

# **GLOBAL ARMS TRANSFERS AND REGIONAL SECURITY COMPLEXES: SOME TIME-SERIES EVIDENCE**

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## *Abstract*

This paper discusses the enduring forces driving the global diffusion of military capability, whether during the cold war or other historical periods, and then considers the competitive dynamics characteristic of the superpower rivalry itself. I argue that the working of the so-called technological imperative along with loosely coupled action-reaction dynamics lead us to expect certain patterns in quantitative data representing arms-transfer levels over time. Concepts in time-series analysis – cointegration and error-correction – are helpful for an understanding of cold-war arms transfers, and very possibly the contemporary arms trade as well. I apply the relevant analytical tools in an effort to discern the hypothesized patterns in the empirical data. American and Russian, as well as NATO and Warsaw Pact, arms transfers are examined at three levels of regional aggregation: the Third World as a whole, the Middle East security complex, and the Persian Gulf subcomplex. There is considerable evidence that the arms-supply policies of the cold-war rivals moved together over time, both driven by the imperatives of military-technological advance as well as by their global rivalry, and that one or both sides adjusted their supply policies to correct for deviations from a moving equilibrium. This describes an action-reaction process, but a loosely coupled one deriving from the complexities of regional security dynamics and the multi-regional character of the cold war competition.

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## **GLOBAL ARMS TRANSFERS AND REGIONAL SECURITY COMPLEXES: SOME TIME-SERIES EVIDENCE**

The end of the cold war rivalry witnessed a substantial drop-off in the export of weapons worldwide. Much of the decline was due to the collapse of the Soviet Union, but recently Russia has been displaying its military hardware for potential foreign purchasers, signaling an interest in resuming its former role as one of the world's two preeminent arms exporters. Although the superpowers once evenly split about three-fourths of the global arms trade, the United States by itself now accounts for half of it, while Russia's share is less than 10 percent. Will we see, as a consequence of the former superpower's desire to get back into the game, a resumption of the global competition in American and Russian arms transfers? Were there indeed consistently competitive dynamics in the arms-supply policies of the two superpowers and their respective cold war alliances? How intense were these competitive dynamics, and how widespread?

This paper offers answers to some of the above questions and, as usual, raises others. Competitive dynamics in cold-war arms transfers have been little studied but roundly condemned. They were condemned for being driven more by the interests of the superpowers themselves than by the interests of arms recipients, particularly in the Third World where the supplied weaponry was most often put to use. Even though I don't question this indictment, here I will focus specifically on the different dimensions of this arms-transfer competition, and not on the implications for regional security (or insecurity) in the Third World (on the latter, see Kinsella 1994, 1995; Kinsella and Tilemma 1995).

The first half of the paper discusses the enduring forces driving the global diffusion of military capability, whether during the cold war or other historical periods, and then considers the competitive dynamics characteristic of the superpower rivalry itself. Drawing on some key insights found in the literature on the evolution of the global arms production and transfer system, I argue that the working of the so-called technological imperative along with loosely coupled action-reaction dynamics lead us to expect certain patterns in quantitative data representing arms-transfer levels over time. I want to suggest that concepts in time-series analysis – cointegration and error-correction – are helpful for an understanding of cold-war arms transfers, and very possibly the contemporary arms trade as well. In the second half of the paper, I apply the relevant analytical tools in an effort to discern the hypothesized patterns in the empirical data. American and Russian, as well as NATO and Warsaw Pact, arms transfers are examined at three levels of regional aggregation: the Third World as a whole, the Middle East security complex, and the Persian Gulf subcomplex. The results are mixed, but there is considerable evidence that the arms-supply policies of the cold-war rivals moved together over time, both of them driven by the imperatives of military-technological advance and by their global rivalry, and that one or both sides adjusted their supply policies to correct for deviations from a moving equilibrium. This describes an action-reaction process, but a loosely coupled one deriving from the complexities of regional security dynamics and the multi-regional character of the cold war competition.

## DIFFUSION OF MILITARY CAPABILITY

The primary means by which military capability diffuses throughout the international system is the arms trade. Although the transfer of weapons, as well as the transfer of the technology and knowhow necessary to produce them, has been a continuous process, some analysts have argued that historical ebbs and flows in the diffusion of military capability conform to identifiable patterns. Krause (1992), for example, sketches three waves in arms transfer and production system. The first wave began with the so-called Military Revolution of the fifteenth century and lasted until the seventeenth century. This was followed by a two-century long period of relative stasis in military-technological development. Arms were produced and traded, of course, but the pace of technological change was slow by comparison to the preceding period, and especially subsequent periods. The second wave began in the middle of the nineteenth century and was associated with the rapid advance of the Industrial Revolution. There was no period of technological stability between the second wave and the current third wave; rather, the end of one and the beginning of the next were condensed by the transformative event of World War II. (See also O'Connell 1989).

During each of these three historical periods, Krause identifies an evolutionary dynamic consisting of five phases. In phase one, significant military-technological innovation is realized by a select group of states that then become the leading centers of global arms production. In phase two, rising demand for advanced weaponry produced by this first tier drives a rapid expansion of the arms trade and, in phase three, rising demand for arms production technology accompanies the demand for finished systems. This gives rise to a second tier of arms producing states, able to manufacture a wide range of military equipment, including the most advanced systems, but generally unable to innovate at the military-technological frontier. Next, in the fourth phase, the international arms market becomes characterized by fiercer competition among a larger number of suppliers. The transfer of arms accelerates, as does the diffusion of arms production capacity, and there now emerges a third tier of weapons manufacturing states. Capacity varies in the third tier, but a common limitation is the need to import designs, machinery, and often the key components necessary for domestic production of the most technologically advanced systems. In the fifth and final phase, military-technological diffusion slows and the arms-production hierarchy solidifies (Krause 1992: 26-32).

Although this evolutionary pattern has been repeated in three waves during the history of the contemporary state system, it is also the case that the second iteration was more compressed than the first, and the third – which some would argue is now yielding to a fourth – has been shorter still. Analysts debate the nature, timing, and historical import of particular military-technological innovations, including whether they count as having triggered revolutions in military affairs (RMAs). Without weighing in on the merits of one side or another in these disputes, Buzan and Herring (1998, 12) have made a compelling argument that the mid-nineteenth century – the height of the Industrial Revolution and the outset of Krause's second wave of military production and trade – demarcates the beginning of the period of *frequent* military-technological change:

The historical norm has reflected a pace of technological innovation so slow that the continuity of weapons systems has been more conspicuous than their transformation.... By the middle of the nineteenth century, a fundamental transformation in military technology was under way. The

industrial revolution, with its ever expanding use of energy and machinery in the process of production, had by this time developed such momentum that major changes in technology began to occur frequently. From around the middle of the nineteenth century, a new norm of frequent change asserted itself. That norm still prevails. It shows little sign of weakening, though it is beginning to assume a new form.

Whatever the timing and nature of specific advances in weapons performance (firepower, mobility, communications, etc.), in the modern period military planners have come to expect that significant military-technological innovation will not be occasional in the sense usually associated with revolutionary change, but will be recurrent, even continuous.

These expectations of frequent change are important because they drive the global arms trade. Arms transfers have a leveling effect. The bulk of high-technology weapons manufacturing takes place in the first and second tiers of the global arms production system. Fortunately, from the perspective of states outside this core group, advanced weaponry can be acquired in the international arms market, and for a whole host of reasons ultimately related to the security dilemma – e.g., decolonization and persistent regional rivalries – the demand for this weaponry has remained rather high throughout the post-World War II period. Many states would like to develop their own arms production capacities, but the industrial and technological hurdles are often too high to clear while at the same time attending to the immediate requirements of national security, as the experiences of many third tier producers show (Anthony 1993; Brzoska 1999). Competition among arms suppliers, characteristic of the mature phases of the evolutionary dynamic just described, means that this demand for advanced weaponry will not go unmet.

If this was all there was to it, we might expect that the pace of technological change will return to “normal” levels after a military innovation, even a revolutionary one, has worked its way through the arms production system. But the leveling effect of the arms trade provides a stimulus for further technological advance among the group of leading states, for this becomes their primary means of maintaining military advantage in an international system where access to modern weaponry is widespread. Thus, the process comes full circle: military-technological innovation generates demand for advanced weaponry, and the proliferation of this weaponry via the international arms market generates incentive for military-technological innovation. Buzan and Herring (1998) refer to the forces behind this process collectively as the “technological imperative.” The technological imperative drives more than the rapid diffusion of advanced military capability in the aftermath of a significant military-technological innovation; it also drives the frequency of both expected and realized innovations.

This notion of frequent change in military technology is not necessarily at odds with the evolutionary dynamic described by Krause (1992), but it does suggest that the technological revolutions that help to define the onset of a new eras in the global arms transfer and production system become increasingly hard to pinpoint. Whether we are talking about RMAs or merely major advances in the performance characteristics of standard weaponry, the high rate of technological change ushered in by the Industrial Revolution may make the process appear more continuous than wave-like.

## COMPETITION AND THE ARMS TRADE

There are several facets to the technological imperative and it has taken different forms at different times. During the cold war, the superpower rivalry itself provided incentive for the United States and the Soviet Union to innovate at the military-technological frontier. Each defined its own military capabilities relative to those of the other and military planners on both sides feared that unmatched qualitative advances would undermine a defense posture based on existing numerical balances. Their competition was extended to the Third World, as military aid and arms sales became a preferred means of courting potential allies in the global struggle for influence. Once patron-client relationships had been established, arms transfers gained additional momentum as both superpowers became invested in the security of their clients, many of whom were engaged in enduring regional rivalries. Ongoing disputes between North and South Korea, Israel and its Arab neighbors, India and Pakistan, Iran and Iraq, and Ethiopia and Somalia became extra-regional affairs when the United States and Soviet Union became the primary arms suppliers of the opposing sides (see, for example, Kinsella 1994, 1995; Wriggins 1992).

Analysts have long been preoccupied with the question of whether the superpower arms competition can be properly called an arms *race*. A race was certainly how it was most often described in the public discourse – in the United States, the Soviet Union, and elsewhere. But a tightly coupled dynamic of action and reaction was not present in the superpower “arms race,” as it was in, say, the Anglo-German naval race prior to World War I. Military planners in both countries reacted to developments in the other, to be sure, but this reaction was not always manifest in the form of reciprocated military efforts. Short-term reciprocity was most evident in nuclear deployments (numbers of both launchers and warheads), but in other areas the action-reaction dynamic was less clear. American and Soviet military expenditures, for example, after moving together during the 1960s (generally upward), followed divergent paths during the 1970s (Soviet expenditures upward, US expenditures downward). The loosely coupled nature of the superpower arms competition is suggestive of the importance of military-technological innovation. When behavior is governed by an intense action-reaction dynamic in the strictest sense, it becomes rather predictable. However, greater flexibility in reacting to threatening military developments was seen to require a sustained devotion of resources to military-technological innovation. And if one side was pushing against the military-technological frontier, the other could hardly afford not to do the same. In this way, the superpower competition intensified the technological imperative operating during the cold war.

If the superpower rivalry accelerated the pace of military-technological change, so too did it accelerate the diffusion of advanced military capability. In return for some measure of political allegiance, the superpowers became willing suppliers of states involved in their own local rivalries. Even though in most cases state-of-the-art equipment was not transferred to client states in the third world, recipients were nevertheless able to acquire very advanced weaponry in their efforts to gain military-technological advantages over their rivals, or to redress disadvantages. Because arms transfers were driven by superpowers’ struggle for global influence, and because they often went to opposing sides in regional rivalries that at times seemed to be reflections of the superpowers’ own, the arms-transfer competition became an extension of the superpowers’ direct arms competition.

As with their own military buildups, American and Soviet arms transfers were competitive, but only loosely coupled. This is explained by both the push and the pull factors operating in the cold war arms trade. On the pull side, in most enduring rivalries, the normal states of affairs usually have not been arms races, if we reserve that term for the most intense form of mutually reactive military buildup. What was true for the US-Soviet rivalry holds more generally, according to Buzan and Herring (1998, 80): “relations between virtually all potential adversary states fall into the grey area between maintenance [of the military status quo] and racing.” On the push side, even if local rivals were inclined to engage in more intense forms of arms competition, they would have to turn to willing suppliers since most do not possess the capacity to produce their own advanced weaponry, and those that do possess it are able to manufacture only a very limited number of systems, a small fraction of their perceived security needs. Contrary to some of the more radical portraits of the cold war in the Third World, the superpowers and their allies generally tried to avoid provoking or feeding regional arms races, especially in high tension areas like the Middle East and South Asia (Miller 1995; Wriggins 1992; Kanet and Kolodziej 1991). They did contribute to less intense forms of regional arms competition, though.

It is easy to see how superpower arms transfers to states locked in enduring rivalries could become driven by an action-reaction dynamic. Arms-flow patterns were more likely to resemble arms competitions than arms races, but the basic logic of local security dilemmas was the same either way. However, although basing rights and other concessions from their client states helped each superpower achieve its desired global military reach, rarely was the security of either of them directly affected in any serious way by developments in the Third World regions they supplied with weapons. The point is made by Ayoob (1995, 94): “despite the mutual interpenetration of superpower competition and regional conflicts in the Third World, a fundamental asymmetry, with very few exceptions, continued to exist in the interaction between these two phenomena” (for empirical confirmation, see Kinsella 1995). Furthermore, the security dilemma did not fuel the cold-war arms trade from above in quite the same way as it did from below. The technological imperative operated during the cold war as it has during other periods, and the superpowers’ military rivalry accelerated the pace of military-technological innovation while their competition for global influence increased the rate at which advanced military capability spread throughout the international system. But the action-reaction dynamic behind the American and Soviet arms-supply competition, a dynamic that helped to shape this particular manifestation of the technological imperative, was less intense than either their own direct arms competition or the regional arms competitions fed, at least in part, by their arms transfers.

As global actors supplying weapons worldwide, we might conjecture that the superpowers’ arms-supply patterns conformed to a competitive dynamic in various regions and at multiple levels of aggregation. In the second half of this paper, I explore the extent to which American and Soviet, as well as NATO and Warsaw Pact, arms transfers to the Third World did in fact exhibit an action-reaction dynamic. I examine their arms exports to the Third World as a totality, to the Middle East security complex, and, finally, to the Persian Gulf, a subcomplex of states within the Middle East. Security complexes, defined by Buzan (1991, 190) as formations of states identifiable by their “patterns of amity and enmity that are substantially confined within some particular geographical area,” have

proven to be useful units of analysis in the study of world politics, especially Third World security issues (see also Buzan, Wæver, and de Wilde 1998).

## ANALYSIS

To review, there are two dynamics to consider when studying the diffusion of military capability by way of the global arms trade. First, a technological imperative operates that drives military-technological innovation ever forward and fuels both demand and supply in the international arms market. This is an enduring dynamic in world politics and it coincides with the quickening pace of military-technological innovation ushered in by the Industrial Revolution. Second, an action-reaction dynamic operates. It is linked to the security dilemma, and although it may take the form of an arms race, it more often manifests as a less intense form of arms competition, even in the context of interstate rivalry. Action-reaction dynamics are common, at the global level between great powers and at the local level between regional rivals, but they tend to be more short-lived than an overarching process like the technological imperative. The action-reaction processes operating during the cold war were integral to the working of the technological imperative during this period, but, following Buzan and Herring (1998), it is useful to maintain the distinction between the two dynamics for analytical purposes.

Before turning to the data analysis, I want to relate these ideas to three key concepts in time-series analysis: integration, cointegration, and error-correction. These concepts, I think, are well-suited to an empirical examination of the diffusion of military capability and the action-reaction processes that helped drive it during the cold war.

### Integration and the Diffusion of Military Capability

What patterns would we expect to observe in the diffusion of military capability over time, in light of arguments put forth by Krause (1992), Buzan and Herring (1998), and others? As regards the *possession* of military capability – global or regional totals, or the capability of the “typical” state – there can be little doubt that the trend over time is generally upward. Military technology moves forward, and the performance characteristics of today’s weapons are almost always superior to yesterday’s. However, when it come to the *diffusion* of military capability – that is, the interstate transfer or spread of weapons and arm-production technology – the expected patterns are less obvious.

Over the long *durée*, we would expect to observe a cyclical patterns of diffusion, though not cycles of fixed periodicity. Krause (1992) identifies recurrent phases during each wave in the evolution of the global arms transfer and production system, but he also points to the increasingly compressed time period over which these phases have worked themselves out. Within a given cycle or wave, like the most recent one which encompasses the cold war period, the overall trend in military diffusion is upward but eventually it trails off as “the motors of innovation either grow dormant or begin to migrate” (Krause 1992, 31). This pattern is visible in arms-transfer time series, as shown in Figure 1 (the data are described below). It is most pronounced at higher levels of aggregation (worldwide transfers and transfers to the Third World), but it is also apparent in arms supplies to the Middle East security

complex and in supplies to the Persian Gulf subcomplex. It makes sense that the pattern is clearest at higher levels of aggregation; as our inspection of the data zooms closer to particular clusters of competitive states, the processes giving rise to this global pattern of diffusion are more likely to be overwhelmed by local processes of conflict and rivalry.

[Figure 1 about here]

Inspection of arms-transfer time series obviously does not constitute a definitive test of the presence of forces said to drive the long-term evolution of the arms transfer and production system. Longer data series would be required to construct a more reliable test, but even then it would be necessary to consider simultaneous developments in the international system that could account for the observed patterns. For instance, the trends visible in Figure 1 also conform to the rise and especially the decline of the superpower rivalry; the United States and Soviet Union together provided 60 to 80 percent of the military equipment and production technology exported in any given year during this time period. The cold war was an integral part of this latest wave in the long-term evolution of the system, but the general pattern of military diffusion described by Krause is supposed to hold irrespective of the interstate rivalries characteristic of one period or another. In any event, what we can say is that the trends apparent in Figure 1 certainly do not contradict what we expect to observe from the evolutionary dynamic Krause lays out.

What about shorter-term trends? Action-reaction processes help to further shape military production and transfer patterns given general form by the technological imperative. But as the arms-race literature demonstrates, these processes are often not well-represented by simple structural models in which one side consistently reacts to the other side's military procurement, and vice versa (McGinnis and Williams 2001; Kinsella and Chung 1998). The shortcomings of these models of external action and reaction have led analysts to refocus their attention on the processes internal to the state that account for the large measure of inertia that we can discern in many states' military budgets (for literature reviews, see Etcheson 1989; Gleditsch 1990). The operation of standard organizational procedures, for example, typically means that in any given period the best predictor of a policy output, including a military budget, is the previous period's policy output. In effect, the domestic forces highlighted by these analysts – organizational routines, but also the influences exerted by governmental and societal actors who have stakes in military production and trade – derive from an institutionalization of the technological imperative. The presence of countervailing domestic forces, even though their influence is often less strongly felt, adds another layer of complexity.

The impact of the technological imperative, intertwined with action-reaction dynamics and domestic forces operating somewhat differently but simultaneously on both suppliers and recipients, suggests that although arms-transfer patterns will exhibit a trend, it is more likely to be a stochastic trend than a deterministic one. That, at least, is a hypothesis I want to test. Buzan and Herring (1998, 121) put it this way:

Although action-reaction and domestic structure factors do play a substantial role in it, it is important not to lose sight of the point that both sets of factors are themselves heavily conditioned by the independent process of the technological imperative. Nevertheless, it must be stressed that one can perceive the existence of a technological imperative without perceiving



technological determinism. The technological imperative represents an unavoidable requirement to consider how to respond to the frequent technological advances of the contemporary world. It does not determine what that response will be or even whether there will be a response of any vigor; that will be influenced to varying degrees by political, domestic structure, and action-reaction factors.

Military-technological innovations are essentially stochastic, even if increasingly frequent, but they have a lasting impact on the production and transfer of military capability. Since it is not always clear how, when, and with what intensity military planners will respond to technological advances, beyond being compelled to take seriously their implications for national security, the spread of military capability should meander. In the long term, an indicator of this military-technological diffusion like global or regional arms transfers may, following Krause (1992), exhibit a tendency to drift upward and then downward, but in the shorter term its pattern should appear more as a random walk. The time series will be nonstationary in that there is no long-run mean level to which the series reverts in the aftermath of military-technological innovations; the impact of technological advances are permanent, or at least “long remembered” (on the distinction, see Beck 1992). In the parlance of time-series analysis, such a series is said to be *integrated*.<sup>1</sup>

### **Cointegration, Error-correction, and Arms-Transfer Competition**

As discussed above, the coupling of action and reaction in military procurement is often not so tight as to constitute an arms race, and more loosely coupled processes would seem even more likely in less direct forms of interstate competition, such as superpower arms transfers during the cold war. There may be times when military planners do react quickly to policy changes undertaken by their counterparts in an opposing states, but we should not be surprised if this pattern of behavior turns out to be the exception and not the rule. What we should expect to observe in the case of competitive arms transfers – what I hypothesize, anyway – is that their data series move together over time. A sudden policy change, whether by an arms supplier or its recipients, can cause one series to stray from this “equilibrium path,” but eventually the series will resume their co-movement. Integrated time series exhibiting such a pattern are said to be *cointegrated*. Again, Buzan and Herring (1998, 51) have put forth the key ideas:

A substantial amount of the behavior that is commonly identified as arms racing (but which... may turn out to be something less than that) stems from the underlying process of technological advance. When countries compete with each other in armaments (whether as potential opponents in war or as competitors in the arms trade), they must also compete with a standard of technological quality that is moving forward.

This forward movement in technology, in effect, represents a stochastic trend shared by the two competitive arms processes.

In this context, the action-reaction dynamic can be manifest in two ways. It could be that the policy outputs of two rival states are in fact tightly coupled and that each side immediately reacts to behavior by the other (or perhaps only one side does the reacting). That is an extreme form of competition – and, when it comes to military budgeting, is not as common as arms-race researchers originally conjectured – but it is not incompatible with long-term co-movement in two (or more) competitive arms processes. The other form that the action-reaction dynamic can take is less rigid, however. If two time series are cointegrated, one or both of the processes will display a tendency to correct for deviations from the equilibrium path. The deviations can be brought about by premeditated changes in policy or by shocks from the external environment (like a regional crisis, in the case of arms supply), and may affect either or both of the rival states' time series. The resulting process of adjustment or re-equilibration, which can take some time to complete, is referred to in time-series analysis as *error-correction*.

My argument is that where competitive dynamics were evident in the cold-war arms trade, these dynamics were more likely to take the form of error-correction than short-term action and reaction. That is what we expect from an arms-transfer competition operating under the technological imperative. That is also what we expect when we take into consideration the multidimensional and multi-regional character of the superpower rivalry in the Third World.

## Estimation and Results

My investigation is conducted at various levels aggregation, but the building block for all of the time series assembled for this analysis is the dollar value of all major weapons transferred between a supplier and a recipient during a given year. The dollar values represent not what was actually paid by the recipient to the supplier, but rather the market value of that weaponry. My assumption is that the value of an arms transfer serves as a good summary measure of the diffusion of military capability and that the technological imperative and action-reaction dynamics discussed above, to the extent that they do operate in world politics, are discernable in arms-transfer time series. The data come from the Stockholm International Peace Research Institute, which publishes its data in the *SIPRI Yearbook: Armaments, Disarmament and International Security*. SIPRI's data collection procedures, including its pricing methodology, are discussed in Brzoska and Ohlson (1987). I examine six pairs of time series for cointegration and error-correction: American vs. Russian and NATO vs. Warsaw Pact arms transfers to (1) the Third World as a whole, (2) the Middle East security complex, and (3) the Persian Gulf subcomplex.

I hypothesized that, due to the technological imperative, arms-transfer time series will be integrated, especially at higher levels of aggregation. To test this proposition, I conduct Dickey-Fuller tests for the presence of a unit root (see note 1) in four steps suggested by Enders (1995, 256-258). The basic idea behind the test is to determine whether  $a_1 = 1$  in the following model of arms transfers,  $y_t$ :

$$y_t = a_1 y_{t-1} + \varepsilon_t \quad [1]$$

If  $a_1 = 1$ , then we conclude that the series is integrated; when this year's arms transfers are best predicted by last year's transfers, the process meanders. The actual procedure involves embedding an equivalent representation of  $y_t$  in a model with fewer restrictions, and then imposing additional

restrictions to ensure the integrity of the test. The exact procedure is presented in the appendix, along with the complete results. Table 1 summarizes the findings.

[Table 1 about here]

As a preface to the cointegration analysis, consider the first column of findings, which pertain to total arms transfers worldwide and to the three regional aggregations. In all four cases, arms transfers exhibit nonstationary movement over time, in accordance with the working of the technological imperative as I interpret it. The rest of the table pertains to arms transfers to each of the regions disaggregated by source. Only two series – Warsaw Pact transfers to the Third World, American transfers to the Middle East – are stationary; the rest, including a borderline case, are integrated.<sup>2</sup> If a pair of arms-transfer time series is cointegrated, the implication is that each is integrated. Therefore, two of the six pairs (the boxed ones) fail to meet this requirement for further analysis.

Since each series in the four remaining pairs exhibits a stochastic trend consistent with the technological imperative, each pair can now be examined for evidence of action-reaction dynamics. Recall that two integrated series are cointegrated if an equilibrium relationship exists between them: they share a common stochastic trend. They need not move in parallel in the sense of being correlated in the short run. Instead, they will appear to shadow one another, never drifting very far apart, so that there is no systematic divergence between them. Suppose that  $x$  and  $y$  are two integrated arms-transfer series. An equilibrium relationship,  $f(x_t, y_t) = 0$ , exists if deviations from equilibrium,  $e_t / f(x_t, y_t)$ , constitute stationary process with a mean of zero. That is, the equilibrium error,  $e_t$ , will not exhibit unbounded growth over time. Operationally, if some linear combination of integrated series produce another,  $e_t = y_t - (\beta_0 + \beta_1 x_t)$ , that is stationary, then we may conclude that an equilibrium relationship exists (Engle and Granger 1987). A linear combination of integrated series will often produce a nonstationary  $e_t$ , in which case the series' stochastic trends are not shared and do not “cancel out” when the series are combined. Because cointegrated series do have a common stochastic trend, we can assume that this shared component is indicative of forces that keep the series in an equilibrium relationship over the long run – i.e., the technological imperative and cold war rivalry. Identifying a “cointegrating vector,”  $\beta$ , that yields a stationary  $e_t$  constitutes evidence of an equilibrium relationship between American and Russian (or NATO and Warsaw Pact) arms transfers, and thus the presence of an action-reaction dynamic.

The equilibrium-error series can be obtained from a bivariate regression using either side's arms-transfer series as the left-hand-side variable. In theory, the specifications should yield similar error sequences in terms of stationarity, but, alas, the actual data are not so well-behaved. Table 2 shows the results of unit root tests performed on the residuals from cointegrating regressions using the two alternative specifications. A significant Dickey-Fuller statistic means that the residual sequence is stationary: the arms-transfer series are cointegrated, with neither showing a systematic tendency to deviate from the other over time. Only in the case of NATO and Warsaw Pact transfers to the Middle East are the results consistent across the two specifications, but since there is at least some evidence of cointegration in the other three relationships, I proceed to the next step and estimate the error-correction dynamics for all four pairs.

[Table 2 about here]

So far, my findings indicate that at certain levels of regional aggregation, the stochastic trend in American and NATO arms transfers was shared by Russian and Warsaw Pact arms transfers, and vice

versa. There is, then, some support for the hypothesized competitive, though loosely coupled, dynamic in cold war arms transfers. The question now becomes: what were the action-reaction processes that returned these relationships to their equilibrium paths on occasions when their co-movement was perturbed by sudden policy changes or external shocks? Consider an error-correction model (ECM) for the current change in arms transfers,  $\Delta y_t$ :

$$\Delta y_t = \alpha_0 + \alpha_y \hat{e}_{t-1} + \sum_{i=1}^k \alpha_{1i} \Delta y_{t-i} + \sum_{j=1}^l \alpha_{2j} \Delta x_{t-j} + \varepsilon_t \quad [2]$$

The first summation term allows for the change in one side's transfers to be affected by past changes in its own transfers,  $\Delta y_{t-i}$ , while the second allows for reaction to past changes in its opponent's transfers,  $\Delta x_{t-j}$ . The intuition behind the inclusion of these two terms is the same as that found in much of the empirical arms-race literature wherein domestic forces and external stimuli are hypothesized to have an impact on military policy outputs in the short term. But it is the error-correction component of the process that is of most interest in light of the previous discussion, because this is the mechanism by which the longer-term equilibrium relationship is maintained. The equilibrium error is represented in the model by the once-lagged residual series,  $\hat{e}_{t-1}$ , from the cointegrating regression, and the test for error-correction is accomplished by examining the estimate and statistical significance of the adjustment parameter,  $\alpha_y$ . Of course, the adjustment parameter should carry a negative sign. Whether the deviation is above or below the equilibrium path, and whether this is due to policy changes undertaken by the actor in question or by its rival, one side's error-correcting behavior implies that its military planners target a new level of arms transfers so as to diminish the prior period's deviation from equilibrium.

In practice, ECMs have been estimated following slightly different procedures. When changes in the opponent's arms transfers,  $\Delta x_t$ , are modeled analogously to equation [2], the two-equation system resembles a vector autoregression (VAR) in first differences, except for the addition of the equilibrium error terms. One approach is to estimate this "near VAR" following standard VAR-modeling procedures (see Enders 1995, 373-377). In particular, this means imposing a single lag structure on all four of the lagged difference terms based on preliminary specification testing, and then conducting F tests to determine if changes in one series "Granger cause" changes in the other. Another approach is to model each side's arms-transfer process separately. This involves imposing equation-specific restrictions on the lagged difference terms after estimating a near VAR. In this case, the restrictions are based on causality tests from a near VAR that includes both  $y_{t+1}$  and  $x_{t+1}$  instead of the error term from the cointegrating regression. These lagged level terms are replaced by the equilibrium-error term in the final error-correction model, however (see Engle and Granger 1987).<sup>3</sup> Both approaches should yield similar results.

The key findings from the two ECM procedures are shown in Table 3. The error-correction parameters on the left side of the table pertain to the tendency of American or NATO arms transfers to adjust to deviations from the equilibrium path; those on the right side to Russian or Warsaw Pact adjustment. A statistically significant (and negative) parameter estimate is evidence of arms-transfer adjustment by that side. In seven of the eight cases of hypothesized error-correcting behavior, the level of significance is the same for estimates from both procedures, which is reassuring. The results indicate

that error-correcting dynamics in arms transfers to the Middle East and to the Persian Gulf were mutual: both sides in the cold war competition adjusted their policies in response to deviations from their moving equilibrium. On the other hand, at a higher level of aggregation – arms transfers to the Third World as a whole – error-correcting behavior is apparent only in Russian policy.<sup>4</sup>

[Table 3 about here]

What accounts for this asymmetry? There does not seem to be a good theoretical explanation, but here is an empirical one. Recall that error-correcting behavior is a tendency to adjust to deviations from the equilibrium path, whatever the source of out-of-equilibrium conditions, including sudden changes in one's own policies. In the case of Russian arms transfers to the Third World, major spikes in activity were associated with supplies to the Arab states – during and after the Six Day War, the War of Attrition, and the Yom Kippur War, as well as to Syria after the break with Egypt. These events were behind the (literally) extraordinary Russian arms-transfer levels during certain years, and neither superpower wanted such “shocks” to shift the equilibrium path so sharply upward. That meant that the United States was unlikely to adjust its transfers to target a new higher level; instead, the Soviets would bring theirs down. The same self-correcting dynamic should operate after major changes in American activity, but the fact is that at this level of aggregation American arms transfers have followed a considerably smoother time path, less responsive to such regional shocks.<sup>5</sup> At lower levels of aggregation, however, regional events loom large. Crises and wars were usually beyond the control of the superpowers, and the uncertainty associated with such volatility – in the Middle East security complex, the Persian Gulf subcomplex, and perhaps elsewhere – suggests that the equilibrium path was in greater flux. In this regional context, when competing arms supplies are indeed cointegrated, it may be more reasonable to expect mutual correction of out-of-equilibrium conditions since both sides were essentially feeling around in the dark.

## CONCLUSION

Interstate arms competition does not always, or often, take the form of a tightly linked process of action and reaction. This was true of the cold war “arms race,” and due to the complicated and largely autonomous dynamics operating in regional security complexes, as well as the multi-regional character of the superpowers' global competition, it should be even more true of their arms-transfer competition. Patterns in cold war arms transfers emerged from a military-technological imperative that has long driven the global arms trade, in addition to the competitive relationship peculiar to the superpowers' global rivalry. Empirically, this competitive relationship seems to imply a co-movement of American and Russian (and NATO and Warsaw Pact) arms-transfer series transfers along an equilibrium path, the general contours of which derive in large part from the forces of military-technological advance. I have argued that the relevant concepts from time-series analysis are cointegration and error-correction, and my analysis has revealed the presence of such data generating processes.

The scope of my empirical study has been limited. Although I have examined arms-transfer competition at a high level of aggregation (the Third World), beyond that I have focused on only one regional security complex (the Middle East), and one subcomplex within it (the Persian Gulf). Even here, the hypothesized dynamics were not in evidence across the board, so it remains to be seen

whether they operated in other security complexes and in what form. That is a worthwhile avenue for further research. More relevant for contemporary world politics, however, is the question of continuity. As the previous discussion has emphasized, the technological imperative has been an enduring feature of the global arms production and transfer system, and there are at present few signs that the rate of military-technological advance will slow down significantly in the near to medium term. But the nature of the global competition in arms transfers most certainly has changed. Whether or not Russia is successful in its bid to renew its place in the sun in the global arms market, competitive dynamics will continue to drive the spread of military capability. The degree to which these differ from those associated with the cold war rivalry, and their consequences for regional security, deserve the sustained attention of empirical research.

## APPENDIX

The Dickey-Fuller (DF) unit root tests used in this paper start with this basic model of a time series,  $y_t$ :

$$y_t = a_1 y_{t-1} + \varepsilon_t \quad [a1]$$

and re-express it as:

$$\Delta y_t = \gamma y_{t-1} + \varepsilon_t \quad [a2]$$

where  $\gamma = a_1 - 1$ . If  $y_t$  has a unit root, then  $a_1 = 1$  and, equivalently,  $\gamma = 0$ . Therefore, in estimating [a2], the null hypothesis is that a unit root is present, and rejecting the null means that we can conclude that  $y_t$  is a stationary process.

The actual testing procedure follows four steps recommended by Enders (1995, 256-258). Step 1 involves estimating the least restrictive model:

$$\Delta y_t = a_0 + \gamma y_{t-1} + a_2 t + \sum_{i=1}^k \beta_i \Delta y_{t-i} + \varepsilon_t \quad [a3]$$

and testing the unit-root null that  $\gamma = 0$ , with critical values for the  $t$  test derived from the appropriate non-standard distribution. If the null is rejected, then we conclude that the series is stationary and the procedure stops there. If we cannot reject the null of a unit root, it still may be possible that the test was weakened by specification error — i.e., the inclusion of a deterministic trend term,  $a_2 t$ , and a constant,  $a_0$ , which allows for a drift in the process. In step 2, then, we examine the statistical significance of the trend component, whether  $a_2 = 0$ , and confirm this result with a joint  $F$  test of a unit root without a deterministic trend,  $a_2 = \gamma = 0$ . If the trend term does belong in the model, then it is appropriate to retest the null that  $\gamma = 0$  using critical values from a normal distribution. If the null is rejected at this step, we conclude that the series is stationary around a deterministic time trend.

However, if the trend term does not belong in the model, step 3 involves re-estimating [a3] without that term, and again testing the unit-root null that  $\gamma = 0$  using non-standard critical values. The remainder of this step is similar to step 2, except that now we ask whether the unit-root process includes a drift, as indicated by the constant,  $a_0$ . If the constant is significant, we retest for the presence of a unit root using the normal. If the drift term does not belong in the model and we are still unable to reject the unit root — that is, if  $a_0 = \gamma = 0$  — then we proceed to step 4 and estimate the most restrictive model: [a3] with neither a trend nor a constant term. Using the appropriate critical values,

we conduct one last test of the unit-root null hypothesis. Failure to reject the null suggests that the series has a unit root but no drift. Note that each of the models may include lagged differences of the series  $y$  in order to allow for autoregressive components in the unit root process, in which case we are conducting Augmented Dickey-Fuller (ADF) tests. Again, these extra terms are included to ensure the robustness of the tests. The number of lags,  $k$ , is determined empirically by conducting likelihood ratio tests for restricted and unrestricted regressions.

The results of this 4-step testing procedure are shown in Table A1. The last column of the table reports statistics from unit root tests conducted on the nonstationary time series after they have been first-differenced. Cointegration analysis assumes that each process has the same order of integration, which is determined by the number of times the series must be differenced before its time path becomes stationary. As can be seen from these results, all nonstationary series examined here are first-order integrated, or  $I(1)$ .

[Table A1 about here]

The procedure used to test for unit roots in the residual series from the cointegrating regressions (see Table 2) begins with step 4 described above. By construction, regression residuals have a mean of zero, so it is not necessary to include a constant (or a trend term) in the model.

## NOTES

1. Somewhat more obscurely, the series is said to contain a unit root, a terminology that derives from the theory of difference equations. Solving difference equations involves finding their “characteristic roots,” and only when all roots are less than one (lie within the unit circle) does the time path of the solution converge to zero. When a root is greater than one, the function explodes; when a root is exactly one, it neither converges nor explodes.
2. The borderline case, American transfers to the Persian Gulf, is worth retaining for subsequent analysis because cointegration and error-correction modeling can yield important insights even when a series, while not integrated in the strict sense, is nevertheless “long-memory” (see Beck 1992).
3. This second approach, although it imposes equation-specific restrictions, is not the same as a single-equation ECM. See, for example, Beck (1992) and Durr (1992).
4. Table 3 also shows F statistics for short-term reaction to arms-transfer changes by the other side. These are Granger-causality tests – i.e., tests of the joint significance of the  $x_{itlj}$  terms from equation [2], with the number of lags,  $l$ , indicated. Interestingly, although the previous discussion has emphasized that the competitive dynamics in the arms trade were not so tightly coupled, some of the evidence indicates that alongside the longer-term competitive process there operated a short-term action-reaction dynamic. And where the evidence exists, the dynamic was always one sided. The United States reacted in the short-term to changes in Russian transfers to the Third World, while the opposite occurred in the Persian Gulf. At the level of cold-war alliances, NATO reacted to the Warsaw Pact’s Middle East transfers, while again the opposite occurred in the Persian Gulf.
5. One exception is the sudden drop associated with more restrictive arms-supply policies adopted by the Carter administration, combined with the collapse of the shah’s regime in Iran, a major US client.



## REFERENCES

- Anthony, Ian (1993). "The 'Third Tier' Countries: Production of Major Weapons." In *Arms Industry Limited*, edited by Herbert Wulf, pp. Oxford: Oxford University Press.
- Ayoob, Mohammed (1995). *The Third World Security Predicament: State Making, Regional Conflict, and the International System*. Boulder: Lynne Rienner.
- Beck, Nathaniel (1992). "The Methodology of Cointegration." In *Political Analysis*, volume 4, edited by John R. Freeman, pp. 237-247. Ann Arbor: University of Michigan Press.
- Brzoska, Michael (1999). "Economic Factors Shaping Arms Production in Less Industrialized Countries." *Defence and Peace Economics* 10: 39-169.
- Brzoska, Michael and Thomas Ohlson (1987). *Arms Transfers to the Third World 1971-85*. New York: Oxford University Press.
- Buzan, Barry (1991). *People, States and Fear: An Agenda for International Security Studies in the Post-Cold War Era*, 2nd ed. Boulder: Lynne Rienner.
- Buzan, Barry and Eric Herring (1998). *The Arms Dynamic in World Politics*. Boulder: Lynne Rienner.
- Buzan, Barry, Ole Wæver, and Jaap de Wilde (1998). *Security: A New Framework for Analysis*. Boulder: Lynne Rienner.
- Charemza, Wojciech and Derek F. Deadman (1992). *New Directions in Econometric Practice: General to Specific Modeling, Cointegration, and Vector Autoregression*. Aldershot: Edward Elgar.
- Durr, Robert H. (1992). "An Essay on Cointegration and Error Correction Models." In *Political Analysis*, volume 4, edited by John R. Freeman, pp. 185-228. Ann Arbor: University of Michigan Press.
- Enders, Walter (1995). *Applied Econometric Time Series*. New York: John Wiley and Sons.
- Engle, Robert F. and C.W.J. Granger (1987). "Co-integration and Error-correction: Representation, Estimation, and Testing." *Econometrica* 55: 251-276.
- Etcheson, Craig (1989). *Arms Race Theory: Strategy and Structure of Behavior*. Westport, CT: Greenwood Press.
- Gleditsch, Nils Petter (1990). "Research on Arms Races." In *Arms Races: Technological and Political Dynamics*, edited by Nils Petter Gleditsch and Olav Njåstad, pp. London: Sage.
- Kanet, Roger E. and Edward A. Kolodziej (1991). *The Cold War as Cooperation: Superpower Cooperation in Regional Conflict Management*. Baltimore: Johns Hopkins University Press.
- Kinsella, David (1994). "Conflict in Context: Arms Transfers and Third World Rivalry During the Cold War." *American Journal of Political Science* 38: 557-581.
- Kinsella, David (1995). "Nested Rivalries: Superpower Competition, Arms Transfers, and Regional Conflict, 1950-1990." *International Interactions* 21: 109-125.
- Kinsella, David and Sam-man Chung (1998). "The Long and the Short of an Arms Race." In *The Political Economy of War and Peace*, edited by Murray Wolfson, pp. 223-246. Boston: Kluwer.
- Kinsella, David and Herbert K. Tillema (1995). "Arms and Aggression in the Middle East: Overt Military Interventions, 1948-1989." *Journal of Conflict Resolution* 39: 306-329.

- Krause, Keith (1992). *Arms and the State: Patterns of Military Production and Trade*. Cambridge: Cambridge University Press.
- McGinnis, Michael D. and John T. Williams (2001, forthcoming). *Compound Dilemmas: Democracy, Collective Action, and Superpower Rivalry*. Ann Arbor: University of Michigan Press.
- Miller, Benjamin (1995). *When Opponents Cooperate: Great Power Conflict and Collaboration in World Politics*. Ann Arbor: University of Michigan Press.
- O'Connell, Robert L. (1989). *Of Arms and Men: A History of War, Weapons, and Aggression*. New York: Oxford University Press.
- Wriggins, W. Howard, editor (1992). *Dynamics of Regional Politics: Four Systems on the Indian Ocean Rim*. New York: Columbia University Press.

**Table 1.** Integration in Regional Arms-Transfers, 1948-1995

<i>Region</i>	Total Transfers	<i>Source</i>			
		American	Russian	NATO	WTO
World	integrated				
Third World	integrated	integrated	integrated	integrated	stationary
Middle East	integrated	stationary	integrated	integrated	integrated
Persian Gulf	integrated	integrated*	integrated	integrated	integrated

*Note:* Conclusions are based on statistics reported in Table A1. The asterisk (\*) indicates a borderline case: the presence of a unit root could be rejected only at the 0.10 level of statistical significance.

**Table 2.** Cointegration in Regional Arms Transfers, 1948-1995

<i>Residual</i>	LHS: American/NATO		LHS: Russian/WTO		<i>cointegrated?</i>
	<i>lags</i>	<i>DF/ADF</i>	<i>lags</i>	<i>DF/ADF</i>	
Third World: American/Russian	1	-2.69	1	-3.71**	yes
Middle East: NATO/WTO	1	-5.44**	1	-5.92**	yes
Persian Gulf: American/Russian	0	-2.90†	0	-2.19	yes
Persian Gulf: NATO/WTO	0	-3.10*	0	-2.74	yes

*Note:* Statistics are Dickey-Fuller (when lags = 0) and Augmented Dickey-Fuller (when lags = 1) unit root tests performed on residuals from alternative specifications of the cointegrating regressions: with American or NATO arms transfers on the left-hand side, or with Russian or WTO transfers on the left-hand side. Tests are performed using models that exclude both the trend term and the constant (see appendix). Critical values are not the standard ones for DF and ADF tests (see Charemza and Deadman, 1992). When Warsaw Pact series are analyzed, the period is 1948-1991.

\*\* significant at the 0.05 level

\* significant at the 0.10 level

† inconclusive at the 0.10 level

**Table 3.** Error-correction in Regional Arms Transfers, 1948-1995

<i>Relationship</i>	American/NATO				Russian/WTO			
	lags	error correction		short-term reaction	lags	error correction		short-term reaction
		<i>near VAR</i>	<i>structural eq.</i>	F		<i>near VAR</i>	<i>structural eq.</i>	F
Third World: American/Russian	1	-0.114	-0.102	4.54**	1	-0.310**	-0.294**	0.67
Middle East: NATO/WTO	4	-0.456**	-0.405**	6.98**	4	-0.583*	-0.242*	1.15
Persian Gulf: American/Russian	1	-0.269**	-0.275**	0.00	1	-0.205**	-0.215**	4.62**
Persian Gulf: NATO/WTO	4	-0.357	-0.241**	1.64	2	-0.417**	-0.421**	8.18**

*Note:* Adjustment parameters are reported twice: first, from a near VAR with the indicated number of lagged difference terms; second, from a single structural equation. F values are from the near VARs, and test the joint significance of all lagged difference terms for the hypothesized causal series. For each hypothesized effect series, the model uses as its equilibrium-error term the residuals from the cointegrating regression in which that same series (in levels) appears on the left-hand side. When Warsaw Pact series are analyzed, the period is 1948-1991.

\*\* significant at the 0.05 level  
\* significant at the 0.10 level

**Table A1.** Dickey-Fuller Unit Root Tests for Arms Transfers

Transfer series	AR lags	trend, constant			no trend, constant			no trend, no constant	Conclusion	DF/ADF test on 1st difference	
		t statistic for $\alpha_0=0$	t statistic for $\alpha_2=0$	F statistic for $\alpha_2=\alpha_0=0$	t statistic for $\alpha_0=0$	t statistic for $\alpha_0=0$	F statistic for $\alpha_0=0$	t statistic for $\alpha_0=0$		AR lags	t statistic for $\alpha_0=0$
Total transfers											
World	0	-0.48	-0.61	1.78	-1.80	2.03*	2.07	-0.03	unit root	0	-6.61**
Third World	0	-0.92	0.14	0.92	-1.36	1.69	1.42	0.00	unit root	0	-5.18**
Middle East	0	-0.94	0.12	0.90	-1.35	1.40	1.08	-0.44	unit root	0	-6.89**
Persian Gulf	3	-2.32	1.73	2.80	-1.57	1.47	1.36	-0.74	unit root	2	-2.96**
American transfers											
Third World	0	-2.38	1.99	2.86	-1.29	1.61	1.29	-0.03	unit root	0	-6.40**
Middle East	1	-3.61**							stationary		
Persian Gulf	0	-3.12	1.59	4.86	-2.64*	1.87	3.53	-1.83*	unit root??	0	-7.90**
Russian transfers											
Third World	1	-2.77	1.42	4.14	-2.47	2.15*	3.08	-0.76	unit root	2	-5.61**
Middle East	0	-1.12	-0.23	1.17	-1.53	1.13	1.17	-1.02	unit root	0	-5.89**
Persian Gulf	0	-1.93	0.76	2.07	-1.89	1.27	1.80	-1.40	unit root	0	-7.99**
NATO transfers											
Third World	0	-1.65	1.16	1.39	-1.20	1.62	1.32	0.16	unit root	0	-6.17**
Middle East	0	-2.23	1.63	2.56	-1.54	1.62	1.43	-0.47	unit root	0	-6.91**
Persian Gulf	0	-3.06	2.01	4.71	-2.25	1.81	2.59	-1.34	unit root	1	-6.75**

Table continues

Transfer series	AR lags	trend, constant			no trend, constant			no trend, no constant	Conclusion	DF/ADF test on 1st difference	
		t statistic for $\alpha=0$	t statistic for $\alpha_2=0$	F statistic for $\alpha_2=\alpha=0$	t statistic for $\alpha=0$	t statistic for $\alpha_0=0$	F statistic for $\alpha_0=\alpha=0$	t statistic for $\alpha=0$		AR lags	t statistic for $\alpha=0$
WTO transfers											
Third World	1	-3.70**								stationary	
Middle East	0	-1.06	0.22	1.11	-1.49	1.21	1.13	-0.89	unit root	0	-5.41**
Persian Gulf	0	-1.86	1.15	1.96	-1.60	1.15	1.30	-1.12	unit root	0	-6.97**

*Note:* Where AR lags = 0, statistics are for simple Dickey-Fuller tests; otherwise statistics are for Augmented Dickey-Fuller tests with the indicated number of autoregressive corrections. Warsaw Pact (WTO) series are for the 1948-1991 period; all other series span 1948-1995. Dickey-Fuller tests on 1st differences are for models with a constant and a trend term.

\*\* significant at the 0.05 level

\* significant at the 0.10 level