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# CHANGING STRUCTURE OF THE ARMS TRADE: A SOCIAL NETWORK ANALYSIS

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## Abstract

The global arms trade should be understood not as a market but as a network, one that shares some important properties with networked forms of organization studied by sociologists. I make this argument and then employ quantitative methods developed for social network analysis in an effort to describe the evolving structure of the arms trade network since the end of World War II. That structure has changed significantly over the past fifty years. It became less dense in the early years of the cold war as newly independent states joined the society of states, but had yet to develop many arms-transfer ties. But from the early 1970s, the network got denser as arms-transfer relations developed among a roughly constant number of actors. At the same time, the supplier structure of the arms trade has become progressively less centralized, even though the United States remains the most central arms supplier. This decentralization is evident from the patterns of arms-transfer relationships in the network, not from aggregate amounts of weapons transferred by the United States and other suppliers, which paint a quite different picture (one of greater U.S. predominance). Mapping the positions of arms suppliers in two-dimensional space sheds some more light on structural changes within the network. Aside from Russia, which maintains several arms-transfer relationships established during the cold war, the leading arms suppliers share an expanding set of common clients. Many analysts of the arms trade have commented on the increasing competition among arms suppliers in the post-cold war era, and the evolving structure of the arms trade seems conducive to further marketization.

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## CHANGING STRUCTURE OF THE ARMS TRADE: A SOCIAL NETWORK ANALYSIS

In 1934, the Book-of-the-Month Club's April selection was *Merchants of Death*, a critical study of the global arms trade. In that best-selling volume, H.C. Engelbrecht and F.C. Hanighen argued that the activities of arms merchants undermine the policies of national governments to whom they owe allegiance. Part of their message was, in essence, that American neutrality was compromised during the Great War by weapons manufacturers whose strict adherence to market principles in peddling their wares left them little incentive to ponder the political or moral implications of their profession. The arms business is exactly that – a business – and business is good when nations are at war, or when they fear it.

*Merchants of Death* figured prominently among the polemics that fueled the flames of American interwar isolationism, culminating in the Neutrality Acts of 1935-1939. Prior to the passage of the Neutrality Acts and the formation of the Munitions Control Board, the export of weaponry by American merchants was largely unregulated. By the outbreak of a second World War in Europe, the U.S. government had established controls over private arms sales, and thus what was for the arms merchants a means of profit became for the government an instrument of foreign policy. This new role for arms transfers was inaugurated with the signing of the Lend-Lease Act of 1941, an effort to avoid direct American involvement in the European war by promising instead that the country would remain the great *arsenal* of democracy. In a relatively short period of time, the foreign transfer of weaponry shifted from the private to the public sphere, contributing significantly to a withering of the popular animus previously directed at the arms industry. In European nations as well, governmental supervision over arms exports was

established during the 1930s, though typically with less fanfare than in the United States (Stanley and Pearton 1972, 25).

George Bernard Shaw appears to have foreseen this transition in the final act of *Major Barbara*, which opened in London in 1906. An exchange between Andrew Undershaft, the arms manufacturer, and Adolphus Cusins, professor of Greek and Undershaft's prospective son-in-law and inheritor, highlights two competing principles at work in the weapons trade:

CUSINS. What on earth is the true faith of the Armorer?

UNDERSHAFT. To give arms to all men who offer an honest price for them, without respect of persons or principles: to aristocrat and republican, to Nihilist and Tsar, to Capitalist and Socialist, to Protestant and Catholic, to burglar and policeman, to black man, to white man and yellow man, to all sorts and conditions, all nationalities, all faiths, all follies, all causes and all crimes....

CUSINS. ...[A]s to your Armorer's faith, if I take my neck out of the noose of my own morality I am not going to put it into the noose of yours. I shall sell cannons to whom I please and refuse them to whom I please. So there!

In the period following World War II, it was not Undershaft's but Cusins's faith that most seemed to guide the arms-supply policies of the major powers. The superpowers, especially, provided and refused weapons to whom they pleased, and often with little regard for whether clients could offer an honest price for them. The arms business ceased to be solely a business; it became also a *political* transaction.

The international arms trade never really became completely managed by the major states for purposes of advancing their foreign policy goals. The economic motives of private stakeholders continue to spark sharp criticism. Reference to military industrialists as "merchants of death" or "traders in death," or to the weapons trade itself as an "arms supermarket" or "arms bazaar" where the "cascade of arms" is ample enough to provide "weapons for all," conjures up

images a free-market bonanza in which commercial interests are paramount and states, whatever their reasons, impose few constraints.<sup>1</sup> Still, for the many actors participating in the production, transfer, and acquisition of weaponry – governments, private and state-run arms manufacturers, financiers and investors, workers, armies – there exists a mix of commercial, political, and military motives. At any given time, these actors (and their motives) also have differential effects on the policymaking process culminating in the transfer of arms between states.

The dichotomy between commercial and noncommercial interests is generally (though not perfectly) linked to that of private and public actors. Both types of interests and both types of actors coexist in the arms trade, and their coexistence raises questions about the proper conception of “governance structure” in this particular realm of international relations. Starting with the fairly obvious observation that the global arms trade is not well characterized as a free and open market, I suggest instead that it more closely approximates a social network. There has been considerable debate among economists and sociologists about the circumstances giving rise to hierarchical entities like firms as compared to anarchic entities like markets. I discuss this debate briefly, and consider the distinguishing features of a social network as an intermediate organizational form. I then turn to a social network analysis of the international arms trade and its changing structure from 1950 to 2000.

This empirical investigation is primarily descriptive; that arms suppliers and recipients constitute a social network, as opposed to some other type of social entity, is not a readily

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<sup>1</sup> In addition to Engelbrecht and Hanighen (1934), these are taken from titles by Adams (1990), Klare (1984), Sampson (1977), Pierre (1997), and Hartung (1994). These works share a critical view of the arms trade, although they differ in the degree to which they focus on the commercial motivations of arms manufacturers. The dynamics of military-technological diffusion are examined by Zarzecki (2002).

testable hypothesis. Rather, my empirical study is premised on the network-like features of the weapons trade and proceeds to employ select quantitative methods developed for social network analysis. These allow me to examine various structural dimensions of the arms-transfer system, including their evolution over time. Formally testing propositions concerning the causal processes behind these structural outcomes, or on the impact of network structure on the political-military relations between states, is not my intention here. In this paper I will do no more than posit certain processes and ask whether the structural characteristics of the global arms trade at various points in time seem to be consistent with them.

### **THE ARMS MARKET?**

A market is a social entity that governs transactions between producers and consumers by way of a price mechanism, and economists typically locate pure markets at one end of a range of possible arrangements for the exchange of goods and services. This is the anarchic end. No authority is exercised in a pure market; economic production is governed by prices, which result from individual decisions affecting supply and demand. At the hierarchical end are organized social entities like firms. Within a firm, economic production is governed by an entrepreneur, whether an individual or a collective, who directs the allocation of resources within the organization. One of the questions that has occupied economists is: Under what circumstances do markets give rise to hierarchical organizations as a means of coordinating economic exchange?

The classic treatment of this issue is by Coase (1937, 392), who maintained that “the operation of a market costs something and that, by forming an organization and allowing some

authority (the ‘entrepreneur’) to direct the resources, certain marketing costs are saved.” In contemporary scholarship, these sorts of costs are termed “transaction costs,” and they generally derive from the inefficiencies associated with incomplete information (e.g., Williamson 1981). Some economic transactions involve uncertainties – e.g., about continued access to specialized inputs into the production process – and although these might be handled by entering into contracts, the continual negotiation and renegotiation of contracts is costly. Such transaction costs, at least some of them, can be eliminated if the parties enter into an exchange relationship governed according to the bylaws of a hierarchical organization. Under these circumstances, firms will realize efficiencies not available in the open market and economic production and exchange will become more profitable.

In this paper, I want to focus on the trade in major conventional weapons systems, so it is appropriate to treat states as the primary actors. While it is true that private manufacturers are involved in the production and marketing of weapons systems, I contend that most major arms transfers are, first and often foremost, transactions between states. This is not to deny the importance of profit motives in the arms trade. However, profit and the various other considerations that motivate the participation of both state and nonstate actors in the arms production and transfer system can be treated as inputs into the foreign policymaking process. The decision to participate in the transfer of major weapons systems, as a supplier or a recipient, is typically a decision made by a government, whether on its own behalf or on behalf of its constituents. Of course, this state-as-actor assumption is not reasonable when examining the black market arms trade, where most transfer decisions are made by private actors beyond the scrutiny of governments, or the small arms trade, where governments often elect to adopt a lower

regulatory profile.

Where should we locate the global arms trade on the anarchy-hierarchy continuum? In the international system, states can be treated as the analogues to firms in the market (Waltz 1979). Their internal affairs are organized hierarchically, but sometimes they choose, in their external affairs, to collaborate with others as members of intergovernmental organizations. Such collaboration is initiated with the signing of treaties or charters, which are essentially contracts. Occasionally, states have taken small steps toward vertical integration, whereby certain international organizations are endowed with a degree of supranational authority over their activities in specific functional areas. But no such entities exist today that direct or coordinate the arms transfer policies of supplier states. The closest approximations, both of which seek to set limits on the conventional arms trade, are the Wassenaar Arrangement and the Missile Technology Control Regime (MTCR). However, both agreements bear more resemblance to arm's-length contracts (largely unenforceable) among independent firms than they do hierarchical arrangements in which supranational authority can be exercised over member states' arms-supply decisions. Wassenaar and the MTCR are no different from other arms control agreements in this respect.

The Wassenaar Arrangement was fashioned as a replacement for the Coordinating Committee for Multilateral Export Controls (CoCom), a mechanism established by the United States and its allies to restrict high-technology exports to Soviet bloc. With the end of the cold war, attention shifted to containing the flow of advanced weaponry and military technology to potentially unstable parts of the world, which has typically meant select rogue regimes and conflict-ridden regions. Wassenaar, whose thirty-three member states include most of the



countries once targeted by CoCom, aims at “preventing destabilizing accumulations” of military equipment and technology “by promoting transparency and greater responsibility” in the policies of arms suppliers.<sup>2</sup> Participants have agreed to exchange information on major weapons exports to non-Wassenaar states, as well as the transfer of sensitive dual-use goods and technology. In contrast to CoCom, member states do not have a veto over other members’ transfers of controlled goods, although for the subset of very sensitive items on the technologies list, Wassenaar calls on members to exercise “extreme vigilance” and foresees the coordination of binding national criteria for export control.

Whatever their differences, the logic supporting the Wassenaar Arrangement seems to be similar to the one behind CoCom – what Stein (1983) has called a dilemma of common interests.<sup>3</sup> All suppliers have an interest in curbing the transfer of military technology to the extent that proliferation threatens to “blowback” and chip away at their own national security. However, each supplier profits by exporting weaponry, especially if that state’s defection does not undermine the collaborative restraint exercised by others. Thus, the choice faced by suppliers often takes the form of a prisoner’s dilemma. Yet each supplier’s incentive to free ride creates a collective action problem resulting in Wassenaar’s feared “destabilizing accumulations,” a jointly suboptimal outcome for all suppliers.

It is perhaps useful to understand CoCom and Wassenaar, as well as other current

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<sup>2</sup> See Wassenaar Arrangement on Export Controls for Conventional Arms and Dual-Use Goods and Technologies, “Initial Elements” (adopted in 1996, amended in 1999, 2001 and 2002); available at <<http://www.wassenaar.org/docs/IE96.html>>.

<sup>3</sup> The most thorough political analysis of CoCom in recent years is Mastanduno (1992). For an examination of CoCom in the context of a game theoretic analysis of sanctions regimes, see Martin (1992, chap. 7).

arrangements like the MTCR and the Nuclear Suppliers Group, as collective efforts to deal with transaction costs.<sup>4</sup> When states produce military goods and technology for export, they hope to profit in various ways: politically, by winning friends and allies and possibly gaining some influence over recipients' foreign and military policies; economically, by generating sales revenue for the defense-industrial sector and thus tax revenue for the state; and militarily, by maintaining the health of the defense-industrial base and by solidifying alliances with recipients, if alliances exist. The realization of these gains is uncertain under the best of circumstances, but the uncertainties are magnified in the context of unrestrained competition among arms suppliers for customers. That is, competition among suppliers in the arms market threatens future political, economic, and military "revenue streams," making arms transfers a more uncertain and therefore costly tool for transacting foreign policy.

The creation of export control regimes suggests that states are making efforts to avoid such suboptimal outcomes, but Wassenaar and other arrangements fall considerably short as analogies to the hierarchical firms theorized by economists. Indeed, Lake (1996) locates the NATO alliance, a much more formal security relationship than the Wassenaar Arrangement, at the anarchy end of the continuum. In contrast to empire, an alternative (if rare) means of achieving security, alliances and less formal arrangements are better understood as contracts among independent actors. This does not mean they are always successful in achieving their aims. To be sure, Wassenaar and the MTCR have been widely criticized as inadequate. Dilemmas of common interest are plagued by the same sort of opportunism – or, as Williamson

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<sup>4</sup> Lipson (1999) considers this type of explanation for the creation of the Wassenaar Arrangement, but finds it wanting. On the MTCR, see Mistry (2002).

(1981, 554) puts it, “self-interest seeking with guile” – that undermines contracting among economic agents.

### **THE ARMS-TRANSFER NETWORK**

Lake (1996) has shown that insights from contract theory and the transaction cost approach in economics are helpful for understanding the range of security relationships we find in world politics (see also Lake 1999). Still, arms transfers are examples of security-relevant interstate behavior that are even less organized than the alliance-making Lake places at the anarchy end of his spectrum. Supplier organizations like the Wassenaar Arrangement are few and involve rather weak constraints on member states’ transfer decisions, while organizations structured around the common interests of recipients, or recipients plus suppliers, are nonexistent. On the other hand, such organizations that do exist, as well as the informal coordination of arms-supply policies (especially during the cold war), suggests that the arms trade is not completely anarchic, devoid of a governance mechanism beyond the hidden and spontaneous forces of supply and demand.

Patterns of economic exchange governed by more than market forces but by less than hierarchical organizations have been of considerable interest to sociologists. Granovetter (1985), for instance, has echoed the common criticism of the neoclassical economic approach to organization as offering a utilitarian and “undersocialized” conception of human action in which little allowance is made for the impact of social relations on economic exchange (except as a drag on the efficient allocation of resources). At the same time, early sociological correctives tended to propose “oversocialized” conceptions of behavior whereby individuals simply, and somewhat robotically, internalize societal norms, also leaving little room for the impact of

ongoing social relations (see also Wrong 1961). For Granovetter and others, economic behavior is governed not only by institutional arrangements designed to discourage malfeasance and reduce transaction costs, or by a “generalized morality” instilled through the socialization process, but also by trust. Economic action is embedded in ongoing social interaction and more emphasis needs to be placed on “the role of concrete personal relations and structures (or ‘networks’) of such relations in generating trust and discouraging malfeasance” (Granovetter 1981, 490).

A similar gap seems to exist in the political science literature on international organization. Liberals have criticized realists for failing to see international institutions as more than epiphenomena deriving from the distribution of state power. Instead, taking cues from new institutional economics, liberals see them as “information-providing and transaction cost-reducing entities” (Keohane 1984, 101). Constructivists, in turn, taking cues from the institutionalist approach in sociology, fault liberals (and realists) for neglecting “the production and reproduction of identities and interests” and for assuming that “how states treat each other in interaction does not matter for how they define who they are” (Wendt 1999, 36; see also Finnemore 1996).<sup>5</sup> But to date the focus of constructivist analysis has been on the socialization of states – “states are people too,” Wendt (1999, 215) says – and on the emergence and reinforcement of norms in international society, rather than on relations between states and

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<sup>5</sup> This argument between realists, liberals, and constructivists fills many pages in the international relations literature (too many, I think). For a shortcut through the debate, see Mearsheimer (1994/95) and the follow-on symposium on institutions in the summer 1995 issue of *International Security*.

outcomes that fall short of norm creation and institution building.<sup>6</sup>

In departing from transaction-cost explanations, sociologists who study economic organization are not abandoning the notion of rational action. They are suggesting that social constraints, or “embeddedness,” often makes seemingly nonrational behavior appear quite reasonable. Many economic transactions “aim not only at economic goals but also at sociability, approval, status, and power” (Granovetter 1985, 506). In realm of world politics, those studying the arms production and transfer system have frequently observed that the arms acquisition policies of both developed and developing states don’t always make sense in terms of either military or economic efficiency. The “rationality” of those procurement patterns becomes apparent only when taking into account less material motives like status, prestige, and the symbols of modern statehood (e.g., Kaldor 1981; Suchman and Eyre 1992; Eyre and Suchman 1996; Wendt and Barnett 1993; Kinsella and Chima 2001). And no less an authority than Hans Morgenthau (1985, 86-87), realism’s chief exponent, believed that “prestige, however exaggerated and absurd its uses may have been at times, is as intrinsic an element of the relations between nations as the desire for prestige is of the relations between individuals.”

Inquiry into the role of social relations in the emergence of various forms of economic organization is of fairly recent origin in sociology. But much of the research that has been done on interpersonal relations in economic life focuses on the creation and maintenance of social networks. Less anarchic than markets, networks of economic actors are at the same time not

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<sup>6</sup> The individualist orientation of the realist and liberal traditions in international relations theory probably guards against any tendency that constructivists might have to adopt an oversocialized conception of state action. Constructivists’ preoccupation with norms, institutions, and identity formation, instead of interstate relationships, is perhaps temporary – due less to the ontology of constructivism than to its newness to the field.

hierarchically organized. Where price serves as a control mechanism in markets and authority serves that function within a vertically integrated firm, personal relationships, typically characterized by trust and a norm of reciprocity, are the glue that binds a social network together. It may well be that, under conditions conducive to social networks, hierarchically organized social entities are not required as a means of reducing uncertainty and managing transaction costs, but from a sociological point of view that begs some important questions. What are those conditions? To what extent can they be explained by the social, cultural, and political practices that embed economic interaction? Alternatively, to what extent can they be explained by the nature of particular forms of economic exchange?

Powell (1990) addresses the last of these questions, maintaining that some forms of exchange are inherently more social than others. They depend not so much on formal authority, but on shared interests and ongoing relationships. In network forms of exchange, “the entangling of obligation and reputation reaches a point that the actions of the parties are interdependent.” The pattern of interaction “looks more like a marriage than a one-night stand, but there is no marriage license, no common household, no pooling of assets” (Powell 1990, 301). Whereas market transactions are undertaken to maximize returns in the short and medium term, network exchanges are sequential and contribute to an overall pattern of enduring interaction. Much of what is exchanged in social networks is difficult to price – know-how and styles of production, for example – so the flow of information through networks is often “richer” than what is transmitted by the price mechanism in markets or by controlled channels of communication within a vertically integrated firm. Finally, because the mechanism of governance rests largely on trust and obligation, network forms of organization function well when composed of

homogenous groups of actors. The opportunism and guile contributing to high transaction costs in the impersonal market setting is less common among those sharing professional, ethnic, or ideological backgrounds, and thus hierarchical governance structures are less likely to emerge.

The arms trade is characterized by some of the same features found in network forms of economic organization. Decisions to supply and purchase weaponry are often elements in ongoing arms-transfer relationships, which are sometimes part of more general military relationships. The supply of finished weapons systems can be accompanied by instruction in the operation and maintenance of equipment, construction of support facilities, and other forms of technical assistance. Arms transfers are, in many instances, embedded in relationships of mutual defense – e.g., weapons flows between members of formal military alliances like NATO – or in less formal commitments by suppliers to the security of recipient states. Those more general military relations, whether formal or implied, may also involve basing and overflight rights, military training and joint exercises, the coordination of strategy and tactics, the sharing of military intelligence, and other forms of collaboration intended to enhance the security of both parties to the transaction. While particular arms-transfer agreements may take the form of arms-length contracts, much of their meaning is lost if they are extracted from this “social context.” Instead of contracts, they may actually resemble long-term investments in mutually beneficial interstate relationships.

Consistent with Powell’s (1990) description of exchanges within networks, it is difficult to attach a value to the political and military commitments that often accompany arms transfers between states. In addition to interstate commitments, weapons supplies embody the transfer of military technology, and many deals include arrangements for the licensed production of military

equipment by the recipient. This flow of technology and know-how between states, which is also hard to price, is an important feature of the contemporary arms trade and has had a measurable impact on the emergence of a “third tier” of arms producers in the international system (Krause 1992; Bitzinger 1994; Kinsella 2000). Thus, the information and meaning embodied in arms transfers can be substantially richer than what might be indicated by the market or military-use value of the weapons themselves.<sup>7</sup>

Much more is involved in these transactions than a shipment of some increment of destructive capability from one to another state. Because arms transfers are indicative of the supplier’s commitment to the recipient’s security, as well as the recipient’s expectation (perhaps backed up with certain concessions) that it can count on this commitment into the future, the most significant and enduring arms-transfer relationships link states with congruent foreign policy orientations. During the cold war, for instance, the United States and its allies tended to supply arms to states whose policies were generally in accord with the global political-economic status quo, while the Soviet Union and its allies tended to supply dissatisfied or revisionist states (Kinsella 1994). There was, then, in the arms-transfer network a certain homogeneity among states with the closest and most dependable ties. Such shared foreign policy orientations are not unlike the shared backgrounds (professional, ethnic, religious) that help sustain social networks comprised of individuals.

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<sup>7</sup> A major issue when it comes to documenting and quantifying the arms transfers between states is how to attach values to, say, yearly aggregates. Generally, collectors and distributors of arms-transfer data, like the Stockholm International Peace Research Institute and the former Arms Control and Disarmament Agency, try to assess the market value of transferred weapons based on their military performance characteristics – that is, their “military-use value.” For a discussion of SIPRI’s methodology, see Brzoska and Ohlson (1987).



Of course, not all arms transfers between states are of this sort, so thick with meaning. Many do resemble market transactions in which little more is involved than the sale of military hardware by one state to another. It is also the case that the degree to which the global arms trade is characterized by the types of relationships and exchanges found in network forms of organization is changing over time. For example, a reasonable working hypothesis is that the cold war arms trade displayed relatively strong network characteristics, and that the post-cold war period has seen a “marketization” of the arms trade in which interstate relationships are gradually becoming less important as a mechanism governing the global proliferation of weapons and military technology. This suggests that the control mechanisms normally associated with networks and markets (and firms) can in fact be intermixed. Bradach and Eccles (1989) identify the business franchise as one such “plural form” of economic organization. They argue that in order to understand plural forms, “the analytic focus must be moved away from exclusive attention to individual transactions; instead, the dynamics of whole structures must be examined since the transactional context affects the control that can be brought to bear on individual transactions” (Bradach and Eccles 1989, 116).

Whatever the precise organizational form of the global arms trade, I believe that it incorporates many of the key characteristics of a social network. In the next section, I employ some of the quantitative methods used in social network analysis to describe its structural features at various points since the end of World War II.

## **SOCIAL NETWORK ANALYSIS**

The focus of social network analysis (SNA) is less on the attributes or behavior of actors than it

is on the structural dimensions of their social environment, which are distilled from the overall pattern of relationships or exchanges among the actors. The “social network” itself is defined as the group of actors and the relationships or interactions that link them, and SNA methods are applied once it is assumed (or demonstrated) that a group of actors constitutes a network. That is, SNA is not a means of distinguishing networks from other forms of social organization, like anarchical or hierarchical forms, nor does it provide a way to assess how “networky” a given social grouping is or is not. The premise of SNA is that the organization of a set of interrelated actors bears some resemblance to a social network and that it is therefore useful to examine its structural features.<sup>8</sup>

For my purposes, the unit of analysis is the arms-transfer relationship connecting two states. States, then, are the *actors* in the network and the existence of a relational *tie* or *link* is indicated by whether one state in the dyad supplied weapons to the other state. An arms transfer is a *directed* tie in that it represents the flow of military resources from one actor to another. Such directional information is not always relevant for an analysis of interstate military relationships; arms flows may be simply an indicator of more general and mutually beneficial security ties between a supplier and a recipient.<sup>9</sup> However, in this study, if a state is neither a supplier nor a recipient of arms transfers, then it remains outside the network. For any given year, the data analyzed consists of a square “sociomatrix” in which there is both a row and a

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<sup>8</sup> The most authoritative and comprehensive guide to the methods of social network analysis is probably Wasserman and Faust (1994). For a briefer overview, see Scott (2000).

<sup>9</sup> Some SNA methods are adapted from graph theory in mathematics, so networks are often referred to as graphs consisting of nodes or vertices (actors) and lines or edges (ties). See Barnes and Harary (1983) and Harary, Norman, and Cartwright (1965).

column for each actor in the network. A cell in the matrix contains a 1 if the state represented by row  $i$ , designated  $n_i$ , transferred arms to the state in column  $j$ , designated  $n_j$ , in which case  $x_{ij} = 1$ ; otherwise  $x_{ij} = 0$ . The main diagonal of the sociomatrix, where  $i = j$ , is ignored.<sup>10</sup> The presence or absence of an arms-transfer relationship is based on data collected by the Stockholm International Peace Research Institute, which is released annually in the institute's yearbook, *Armaments, Disarmament and International Security*.

The next sections present some descriptive results from an analysis of the arms-trade network from 1950 to 2000. They give a sense of the changing structural features of the network, like its density and degree of centralization, as well as the structural positioning of the most important arms suppliers.

### *Network Density*

Social networks are dense to the extent that there are many social ties between many actors. A dense arms trade network is one in which there are many suppliers and recipients, and in which the typical supplier has a large number of clients while the typical recipient has a large number of patrons. In fact, the arms trade network is not especially dense, mainly because there are relatively few suppliers. The *outdegree* of state  $i$ ,  $d_o(n_i)$ , is the number of other states to which  $n_i$  has transferred arms in a particular year; *indegree*,  $d_i(n_j)$ , is the total number of states supplying arms to  $n_j$ . That is,

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<sup>10</sup> There are SNA procedures that work with valued data – in the present context, for example, the total dollar equivalent of arms transferred between states – but my analysis is based only on binary data indicating the presence or absence of an arms transfer in a particular year. Some more elaborate techniques, including some statistical estimators, make use of information about the attributes of actors as well as their ties. See Wasserman and Faust (1994, chaps. 10 and 15).

$$d_o(n_i) = \sum_{j=1}^g x_{ij} \quad \text{and} \quad d_r(n_j) = \sum_{i=1}^g x_{ji} ,$$

which are, respectively, the row  $i$  and column  $j$  totals of the sociomatrix. If there are  $g$  states in the network, the maximum number of directed ties between states is  $g(g-1)$ . A measure of the *density*,  $\Delta$ , of the network is the sum of all outdegrees plus the sum of all indegrees (they are equal) as a proportion of all possible directed ties:

$$\Delta = \frac{\sum_{i=1}^g d_o(n_i) + \sum_{j=1}^g d_r(n_j)}{g(g-1)} .$$

Network density ranges from 0 to 1, but since I do not include states that are neither suppliers nor recipients,  $\Delta > 0$  because the numerator will always be at least  $g-1$ . In the arms trade network, density never even approaches the maximum, which would mean that every state supplied and received arms from every other state (a “complete” network or graph).

Figure 1 shows the density of the arms trade network over time. Density gradually declined from 1950 until the mid-1970s due to the addition of new actors to the network – i.e., recipient states, some newly independent, but with too few arms-transfer ties to keep the overall density of the network constant. From the latter half of the 1970s until the end of the cold war, the density of the network gradually increased. There were relatively few additions to the society of states during this period, so the development of arms-trade ties within the network outpaced the expansion of network membership. In the decade since the end of the cold war, network density seems have leveled off. There was been an increase in network membership in the first half of the 1990s, mainly due to the dismantlement of the Soviet Union and Yugoslavia, but most

new states have entered into arms-transfer relationships at a rate that has kept the density of the network fairly stable.

[Figure 1 about here]

### *Supplier Centrality and Network Centralization*

In most social networks, certain actors are more prominent than others, maybe because they are elites, and the evidence of their prominence is often the number and type of social ties they maintain with other actors. In the arms trade network, the leading arms suppliers occupy such positions of prominence. The *centrality* of a network actor is sometimes indexed as its outdegree or indegree (or both), but since these measures are greatly affected by the number of actors in a network, it is useful to normalize the index, especially for purposes of cross-temporal comparison. Thus, a normalized centrality index for arms suppliers,  $C'(n_i)$ , can be computed as

$$C'(n_i) = \frac{d_o(n_i)}{g-1} .$$

If a state supplied weapons to every other state in the network, it would have a centrality measure of 1. A centrality index for recipients would be computed similarly, except that indegree,  $d_i(n_j)$ , would be used in the numerator.

The idea of centrality can also be generalized to an entire network. A more centralized arms-trade network is one in which there are relatively few suppliers of relatively high centrality. A centralized network can also be conceived as one with few actors with high indegree centralities, but to the extent the arms trade network has become more or less centralized over time, it is due to the centrality of suppliers, not recipients. For arms suppliers, an index of

network *centralization* starts with the deviation between each actor's outdegree, or number of clients, and the outdegree of the supplier with the largest number of clients (which, for the 1950-2000 period, is always the United States). This deviation is summed over all actors and expressed relative to the sum of deviations that is the maximum possible for a network of  $g$  actors:

$$C = \frac{\sum_{i=1}^g [d_o(n^{\max}) - d_o(n_i)]}{(g-1)^2},$$

If all actors were suppliers with similar centrality measures, the centralization index would be close to 0; when a single supplier dominates the network, the index is close to 1.

Figure 2 consists of diagrams of the arms trade network at four points since the end of World War II: 1955, 1970, 1985, and 2000. In each diagram, each state is displayed in concentric rings corresponding to its centrality as an arms supplier. Most states are not arms suppliers, of course, so they appear around the perimeter of the graphs. In all four years, and indeed throughout the entire period, the United States has been the supplier with the highest centrality measure, so it appears in the center of each graph. The lines connecting the nodes of the graph indicate the presence of an arms-transfer relationship during the year, so the diagrams also give a sense of the changing density of the network over time. Of the four years drawn, the arms trade network was densest in 1985, although as suggested by Figure 1, it would become denser still in some of the cold war's remaining years.

[Figures 2a, 2b, 2c, and 2d about here]

Another pattern apparent from Figure 2 is that over time other suppliers have moved

closer to the center. Throughout the period, Britain consistently has been a fairly central supplier, but it is France that has come closest to rivaling the United States. Russia, of course, was the main ideological alternative to the Western arms suppliers, and in terms of the volume of its arms supplies, it really did rival the United States. But in terms of the number of states with whom it maintained arms-transfer relationships, it has been somewhat less central than France, at least since the late 1960s, and more on par with Britain and, in recent years, Germany. The diagrams also show the emergence of lesser second- and third-tier arms suppliers closer to the perimeter of the graphs.

“Centralization” is perhaps not the best term to use for a measure of the degree to which a network is dominated by central actors, because it suggests that the centrality of a core group (or single actor) is increasing over time. This is clearly not the case in the arms trade network, as can be seen in Figure 3. Since 1950, there has been a steady *decentralization* of the arms trade in regard to suppliers, while among recipients the degree of centralization has remained rather stable. The decentralization of the network as a whole mirrors the declining centrality of the United States, which follows the same downward trend over time. (The time series for U.S. centrality is not shown in the figure.) This trend stands in contrast to the impression given by volume of U.S. arms exports over the past two decades, which has remained pretty stable, and especially the impression given by the U.S. share of world arms exports, which has increased substantially. Decentralization of the arms trade has thus provided a social context for attempts by the United States and other suppliers to use arms transfers to influence client states. It suggests that the increasing presence of other centrally positioned suppliers may continue to check the leverage once exercised by the most prominent actors in the network (Catrina 1988;

Sislin 1994; Kinsella 1998).

[Figure 3 about here]

### *Structural Equivalence Among Suppliers*

The ongoing decentralization of the arms trade network raises other questions about the positions of leading suppliers. A “position” in a social network is understood as a particular set of relations with particular groupings of actors. Two or more actors who occupy similar positions in the network have similar relations with those groupings. Two or more actors are *structurally equivalent* if they have exactly the same ties to all other actors in the network. Rarely are actors structurally equivalent, except in trivial ways, so the task for SNA is to determine how close actors’ positions are to one another.

The Euclidean distance between actors  $i$  and  $j$ ,  $d_{ij}$ , is measured based on the presence or absence of relations with all other actors in the network. This distance can be computed with respect to either directed or undirected ties, but my interest here is directed ties – i.e., arms supplies from  $i$  and  $j$  to the  $g - 2$  other states. Therefore,

$$d_{ij} = \sqrt{\sum_{k=1}^{g-2} (x_{ik} - x_{jk})^2}$$

for  $i \neq k$  and  $j \neq k$ . This is simply the total difference between row  $i$  and row  $j$  of the sociomatrix. For structurally equivalent actors,  $d_{ij} = 0$ , and for all other pairs,  $d_{ij} > 0$ . The maximum Euclidean distance between a pair of actors, occurring when the pair has different ties to all  $g - 2$  other actors, is  $\sqrt{2(g - 2)}$ . The pairwise distances between arms suppliers is used to construct a symmetric  $g \times g$  matrix,  $\mathbf{D} = \{d_{ij}\}$ , and this new distance matrix becomes the raw data for a



“map” of the arms trade network in two-dimensional space. For purposes of visualization, the distances between the actors on this map should correspond as closely as possible to the Euclidean distances in  $\mathbf{D}$ , and to that end multidimensional scaling (MDS) can be employed to obtain each actor’s coordinates in two dimensions from the distance matrix.

[Figures 4a, 4b, 4c, and 4d about here]

Figure 4 shows the network maps for the years 1955, 1970, 1985, and 2000. All four of the maps include a large clump of states near the intersection of the two axes, which represents these states’ network positions as arms recipients and not suppliers. As can be seen from the 1955 map, far from that position, and far from each other, are the United States and Britain. No other arms suppliers had significant numbers of clients, so they remain relatively close to the origin. Compared to the other suppliers, the U.S. and Britain supplied a large number of states, but mainly different states, which accounts for structural dissimilarity. By 1970, the network’s supplier structure had changed significantly. Now the greatest distance is found between the two superpowers, with France and Britain occupying similar middling positions between them. Other Western suppliers are still rather close to the origin, given that the Western arms trade was dominated by the U.S., Britain, and France. Within the other cold war bloc, Czechoslovakia by this time emerged as a significant arms supplier, although still some distance from Russia. It is apparent from this mapping that the scaling procedure has positioned suppliers with more clients farther from the origin, while those with overlapping client lists are positioned along the same radial.

There is no radical change in this basic supplier structure by 1985, shortly before the cold war began to unravel. However, France had come to occupy a more central position in the

network, still midway between the superpowers, while Britain's position had gravitated closer to the American radial, suggesting an increased similarity in their client bases. Since the end of the cold war, a more pronounced structural shift has taken place. The greatest positional distance remains that between the former cold war rivals, an indication of the endurance of cold war arms-transfer relationships. But now most other major arms suppliers are arrayed, somewhat loosely, around the same radial along with the United States. The U.S. still transfers weapons to many more states, but many recipients of American arms are also importing arms from European and other suppliers.

These findings seem to reinforce and amplify what is implied by the general pattern of network decentralization. The structure of the contemporary arms trade allows for a good deal more competition among suppliers than is suggested by the huge share of global arms exports currently coming from the United States. Several other major suppliers now maintain arms-transfer relationships with a largely overlapping set of recipient states. The supply of weaponry tends to signal more than an arms-length market transaction between supplier and recipient, so the potential exists for increased arms flows through the network's existing channels. At the same time, the strong ideological element characterizing many of the relationships established and maintained during the cold war has vanished. Consequently, the economic motives behind states' arms-supply policies have gained in relative importance. The global arms trade will retain key properties of a social network, but its changing structure may also provide for a smoother functioning of the price mechanism in both the production and transfer of weaponry. One of several pressing questions for future research is: how far will marketization proceed?

## CONCLUSION

Network forms of organization are nonanarchical and nonhierarchical. Relations among actors in networks are guided by mechanisms of “governance without government,” and such mechanisms are manifest in many realms of international and transnational relations (e.g., Rosenau and Czempiel 1992). I have argued that the global arms trade should be understood not as a market but as a network, one that shares some important properties with networked forms of organization studied by sociologists. The sociological approach to world politics, constructivism, despite being broadly compatible with research on the network dynamics in the relations between states, has generally focused on grander themes like state identity formation. In this paper, I restrict my attention to arms-transfer relations between states, and employ quantitative methods developed for social network analysis in an effort to describe the changing structure of the arms trade network since the end of World War II. Structural analysis, by whatever method, is essential for a fully developed sociological approach to international relations theory and research.

The structure of the arms trade network has changed significantly over the past fifty years. It became less dense in the early years of the cold war as newly independent states joined the society of states, but had yet to develop many arms-transfer ties. But from the early 1970s, the network got denser as arms-transfer relations developed among a roughly constant number of actors. The density of the network seems to have stabilized somewhat since the end of the cold war. Over the entire fifty-year period, the supplier structure of the arms trade has become progressively less centralized, even though the United States remains the most central arms supplier. This decentralization is evident from the patterns of arms-transfer relationships in the

network, not from aggregate amounts of weapons transferred by the United States and other suppliers, which paint a quite different picture (one of greater U.S. predominance). Mapping the positions of arms suppliers in two-dimensional space sheds some more light on structural changes within the network. Aside from Russia, which maintains several arms-transfer relationships established during the cold war, the leading arms suppliers share an expanding set of common clients. Many analysts of the arms trade have commented on the increasing competition among arms suppliers in the post-cold war era, and the evolving structure of the arms trade seems conducive to further marketization.

Barabási and Bonabeau (2003) have observed the ubiquity of networks in physical, biological, and social systems, and they point out that many of these networks have “scale-free” structures (see also Barabási 2002). In contrast to random networks, in which links or social ties are distributed randomly across the nodes, scale-free networks consist of some nodes with large numbers of connections and many others with very few connections. The arms trade network is also scale-free; the global pattern of arms-transfer relationships looks less like an evenly dispersed interstate highway system and more like an airline routing system anchored by well-connected hubs. As in other scale-free networks, arms-transfer ties at any given time do not have a symmetric distribution, like a bell-shaped curve, but are highly skewed in the form of a “power law” distribution.<sup>11</sup> Barabási and Bonabeau (2003, 64-65) note that power law distributions are driven in part by processes of “preferential attachment,” and can be found in such diverse

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<sup>11</sup> I have confirmed this by fitting power-law curves to the annual frequency distributions of arms-transfer ties (both directions). For every year from 1950 to 2000, the estimated curve parameters are statistically significant and the models explain between 64 and 88 percent of the variation from the mean number of ties. These results are available on request.

assemblages as co-starring roles in movies, Internet router connections, biotechnology alliance partners, and citations in the scientific literature.

This structural property of the arms trade network may have implications for research on the transfer of light weapons and military-related contraband by nonstate actors. Mapping the small arms trade is hampered by the secrecy with which many deals are concluded and the shadiness of some of the actors involved. The analysis of network dynamics often requires fairly complete information about the network's nodes, especially if an aim of the analysis is to identify network vulnerabilities. If the lack of available information makes it necessary to restrict analysis to a sampled data, important elements of the network structure may be missed. This danger is less pronounced when examining scale-free networks because even incomplete information is likely to identify the most prominent nodes. Since there is reason to believe that the black- and grey-market arms trade is scale-free like the trade in major weapons, the fact that much of it remains hidden from view need not prevent us from mapping its basic structure. This should come as good news to scholars and activists who are increasingly shifting their attention to the scourge of light weapons.

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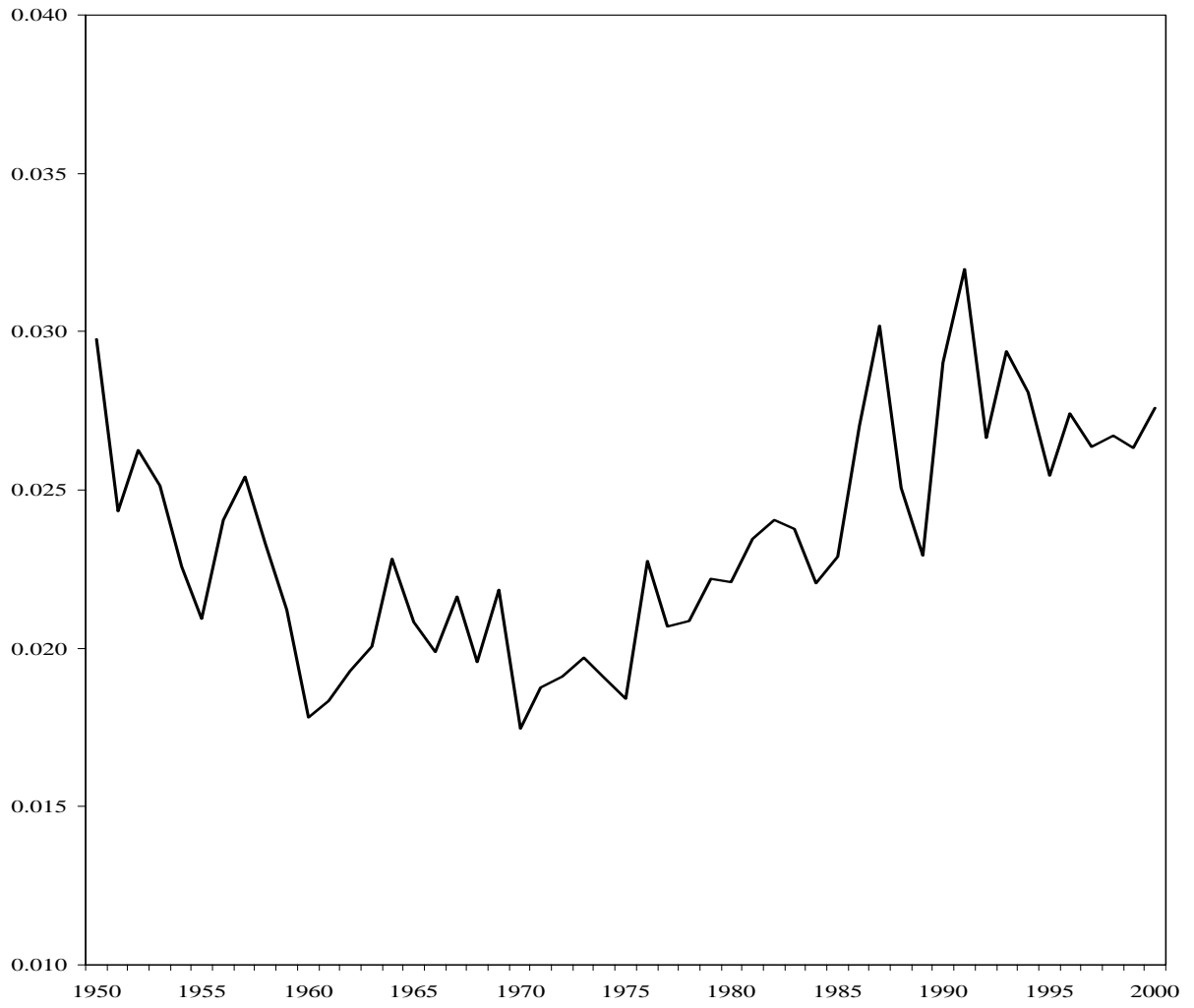
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**Figure 1:** Density of the Arms-Trade Network, 1950-2000

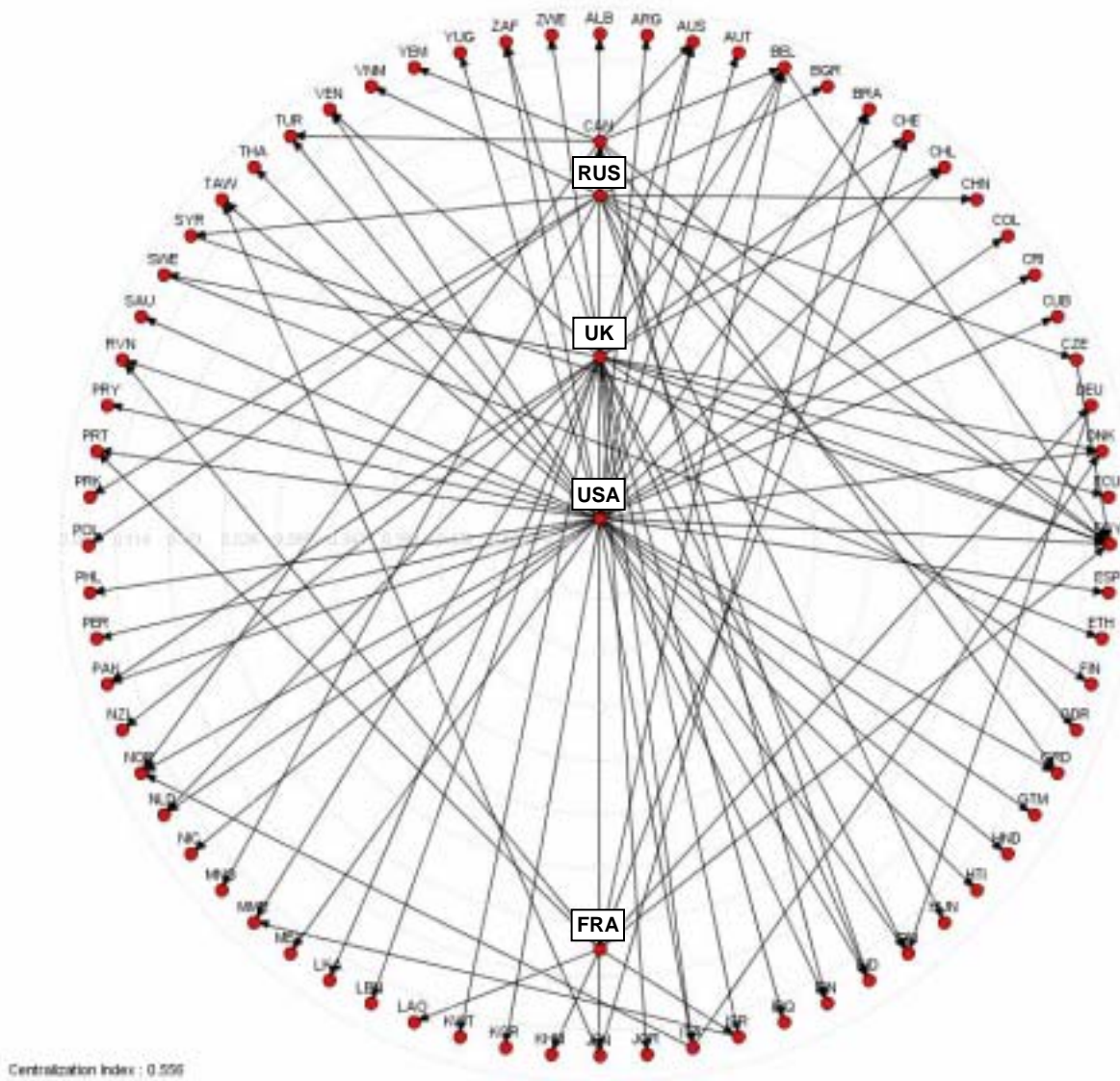
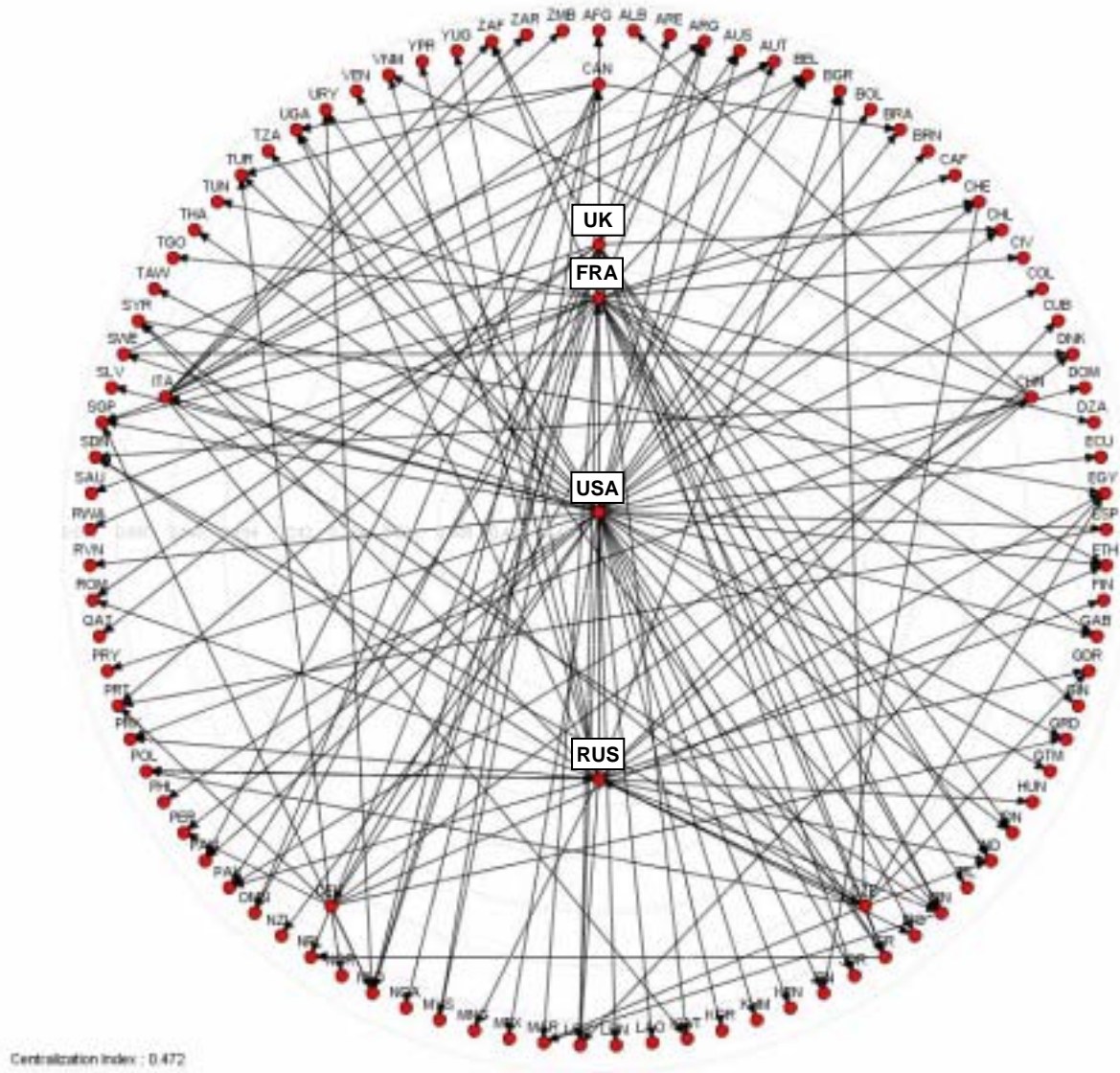
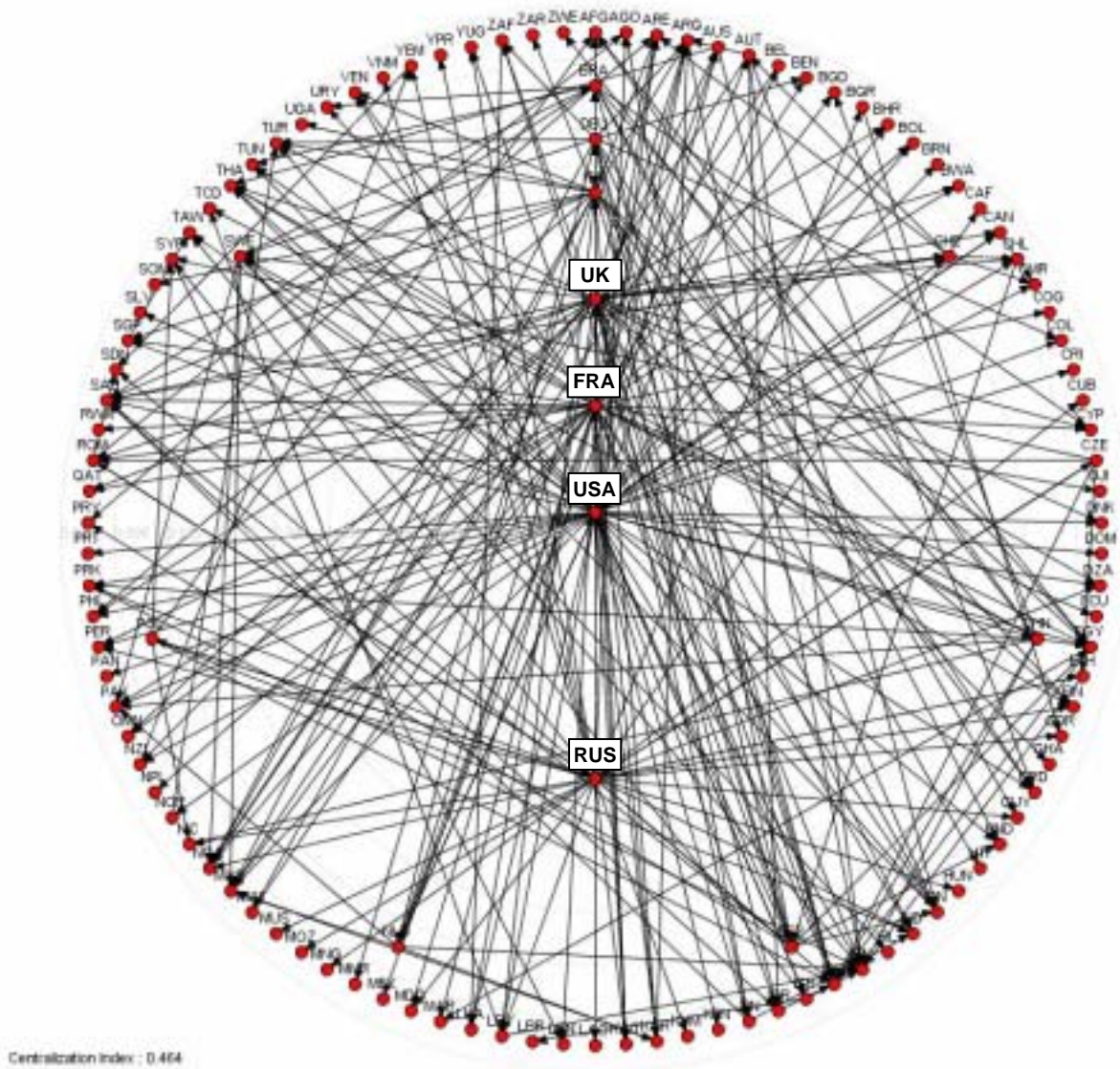


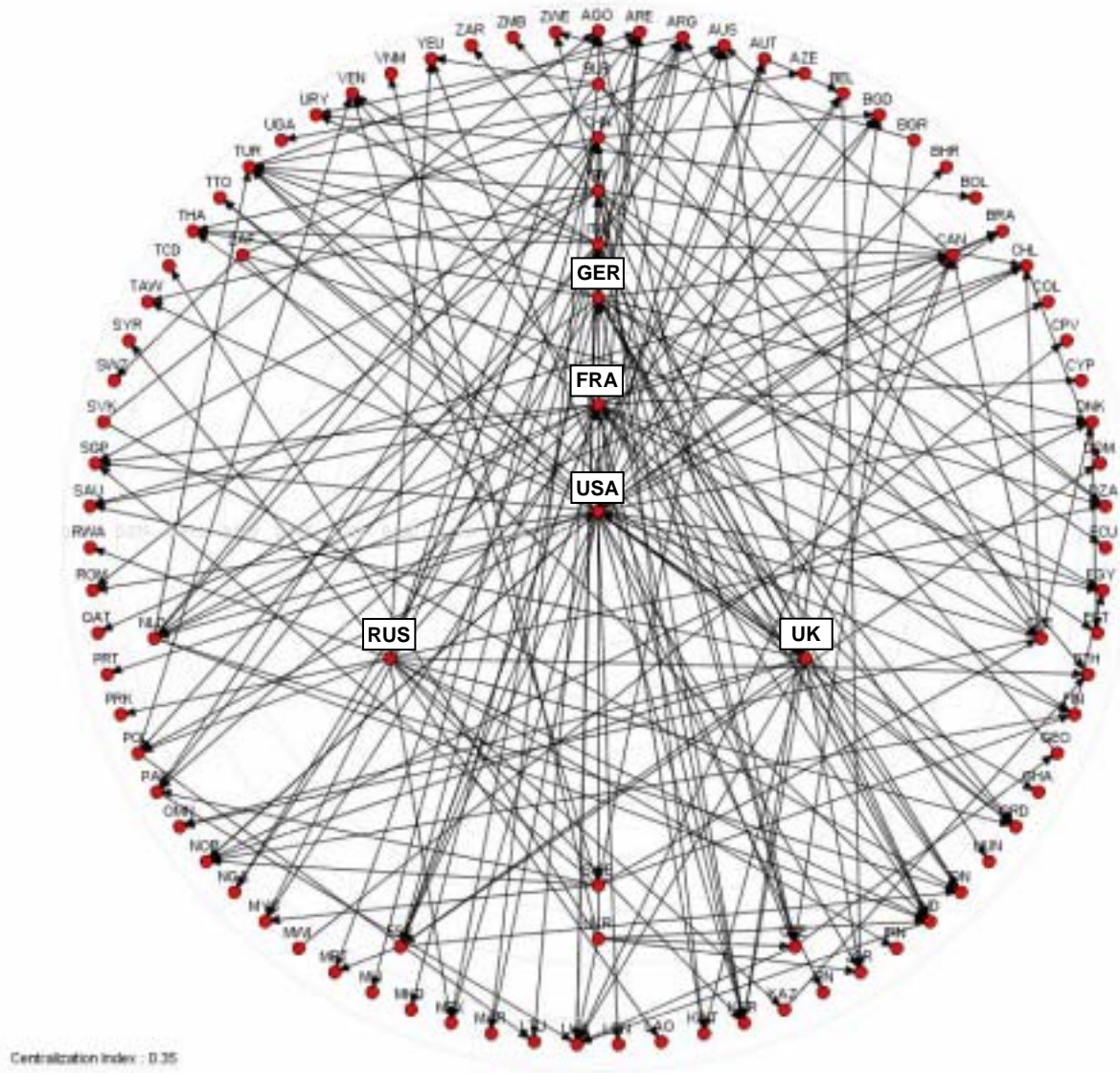
Figure 2a: Supplier Centrality, 1955



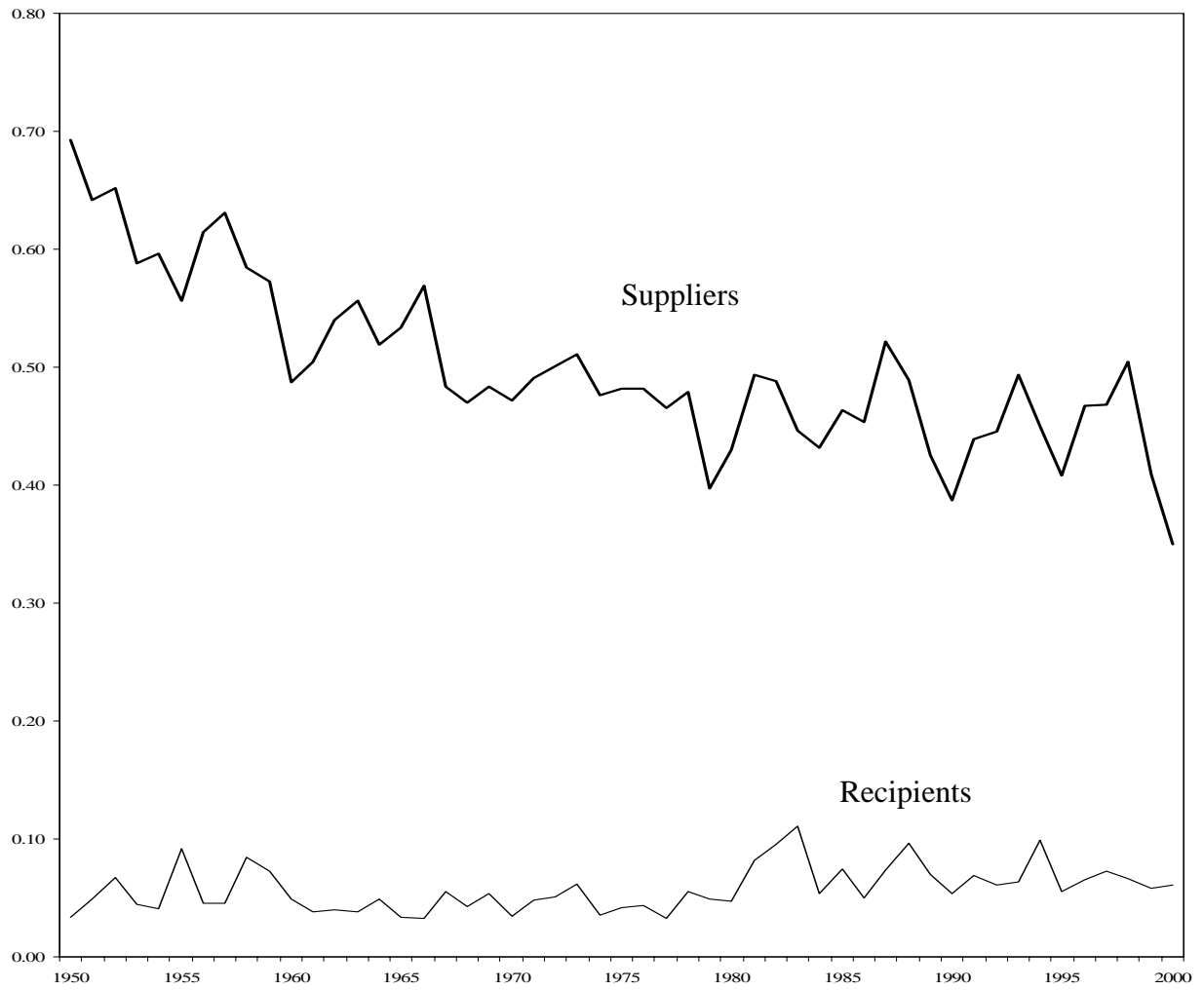
**Figure 2b:** Supplier Centrality, 1970



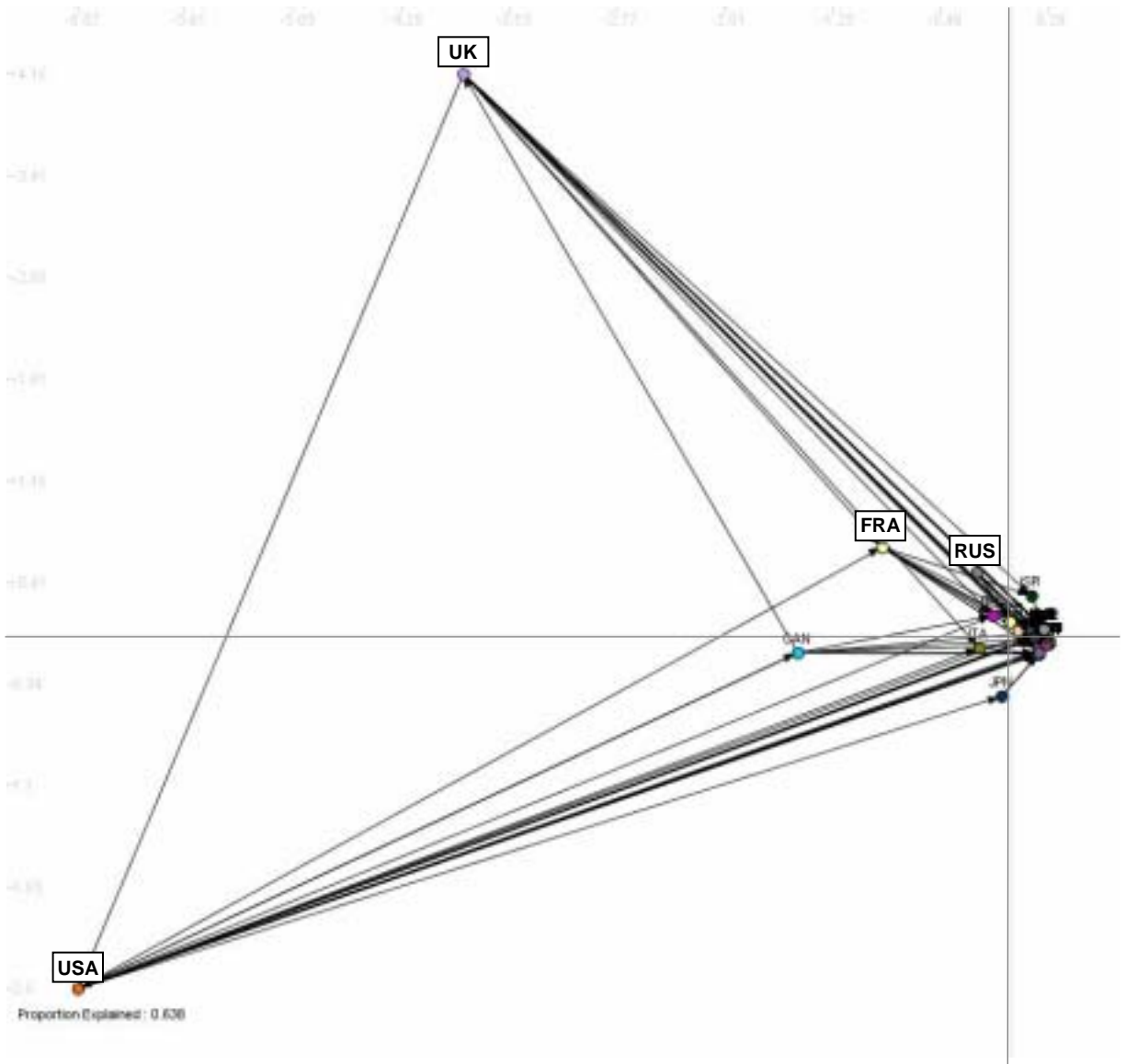
**Figure 2c:** Supplier Centrality, 1985



**Figure 2d:** Supplier Centrality, 2000

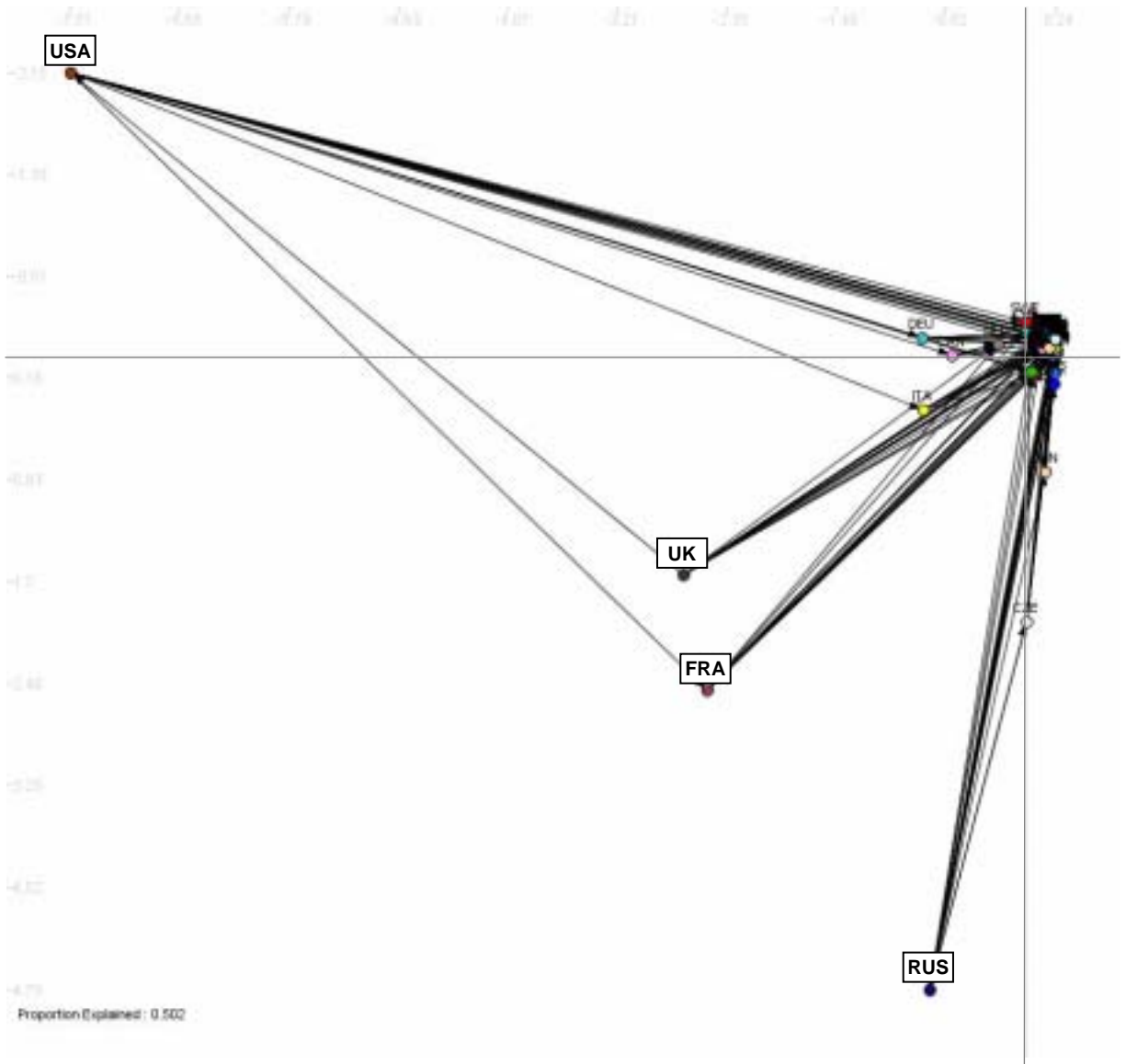


**Figure 3:** Supplier Decentralization in the Arms-Trade Network, 1950-2000

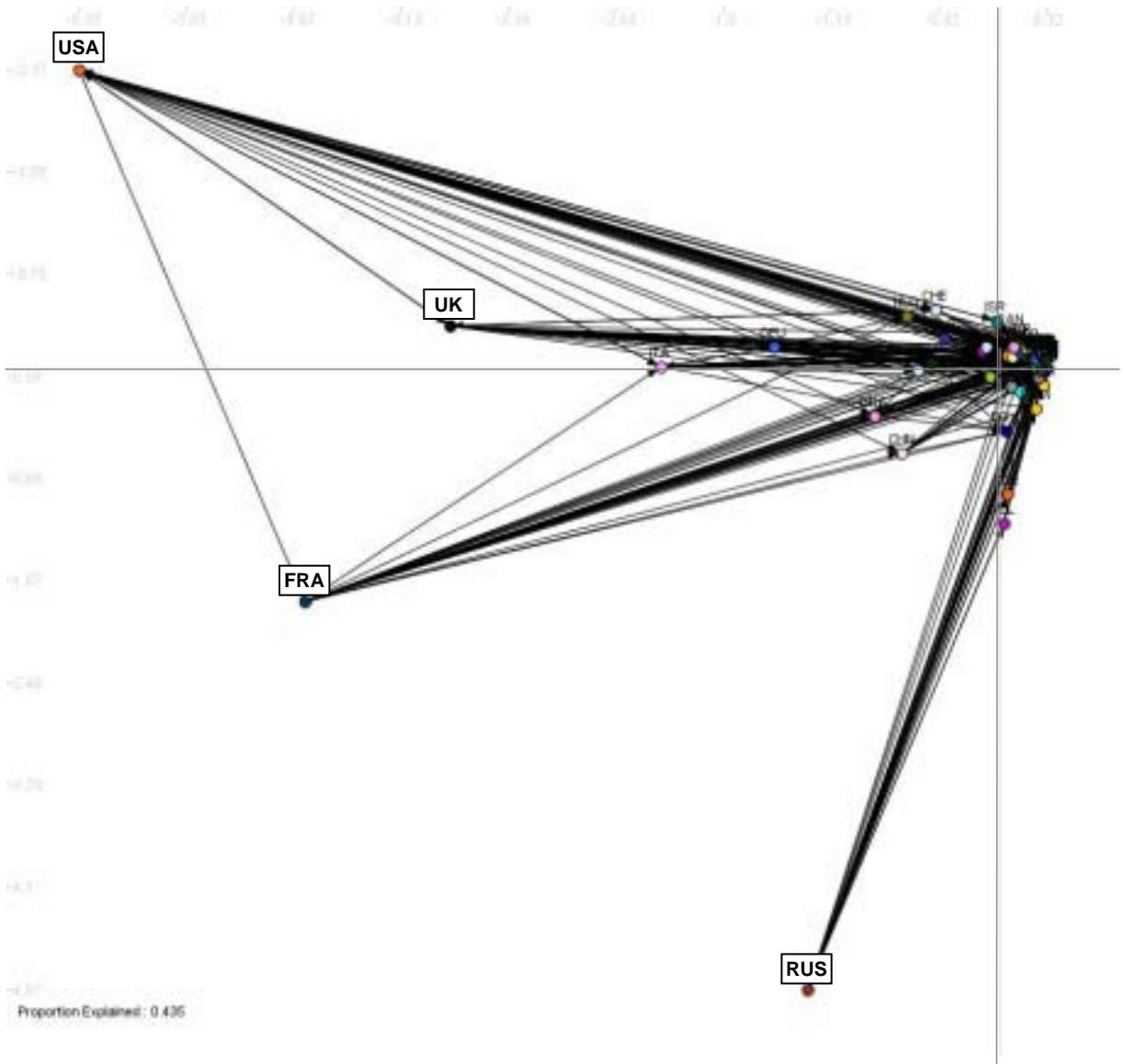


**Figure 4a:** Structural Positions of Suppliers, 1955

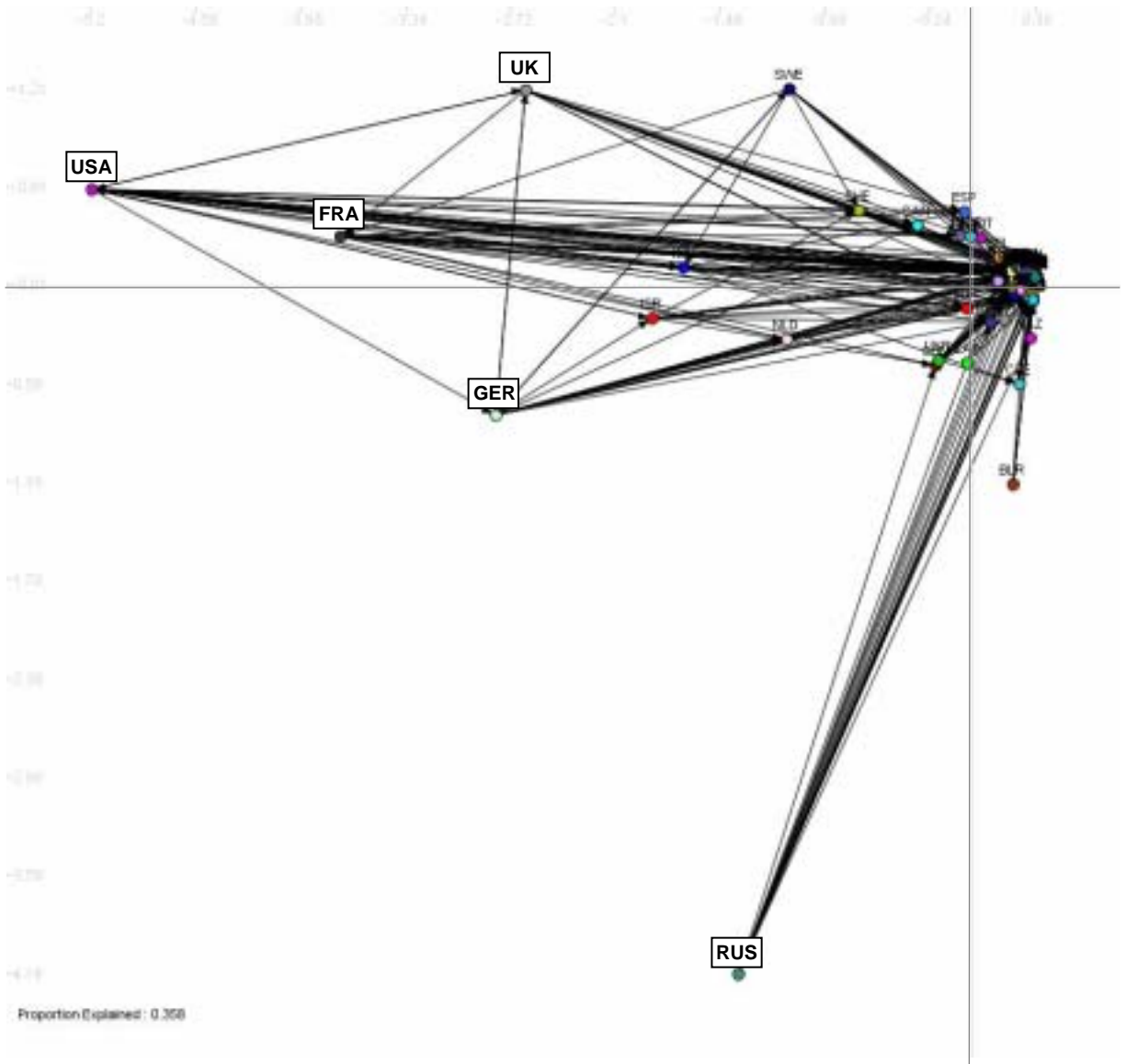




**Figure 4b:** Structural Positions of Suppliers, 1970



**Figure 4c:** Structural Positions of Suppliers, 1985



**Figure 4d:** Structural Positions of Suppliers, 2000