The estimated parameter is remarkably stable throughout the sample period. Again, we compare this result to trade in other goods. Figure 10 reports the impact of distance in polity on arms trade, total trade and trade in cars. The plot corroborates the findings in Table 1 and lends support to the hypothesis that

[8] Data from the International Organization of Motor Vehicle Manufacturers (OICA).

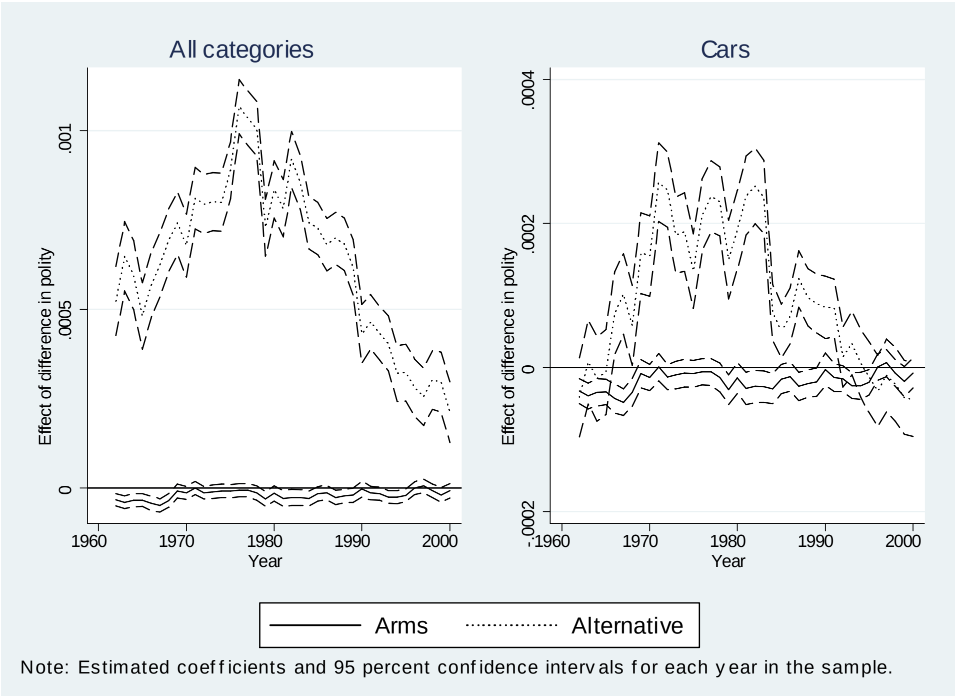

Figure 10: Polity divergence, arms trade, aggregate trade and trade in cars.

polity divergence is no barrier to trade in other goods than arms.

However, production and trade in cars and coffee is clearly very different from production and trade in arms. In order to address the unique and politically charged nature of arms trade, we need to compare arms trade to trade in a good that is as similar to arms as possible. To this end, we estimate the effect of distance in polity on the likelihood of trade in aircraft. In addition to involving high fixed costs of production, aircraft are mainly consumed by the receiving government. It would be ideal to provide an estimate of spacecraft or large aircraft but unfortunately, the data quality for these categories is so low that we deem them unusable. We therefore settle for the broader category aircraft, comprising spare parts as well as helicopters etc. Although the category contains items likely to be consumed also by private agents in the receiving country, we find aircraft the best alternative available for a comparison to arms trade. The estimated coefficients and the associated 95-percent confidence intervals are plotted in Figure 11. The results show that while the effect of distance in polity on the likelihood of

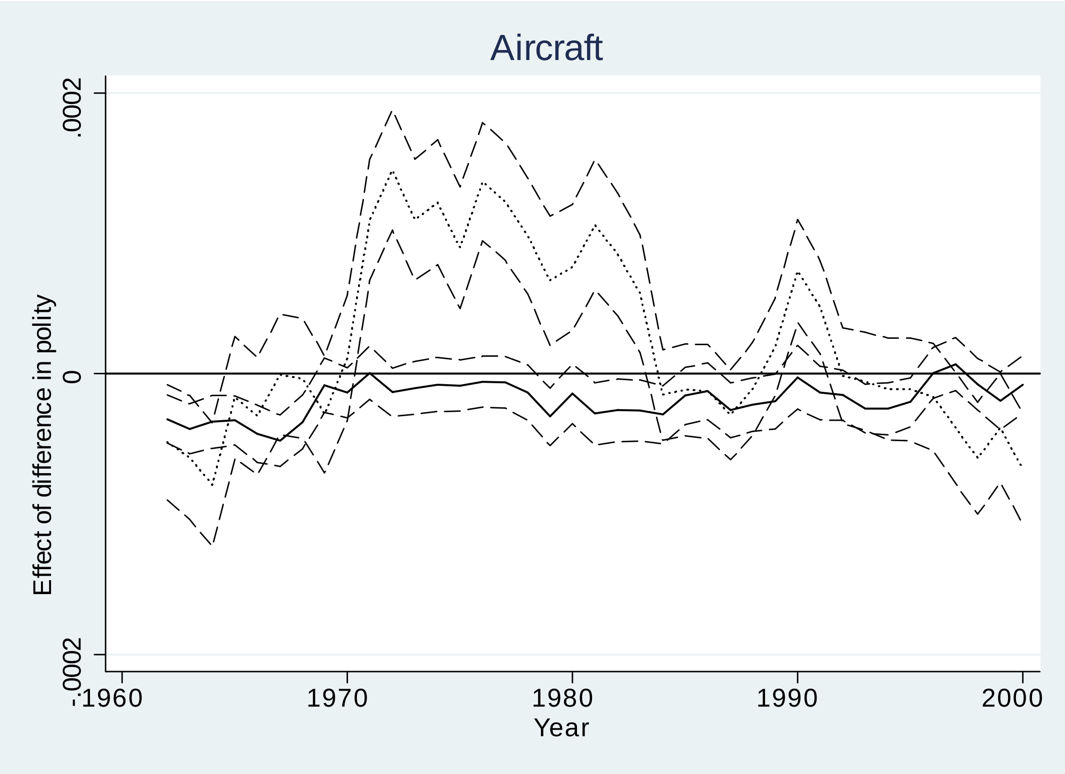

Figure 11: Polity divergence, arms trade and trade in aircraft.

trade is negative in the 1960s and in the late 1990s, it is far from the stable, negative relationship that we see for distance in polity and arms trade. This suggests that political motives and the possible reciprocity involved in each sale are indeed important factors behind arms trade.

Similar graphs for other groups of goods (coffee, chemicals, leather, rice, textiles and wheat) are given in Figures A11-A13 in the Appendix.

4 Concluding Remarks

In this paper, we study the evolution of the global arms trade network using a unique dataset on all international transfers of major conventional weapons over the period 1950-2007. The analysis consists of two parts. First, we characterise global arms trade over the sample period, using methods from social network analysis. Second, we address the relationship between distance in POLITY-scores and likelihood of arms trade, using a gravity equation augmented by political and economic controls.

The first part of the analysis reveals that the arms trade network shares common traits with other networks, notably a small world property, negative correlation between degree and clustering coefficients and a scale-free degree distribution. Moreover, the network exhibits negative assortativity, a property found to characterise other trade networks as well.

The data mirrors common views of the ideological divide of the Cold War. There is a clear division between NATO and the Warsaw Pact until the disestablishment of the latter in 1991. Moreover, the Warsaw Pact is more centered around the Soviet Union than NATO around the US; the Warsaw Pact thus closely resembles a star network with a number of peripheral traders interacting almost exclusively with the USSR.

The sharp dichotomy between NATO and the Warsaw Pact is an indication that political rule is a key determinant when choosing arms trading partners. In the second part of the analysis we seek to quantify this relationship by relating distance in POLITY-scores to the likelihood of arms trade. Using a gravity equation, we find evidence that differences in polity have a significant, negative effect on the likelihood that arms trade occurs. Estimating the relationship for each year in the sample, reveals that the relationship is remarkably stable throughout the sample period and even survives the end of the Cold War. We do not find such a negative relationship for any other good we study, including commodities highly similar to arms in terms of market structure and production technology. Our estimation results are supported by plots of arms exports and polity of destinations. We find that, on average, democracies tend to export arms to other democracies. However, the bias is even stronger for autocracies, who strongly prefer trading with other autocratic states.

Our results suggest that polity matters for arms trade: countries with divergent political regimes are unlikely to trade in arms. The fact that we find no such relationship for trade in other goods indicates that the unique properties of arms trade account for this finding. We find it plausible that the security issues involved in each trade implies that states are unlikely to sell arms to governments that they perceive as potential adversaries. The observation that it is extremely uncommon for two democratic states to engage in armed conflict, as suggested by the Democratic Peace Theory, may help explain why democracies prefer trading with other democracies; they are simply not perceived as threats.

The finding that political regime seems to be such an important determinant of arms trade suggest that arms trade may be thought of as a proxy for political relationships between states. In this study, we have assumed that causality runs from polical rule to arms trade but it may well be that arms trade affects political regime. First, we may think of arms trade as enabling coups and civil uprising, leading to political regime shifts. Second, it is not uncommon that arms trade is conditional on a set of requirements on the receiving government. This suggests that arms trade between two states is correlated with the political influence that they may exert on each other. We conclude that some measure based on arms trade is likely to be a valid proxy for intergovernmental political ties, but recognise that a number of factors need to be taken into account when constructing such a variable. We therefore leave the optimal design of such a proxy to future research.

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Tables

Table A1: Member Countries of NATO and the Warsaw Pact.

NATO	Entry	**The Warsaw Pact**	Entry	Exit
Belgium	1949	People's Republic of Albania	1955	1961
Denmark	1949	People's Republic of Bulgaria	1955	1991
France	1949	Czechoslovak Socialist Republic	1955	1991
Iceland	1949	People's Republic of Hungary	1955	1991
Italy	1949	People's Republic of Poland	1955	1991
Canada	1949	People's Republic of Romania	1955	1991
Luxembourg	1949	The Soviet Union	1955	1991
Netherlands	1949	East Germany	1956	1990
Norway	1949			
Portugal	1949			
Great Britain	1949			
USA	1949			
Greece	1952			
Turkey	1952			
(West) Germany	1955			
Spain	1982			
Poland	1999			
Czech Republic	1999			
Estonia	2004			
Latvia	2004			
Lithuania	2004			
Romania	2004			
Slovakia	2004			
Slovenia	2004			
Croatia	2009			
Albania	2009			

Figures

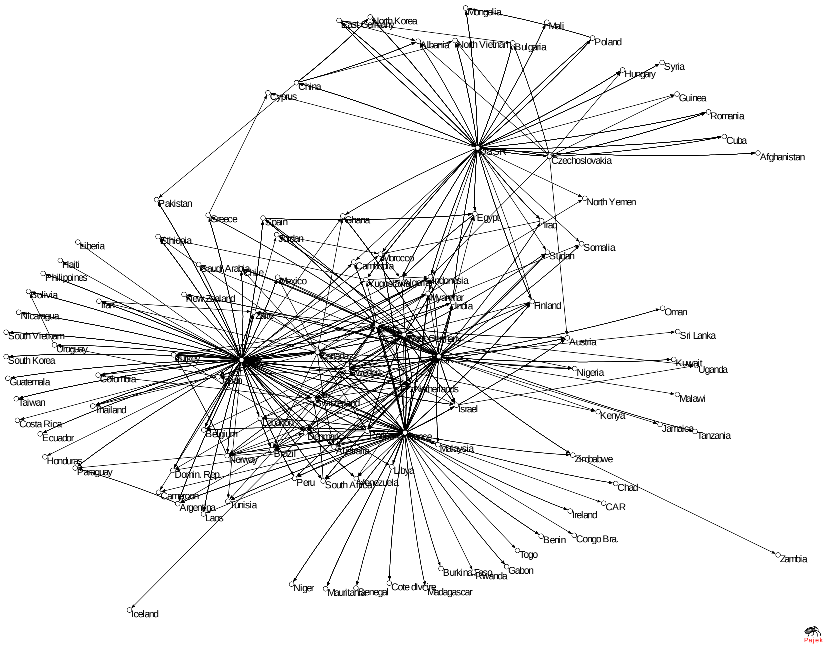


Figure A1: The global arms trade network, 1960-1964.

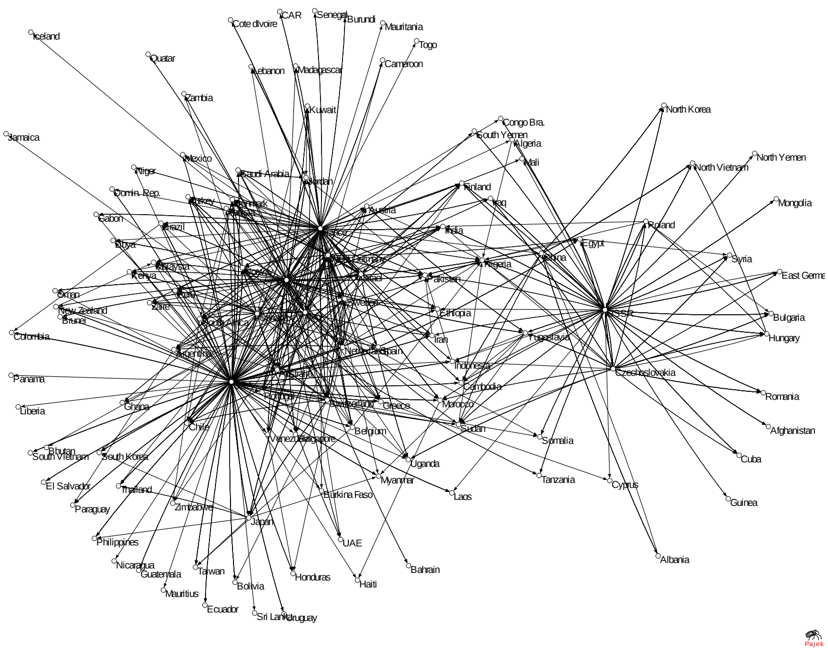


Figure A2: The global arms trade network, 1965-1969.

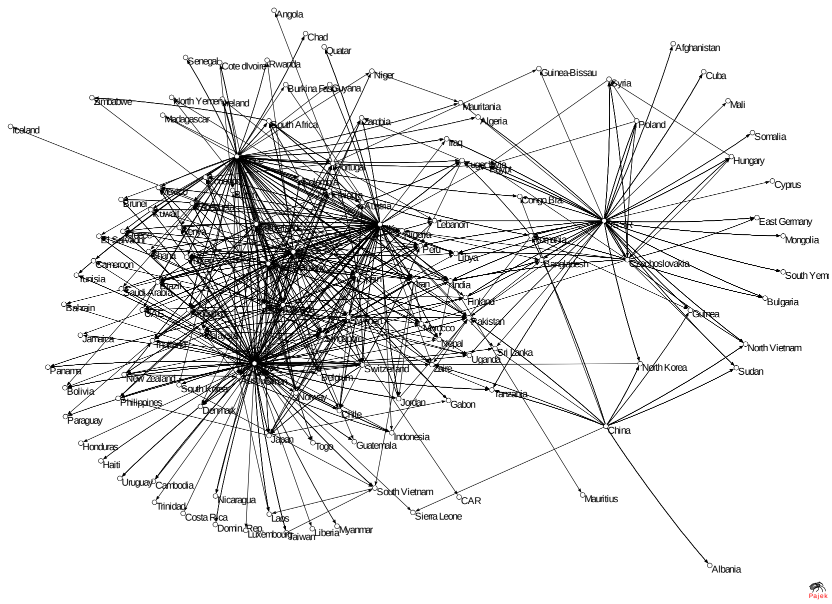


Figure A3: The global arms trade network, 1970-1974.

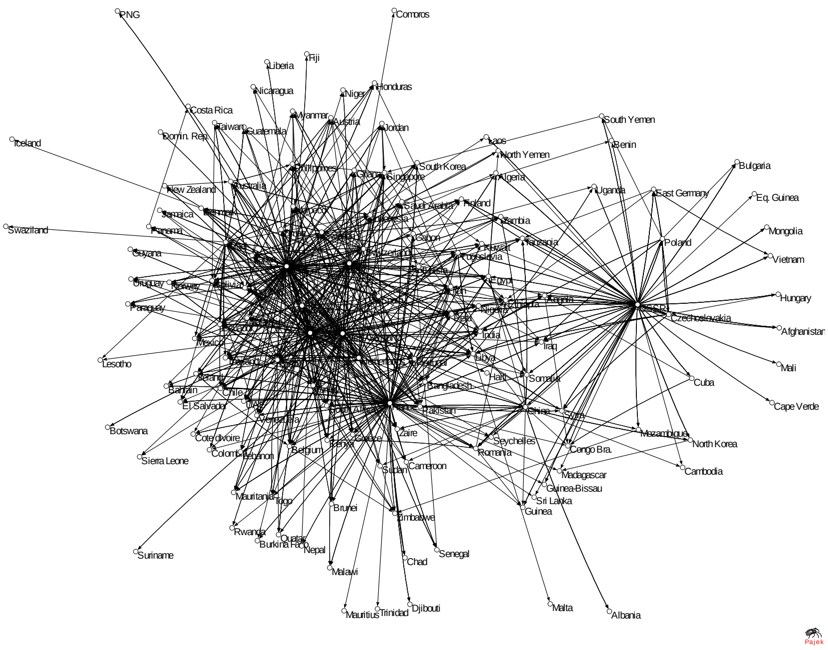


Figure A4: The global arms trade network, 1975-1979.

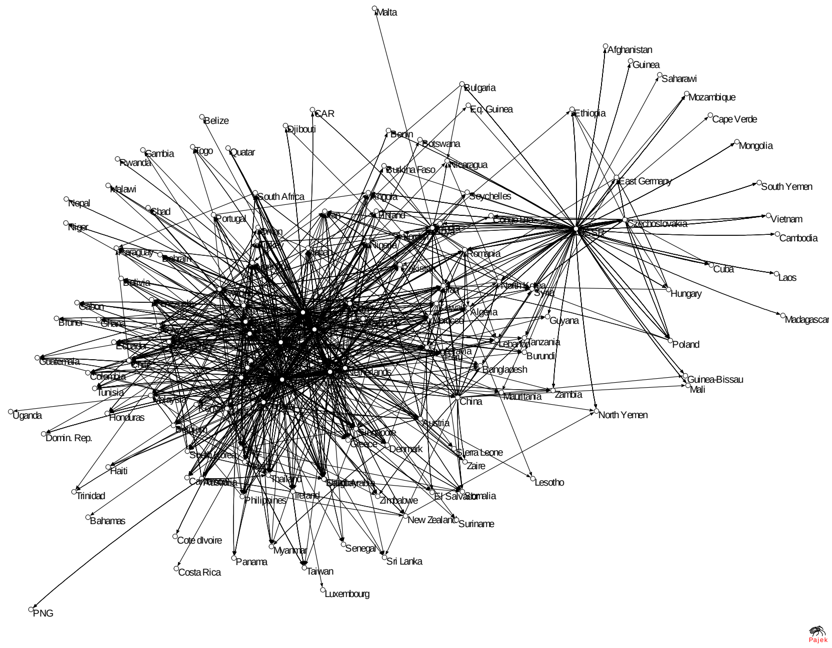


Figure A5: The global arms trade network, 1980-1984.

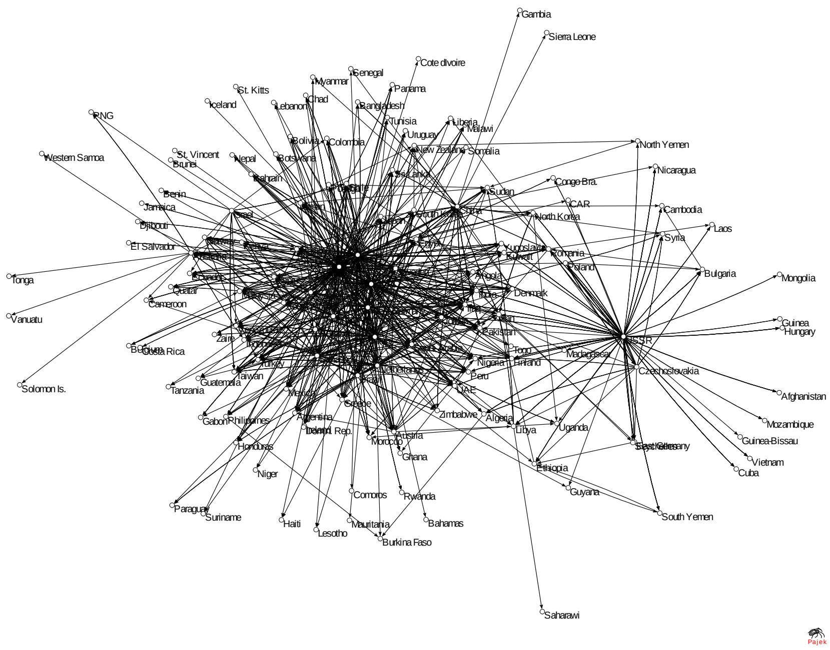


Figure A6: The global arms trade network, 1985-1989.

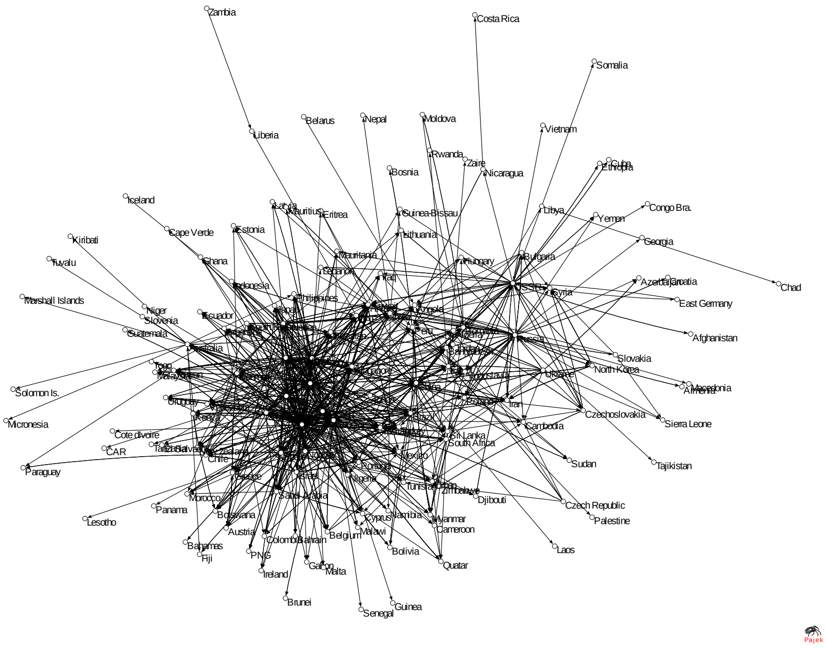


Figure A7: The global arms trade network, 1990-1994.

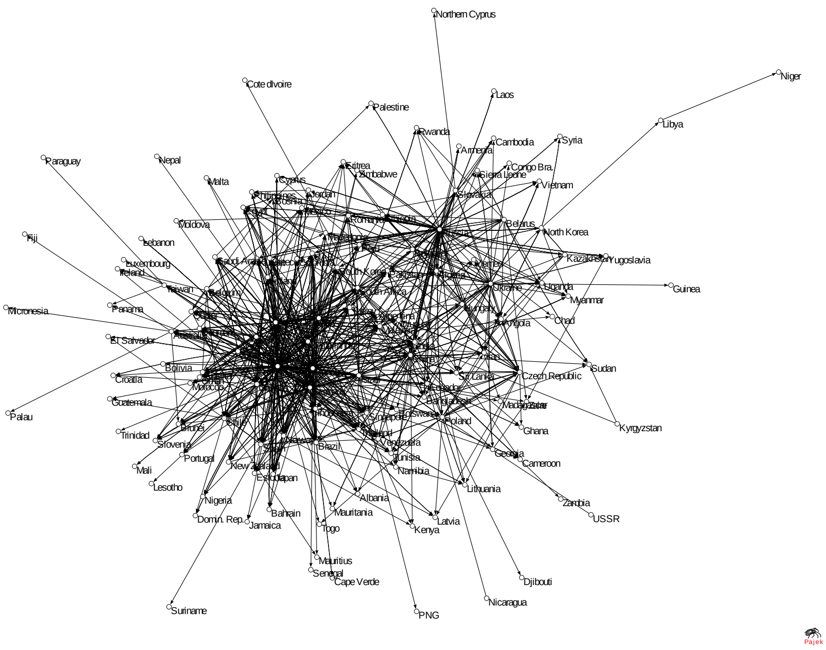


Figure A8: The global arms trade network, 1995-1999.

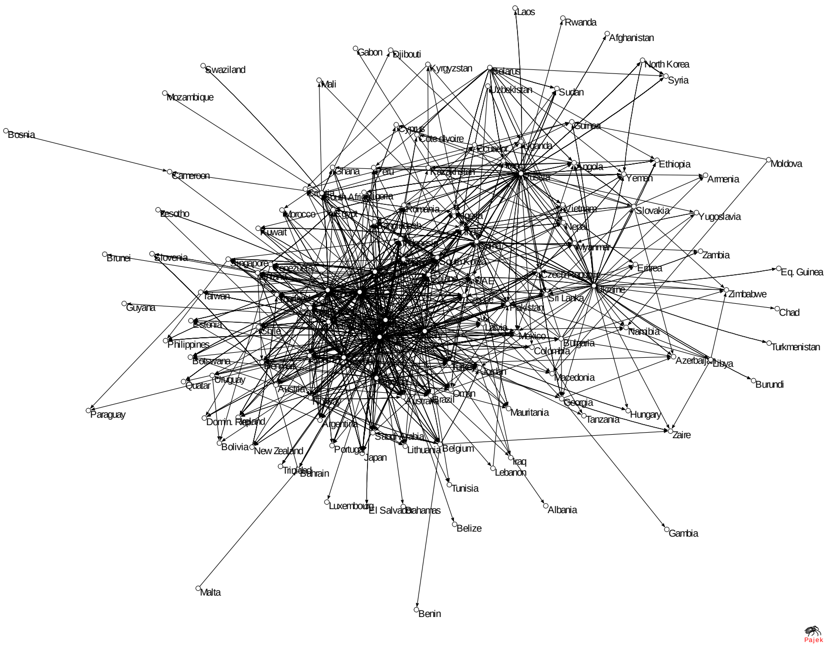


Figure A9: The global arms trade network, 2000-2004.

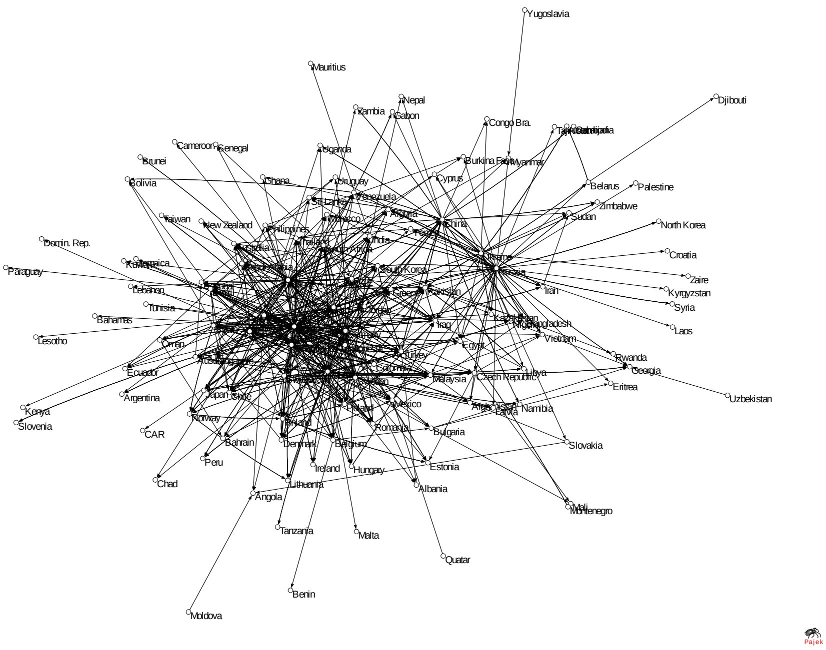
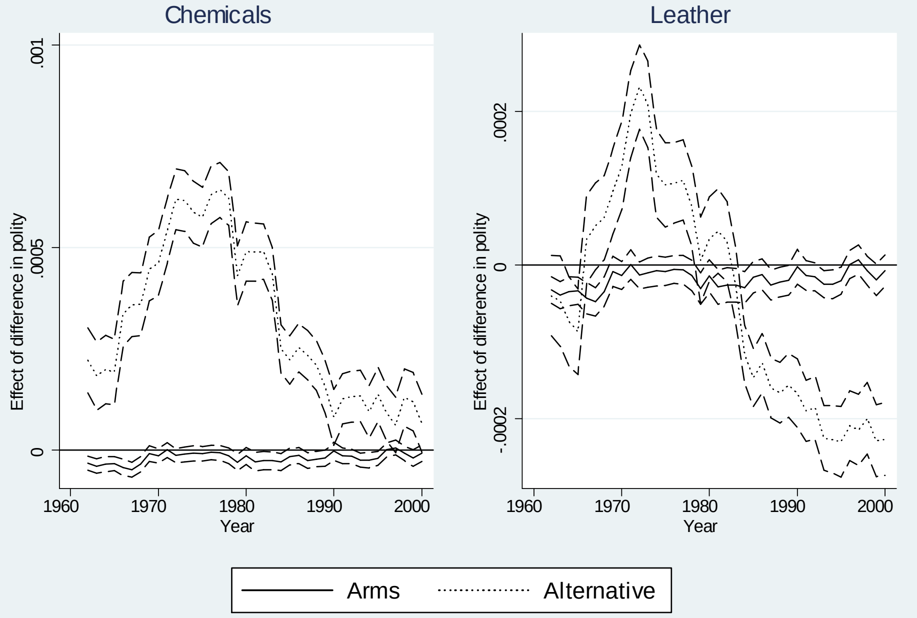


Figure A10: The global arms trade network, 2005-2007.



Note: Estimated coefficients and 95 percent confidence intervals for each year in the sample.

Figure A11: Polity divergence and trade in arms, chemicals and leather.

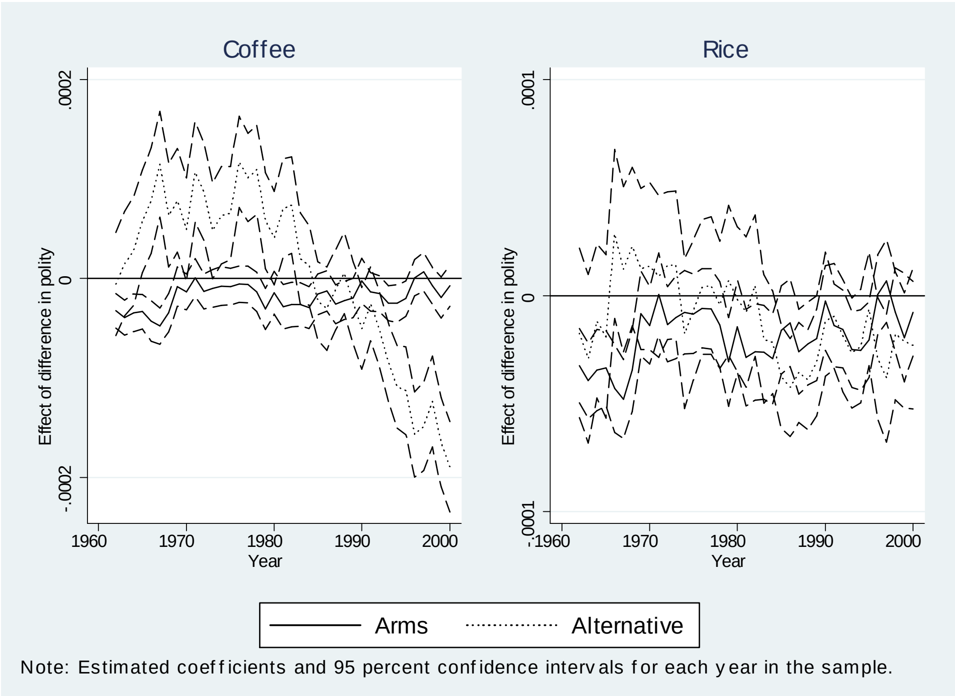


Figure A12: Polity divergence and trade in arms, coffee and rice.

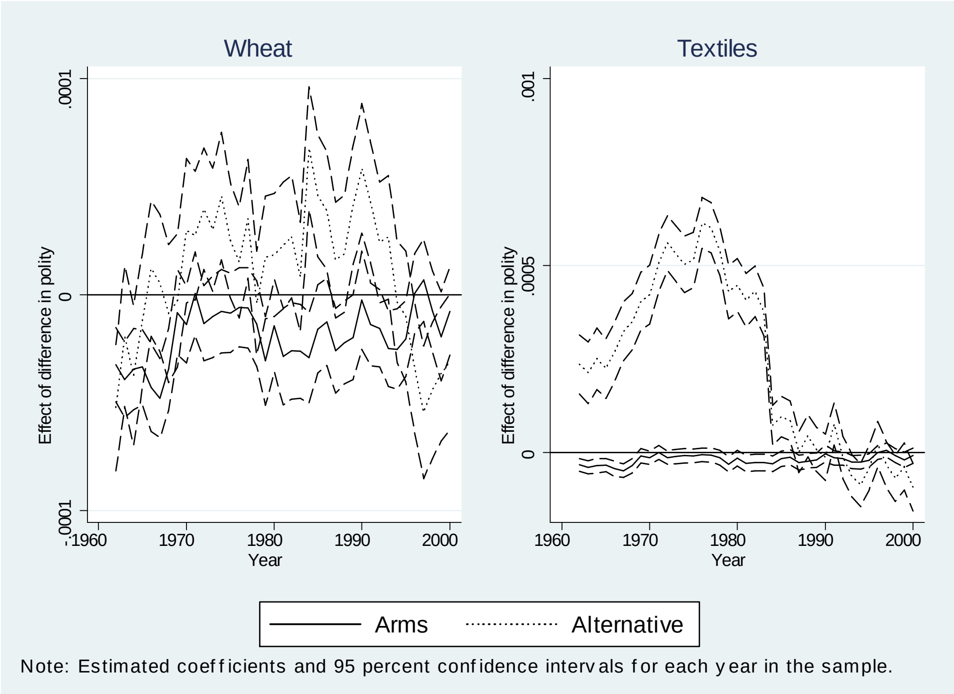


Figure A13: Polity divergence and trade in arms, wheat and textiles.