Arms Trade Network Analysis

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https://github.com/cse416a-sp22/final-project-dhruvpatel-amritjohar-tejas-mattur

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Abstract

In the modern world, countries are highly interconnected and are constantly engaged in strategic military agreements, especially during periods of conflict. In order to learn more about the behavior of countries both during and outside of these periods, a key indicator to analyze is the international arms trade. The primary objective of this project is to construct a comprehensive network with information on countries and the arms deals they have engaged in over time and examine said network with techniques such as calculating centrality measures, conducting temporal analysis and analyzing reciprocity scores. Our results have shown that suppliers of arms tend to be highly developed countries across history, and have found that groups of countries such as the Nordic countries tend to have strong two-way relationships as both suppliers/buyers of arms. These insights as well as others are further discussed in the paper.

Keywords: Arms Trade, Buyer/Supplier, Reciprocity

1 Introduction

Arms deals are defined as agreements to buy or sell weapons between two countries. These deals can be classified into various groups such as munitions, aircraft, etc, but this paper will look at arms deals as a whole rather than specific types. These deals are important as they involve a massive amount of money, as the global arms trade has an estimated financial value of at least $199 billion in 2019 alone[4]. In order to clarify the purpose of this paper, some of the keywords we explored (on a standard search engine) were "centrality of arms deals", "arms trade network analysis", and "structural analysis of arms trade." This proved to be helpful in our findings, as we were able to come across papers that explored similar topics and provided us guidance. These papers [2,3] looked at different types of arms trades such as the small arms trade and looked at measures such as the centrality of actors that we used to build upon for our project.

Overall, we have a few main goals with the project. First, our primary objective is to use the SIPRI dataset to build a global arms deal network with countries as the nodes and edges representing deals between countries over the past 70+ years. After the network is built, we will move into analysis. We will provide basic network statistics as well as analyze centrality scores to identify influential leaders in the arms trade over time. In addition, we will conduct temporal analysis to analyze leading suppliers and buyers of arms during specific warring periods and identify changing trends. Lastly, to explore the relationship between tightly connected groups of countries, we will look into factors such as reciprocity and neighborhood overlap. These tactics should give us a comprehensive overview of the global arms trade.

2 Data Collection

We have located a dataset from the Stockholm International Peace Research Institute (SIPRI), which provides information on all arms trades since 1950. It should be noted that this initiative began about 5 years after the end of World War 2 in hopes of preventing major global conflicts from happening again by keeping countries accountable for what they are purchasing. When downloading the data from SIPRI, the site provides the data in a .rtf file format, a relatively unusable file format programmatically as it's primarily designed for viewing. Therefore, to use the data we decided to create a library within pip. With this built-in library, we obtained the data in an ambiguous format. After trimming the data down to usable columns and renaming, we were left with a csv table with the following information: Supplier

Country, Recipient Country, Year Ordered, Year Delivery, Category, Description, and Amount Delivered. For clarification, Category is a column containing unique values as to the overall grouping/class of the weapon. Some examples of categories are Artillery, Naval Weapons, or even Satellites.

3 Network Overview

3.1: Network Construction

The network was constructed using the dataset and adding directed edges for each trade a supplier and buyer engaged in. If a directed edge already exists, then in turn we will add weights for additional trades between a supplier and buyer. So for example if country X has only sent 45 trucks in one trade and 3 UAV's in another trade since 1950 to country Y, then there would be a directed edge of weight 2 from X to Y. It should be noted that not every trade is of equal weight. For example one helicopter is not of the same value as one pistol. However, the amount of trades between two countries more signifies the strength of the relationship. Countries can have several trades in one time period and none in a different one due to a change of relationship. A visualization of the overall network can be seen in **Figure 1**.

3.2: Network Statistics

Within the network, there are 264 nodes with 2992 edges. This might come as a surprise because the current number of countries in the world is less than 200. This is because the database contains past countries and organizations such as the United Nations, Soviet Union, Viet Minh, and more. The most surprising nodes are nodes like Unknown Buyers and Unknown Rebel Groups as it is suspicious they are receiving arms with no way to identify them. For the edges, it should be noted that the edges themselves have weights, so a single edge could signify multiple trades between countries. The network has an average shortest path length of 1.189 and a clustering coefficient of 0.330. Both of these statistics were calculated using an undirected graph since we are looking more for relationships. The average shortest path of 1.189 is extremely small and gives evidence for the small-world phenomenon. The relatively low clustering coefficient means that a country's neighbors are less likely to be connected.

4 High level Analysis

4.1: Network Centralities

With the network constructed prior, one of our main tasks was to identify the most important countries within the network. The best way to measure node importance in a network is through centrality measures, so we calculated these for countries across the whole network from 1950 to present day. The top 5 countries by centrality measure are displayed in **Table 1**.

Leading Countries by Centrality Measures Over Time					
Rank	In-Degree	Out-Degree	Closeness	Betweenness	Eigenvector
1	Iraq	United States	United States	United States	Iraq
2	Indonesia	France	Iraq	France	Jordan
3	Nigeria	UK	Nigeria	Israel	Nigeria
4	Egypt	Germany	Jordan	UK	Indonesia
5	United States	Italy	Indonesia	Jordan	Pakistan

Table 1: Leading Countries by Centrality Measures Over Time

This data on leading countries by centrality measures leads us to some interesting insights Starting off, to clarify, in an undirected graph, degree centrality would be computed as one measure, as it simply sums the number of edges a node has. Since our graph is directed, we calculated both in-degree and out-degree centrality scores to identify the leaders in terms of the number of incoming and outgoing edges. In-degree centrality leaders represent top buyers of arms, whereas out-degree centrality leaders represent top suppliers. In general, the top buyers seem to be relatively large countries that have been involved in different warring periods over time but may not have the same production power as more developed countries, with the exception of the United States. On the other hand, the top suppliers all rank highly

in the Human Development Index [1], a United Nations metric that tracks the most developed countries in the world, suggesting that the resources of these countries have allowed them to produce and supply the most arms in the last 70 years. These takeaways tie into the next metric, closeness centrality, which indicates how close a node is to all other nodes to other nodes in a network. The countries listed for this metric (United States, Iraq, Nigeria etc.) contain a mix of both top buyers as well as suppliers, since the closeness centrality metric utilizes average shortest path in its calculation, treating suppliers and buyers as equal in an undirected graph. Therefore, this metric simply reveals the most well-connected countries within the overall graph, as opposed to classifying them as suppliers/buyers.

Next, betweenness centrality measures the amount of influence a node can have over the flow of information in the graph. This could imply that countries such as the United States, France, and Israel work with a variety of different types of countries, allowing them to have significant control over information flow in the network at large. This concept is further looked into in visualizations to be discussed later. Lastly, the leading countries with respect to eigenvector centrality have three overlapping countries (Iraq, Nigeria and Indonesia) with the in-degree and closeness measures. This could be due to the fact that these countries are relatively large and are top buyers in the network implying that they have connections with influential neighbors that are likely leading suppliers. These countries, like the United States, France and the United Kingdom, may also have additional connections with countries of very small populations given that they are major suppliers, which would serve to lower their eigenvector scores and remove them from the leaderboard in this category.

4.2: Temporal Analysis

In order to find more specific insights on certain warring periods, we decided to conduct temporal analysis by looking at the data during specific periods of time. Specifically, we chose to analyze the Cold War and the Afghanistan War given their significance in world history. Visualizations of the graphs generated for the Cold War and the Afghanistan War can be seen in **Figures 2 and 3**. Within these periods, we looked at leading countries of in-degree and out-degree centralities to identify top buyers and suppliers. This data is shown in **Table 2**.

Rank	Cold War In-Degree	Cold War Out-Degree	Afghanistan War In-Degree	Afghanistan War Out-Degree
1	Egypt	United States	Indonesia	United States
2	Iraq	France	UAE	France
3	Iran	United Kingdom	Iraq	Russia
4	Morocco	Germany	United States	Italy
5	India	Italy	Malaysia	Germany

Table 2: Leading Countries in Degree Centrality During Warring Periods

First off, the out-degree centrality leaders for both periods are very similar, with 4 of the countries being identical in the top 5 in both periods. In addition, these leaders are very similar to the out-degree centrality leaders from **Table 2**, implying that the top suppliers remain somewhat constant both during periods of conflict as well as outside these periods. There are some changes with respect to the in-degree leaders, meaning that buyers during periods of conflict do change. For example, Egypt comes in as the top buyer during the Cold War, which makes sense given that Egypt transferred its loyalty from the USSR to the United States in the midst of the Cold War [5], so it likely bought military supplies from countries on both sides of the war, leading the country to have a significant amount of edges at this time. Overall, there are significant changes in the in-degree leaders with countries such as Iran, Morocco, Malaysia and the UAE appearing as leaders due to their involvement with the conflict after not appearing as leaders in the overall graph.

5 Additional Analysis

5.1: Reciprocity

The domination of the superpower countries as arms suppliers in our results so far come as no surprise. Apart from this, we want to see if we can find useful information from our network at a mesoscopic level.

We've already examined centralities for the entire network, both as a whole and temporally. We think it would be interesting to see if we can better learn about the relationships between groups of countries through their trade habits. Specifically, we want to look at relatively smaller countries (in terms of trade volume) and look for strong two-way relationships between them and their neighbors in the graph. That is, we want to see if we can find countries that exhibit high "buyer and seller" relationships with countries they deal with to get a better understanding of their similarity from a production standpoint as well as the potency of their relations.

This is where we turn our heads to reciprocity. Defined as the ratio of the number of two-way edges for a node to the total number of edges attached to a node, we think that reciprocity is an appropriate analysis measure to try to determine if we can find potent groups of nodes that exhibit high two-way relationships amongst each other. Let r be the reciprocity of an entire graph and u, v as two nodes in the graph. Then we can calculate the reciprocity of the graph as such:

$$r = \frac{|(u,v) \in G | (v,u) \in G|}{|(u,v) \in G|}$$

As discussed above, this definition can be extended to a single node as well. Given this definition, we went ahead and calculated the reciprocities of each node in our directed graph. The top five reciprocity leaders and their scores were as follows:

Finland: 0.462; Norway: 0.441; Denmark: 0.373; Sweden: 0.369; Jordan: 0.333

Note that 'FMLN (El Salvador)*', a political party in El Salvador which has a reciprocity of 1.000, was excluded from this list given that it only had a degree of 2. This, of course, is telling for us, as the top four reciprocal countries are the Nordic countries that are all geographically close and tightly connected in political relations. It is reasonable here to think that much of the reciprocity with these nations is accounted for by back-and-forth arms trades within their group. Jordan is also high on this list, likely due to heavy two-way trades with other countries in the Middle East.

It is important to note that high reciprocity alone does not directly tell us that a group of nodes are tightly connected; two countries that share no political or militarial connection may still have high reciprocity with their respective neighbors and therefore show up high on the list. As a result, looking at just the reciprocity numbers to extract well-connected groups of countries is not possible. We would need to compare these figures with another metric to know if this reciprocity is actually due to their trade relations with each other or if it's a mere coincidence.

5.2: Neighborhood Overlap

Based on our findings on reciprocity, we decided that the best metric to cross-reference with the reciprocity values is the neighborhood overlap of each node with our suspected "tight" groups. If we suspect the Nordic group to be a tight group, we should see similar reciprocity numbers between the Nordic countries as well as high neighborhood overlap between each of the countries in the group. We went ahead and found the neighborhood overlaps for the Nordic groups to test this notion (see **Table 3 and 4**).

We can see now that on top of the similar reciprocities, there is also high overlap between the Nordic countries. Thus, it is reasonable for us to say that the Nordic countries outlined above form a tight group in terms of political and military alliance. We decided to test this on two more regions in the world to determine if we can find other tight groups. We opted to look into the Middle East as well as African countries for our analysis. These results are outlined in **Tables 5, 6, 7 and 8**.

The similarities in the reciprocity scores for each group couples with the strong neighborhood overlaps exhibited within them give us appropriate reason to believe that the selected countries in the Middle East and Africa form tight groups (note that the low reciprocities in the African group do not skew our results, as a country can have a large breadth of deals but only have reciprocal deals with a few neighbors. For this reason, we only care about how similar the reciprocity values are).

6 Conclusion and Future Work

To conclude, in this project, we successfully built a global arms deal network with countries as the nodes and edges representing deals between said countries over history. The network itself is highly connected with a low average shortest path between two nodes. However, the nodes themselves are unique and contain countries to past nations to even global organizations. We also see that the graph's edges may be diverse (ranging from artillery to fighter jets) but the graph overall shows relationships between different nodes. From the high-level analysis we conducted, we were able to identify two broad results. First, highly developed countries are major suppliers of weapons throughout all periods of history, undeterred by periods of military conflict. Second, large countries such as Iraq, Nigeria, and Indonesia tend to be significant buyers over the course of history which increases their influence in the overall network due to a significant amount of deals undertaken as well as their close proximity to powerful, developed countries that tend to be suppliers for these countries.

Lastly, our main takeaway from the additional analysis we conducted is that reciprocity serves as an interesting metric to track in the context of our problem as a first step to find groups of tightly-connected countries. By taking the reciprocity scores of each country and cross-referencing these with the neighborhood overlaps of the countries in the proposed group, we were able to find meaningful connections between the two metrics that gave us a better idea of how smaller countries (i.e., not superpower suppliers) form coalitions through arms trade. Specifically, we found reasonable evidence of tight groups in the Nordic countries (Finland, Norway, Denmark, Sweden), the Middle East (UAE, Libya, Iran, Syria), and Africa (Zimbabwe, Uganda, Ghana, Sudan). There is plenty of reason to believe we can detect more, even ones that are not geographically close.

In the future, we would like to dig deeper into the network. Specifically, we'd like to explore specific categories of weapons in further depth, such as artillery, naval weapons, and more. Through this analysis, we could discover if certain countries dominate the trade of certain types of weapons and if there are countries where potentially destabilizing build ups of weapons are occuring. In addition, another possibility to look into in the future is analyzing the monetary value of the arms trade. Our current network primarily focuses on the breadth of relationships between countries, but it would be insightful to quantify the arms deals by assigning money to the different categories of deals to see if there are any changes in network trends that this brings about. This specific data would likely involve further research as it wasn't contained in the initial SIPRI dataset, but we believe it'd be worthwhile looking into.

References

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7 Appendix

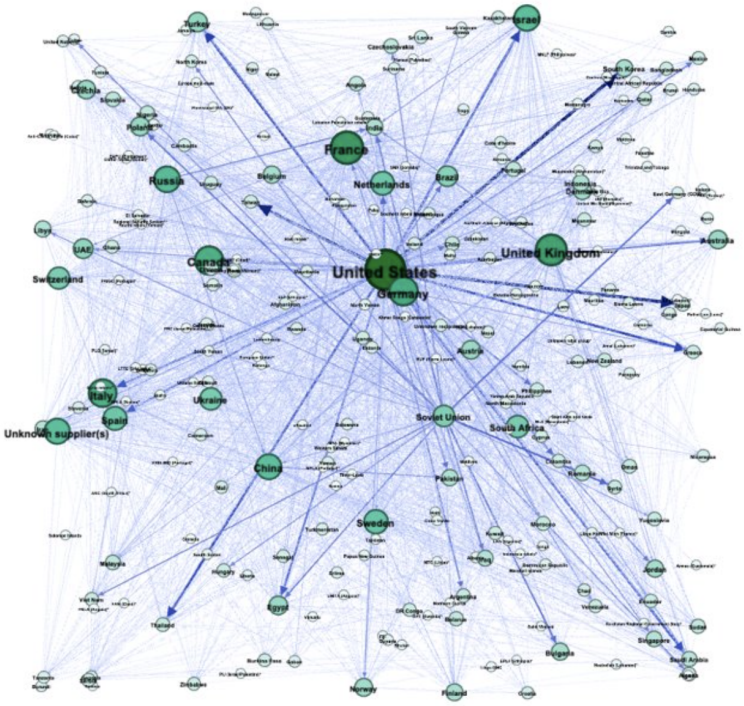

Figure 1: Overall Network

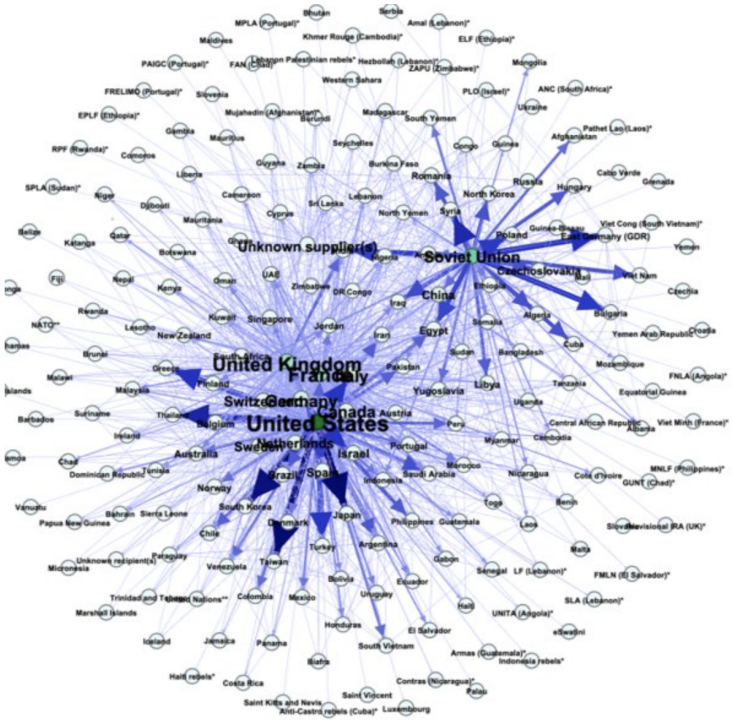

Figure 2: Cold War Network

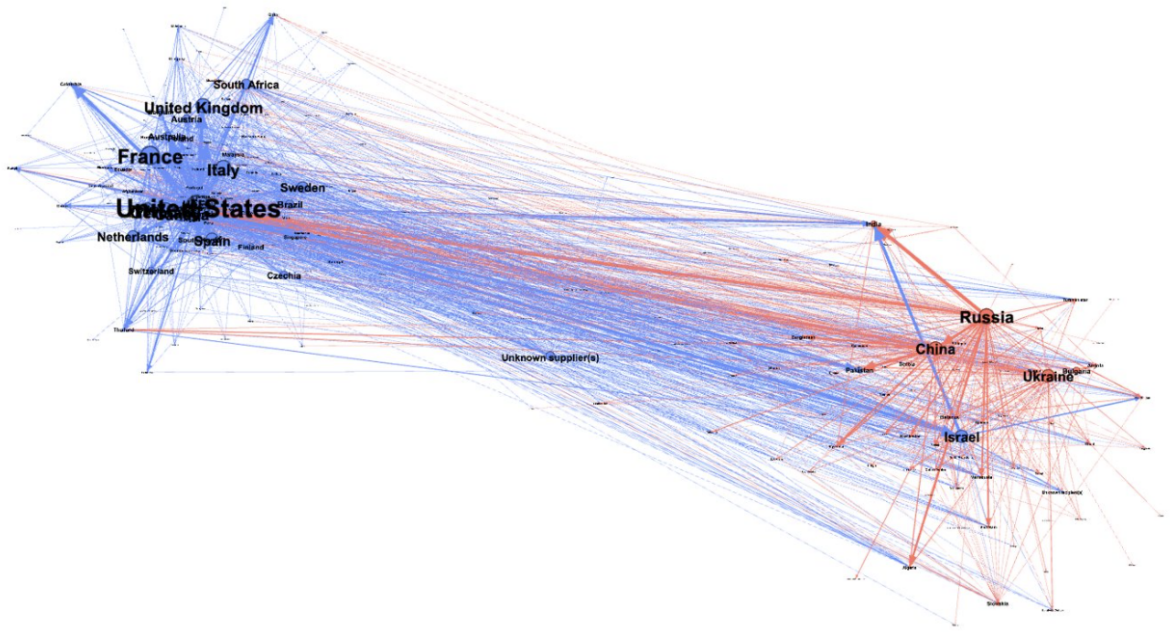

Figure 3: Afghanistan War Community Network

	Finland	Norway	Denmark	Sweden
Finland	1.000	0.448	0.433	0.402
Norway	0.448	1.000	0.460	0.422
Denmark	0.433	0.460	1.000	0.444
Sweden	0.402	0.422	0.444	1.000

Table 3: Neighborhood Overlaps of the Nordic Countries

Finland	0.462
Norway	0.441
Denmark	0.373
Sweden	0.369

Table 4: Reciprocities of the Nordic Countries

	UAE	Libya	Iran	Syria
UAE	1.000	0.247	0.325	0.200
Lybia	0.247	1.000	0.290	0.214
Iran	0.325	0.290	1.000	0.280
Syria	0.200	0.214	0.280	1.000

Table 5: Neighborhood Overlaps of Middle Eastern Countries

UAE	0.194
Libya	0.170
Iran	0.143
Syria	0.138

Table 6: Reciprocities of Middle Eastern Countries

Neighborhood Overlaps of African Countries				
	Zimbabwe	Uganda	Ghana	Sudan
Zimbabwe	1.000	0.500	0.438	0.325
Uganda	0.500	1.000	0.469	0.385
Ghana	0.438	0.469	1.000	0.310
Sudan	0.325	0.385	0.310	1.000

Table 7: Neighborhood Overlaps of African Countries

Reciprocities of African Countries	
Zimbabwe	0.083
Uganda	0.080
Ghana	0.077
Sudan	0.061

Table 8: Reciprocities of African Countries