

ARMS RACES

by

Michael D. Intriligator

University of California, Los Angeles

and

Dagobert L. Brito

Rice University

Article for Special Tenth Anniversary Issue of

Defence and Peace Economics, February 2000, Vol. 11 (1)

1. Introduction

This tenth anniversary issue of the journal *Defence and Peace Economics* represents an important occasion for both looking back over the last decade and looking forward over possible future developments for the field of defense economics and of peace studies. In this paper we will consider arms races from this perspective, examining the changing nature of arms races and their impacts on arms expenditure and international stability, comparing and contrasting global and local arms races, and discussing important unanswered modeling questions related to arms races. We will attempt in a relatively short paper to provide an overview of the topic of arms races, followed by gaps in the literature and profitable directions for future research, as requested by the Editors of this special issue.

2. Definition of the Arms Race and Related Issues/Questions

We start by defining an arms race as the competitive, resource constrained, dynamic process of interaction between two states or coalitions of states in their acquisition of weapons. Such arms race phenomena have been known in virtually all recorded history. Arms races

were certainly known to the ancient Greeks and Romans. The Greeks built fleets in the Persian Wars and the Romans in the Punic Wars. In this century there was the naval arms race prior to World War I and the East-West arms race of the Cold War. Today there are various regional arms build ups, some of which are arms races. Until the East-West arms race of the Cold War period, most arms races were naval. There are several reasons. First, aircraft did not exist until the twentieth century. Second, until the twentieth century, armies were highly labor intensive institutions with relatively little capital. Roman soldiers furnished their own equipment until the late Republic. Feudal levies also furnished their own equipment, where the obligation of a fief holder under military tenure was to furnish a certain number of knights and men at arms for a given number of days a year and to provide arms and horses for these men. The key element in deploying military power at that time was the organization of the state and its ability to raise revenue. The possibility of organizing and disciplining free men to serve as heavy infantry was the key to the Greek and Roman armies. Heavy infantry required a body of free men willing to serve. It is very difficult to find examples of heavy infantry manned by mercenaries until the sixteenth century.

Arms races as exemplified by the accumulation of stocks of weapons represent a very special case of weapons as an instrument of power. We have argued that arms races in the twenty-first century will be very different from the Cold War arms race. One of the things that is different about arms races now is the presence of increasing returns in the production of weapons. Further, the presence of increasing returns to scale in production is reinforced by the fact that software, microelectronics, and information are becoming increasingly important

components of modern weapons systems. A thirty-year old airframe with modern electronics, software, and computers can dominate a modern airframe with antiquated equipment.

Constant or increasing returns to scale have always created difficulties for economic theory. An economy with constant returns to scale is indeterminate with respect to the scale size of firms, and it is necessary to appeal to some fixed factor to determine the size of the economy. Increasing returns to scale leads to monopolies constrained only by demand. Behavior then becomes strategic and none of the standard welfare theorems that hold in competitive markets apply. Thus, it is not surprising that increasing returns to scale in an arms race leads to very different results than constant or decreasing returns to scale.

3. Changing Nature of Arms Races

There have been several major changes in the nature of the arms race over the last ten years. The most important has clearly been the end of the Cold War. This epochal change began with the emergence of independent states in Central and Eastern Europe and the end of the Warsaw Pact in 1989 and ended with the dissolution of the Soviet Union in December 1991. The result has been the end of the global East-West arms race of the Cold War period, with an end of global politics being dominated by the existence of such an arms race. Among the implications of this profound change, there have been drastic reductions in arms expenditures by states of the former Soviet Union and its former allies, accompanied by relatively smaller reductions in arms expenditures by the United States and its allies in NATO. As a result, the United States is currently by far the world leader in expenditures on arms, spending more than the next several nations put together.

Another major change over the last ten years has been the substantial increases in arms expenditures by China and its neighboring states in East and Southeast Asia. In China, the reforms that started as a result of Deng Xiaoping's four modernizations of 1978 profoundly changed the course of the country and its economy and society. The last of these four modernizations, however, was that of the military. It led to the rapid modernization of the Chinese People's Liberation Army (PLA), involving the deployment of newer weapons and major expenditures on arms. The neighboring nations of East and Southeast Asia have reacted to the developments in China by increasing their own arms expenditures. As a result, this region is witnessing major increases in arms, including substantial arms imports that have moderated but not stopped as a result of the Asian financial and economic crisis that began in July 1997.

The Arab-Israeli arms race has demonstrated a continuity in terms of continued qualitative and quantitative arms developments, including imports of arms and weapons technologies. The India-Pakistan arms race also continues with both qualitative and quantitative arms developments, both nations having demonstrated their nuclear weapons capabilities in tests conducted in May 1998. In both cases, third parties have played an important role. In the Middle East, the United States has provided Saudi Arabia with weapons, given financial and military assistance to both Israel and Egypt, and has shared anti-missile defense technology with Israel. China has shared nuclear and missile technology with Pakistan. While Russia can no longer afford to support the former client states of Soviet Union, it appears to be willing to sell weapons technology to any country that can afford it for purely commercial, as opposed to diplomatic or military, purposes.

An important change of recent years has been the appearance of certain newer or evolving regional arms races or arms buildups. One is the important arms race of the nations of the Gulf, including Iraq, Iran, Syria, Saudi Arabia, Kuwait, and the Gulf States, that was both stimulated by and resulted in wars in the region, including the Iran-Iraq war and the Iraqi invasion and annexation Kuwait, with the resulting war to liberate it. The major supplier of weapons to all parties in the region except Iran is the United States and its European allies. Second, there have also been arms buildups among the states of the former Soviet Union that are seeking to preserve their independence through their military capabilities. A third type of arms buildup is that in the former Warsaw Pact states of Central and Eastern Europe that have joined NATO or hope to do so and that have to upgrade their weapons capabilities to become members of the alliance.

The major weapons states have played an important role in fueling these and other regional arms races through arms exports, including the disposal of surplus weapons in the post-Cold War period. The United States, Russia, Germany, Britain and France are the leading suppliers of surplus weapons, while Turkey, Greece, Pakistan, Morocco and a number of Middle East countries are the main recipients of such weapons.

4. Impacts of Recent Changes on Stability

These changes in arms races over the last decade have had important impacts on the stability of both the regional and global systems. As a result of these changes, we believe that there are probably greater instabilities today than those of the earlier Cold War period.

Consider first the principal antagonists of the Cold War. Where there had earlier been two "superpowers," now there is only one such superpower as measured by arms expenditure and military capabilities,

the United States. Russia has assumed most of the Soviet weapons of mass destruction and the associated responsibilities involved with such weapons. The continued presence of nuclear weapons in Russia and the U.S., albeit at lower levels, is probably adequate for mutual deterrence, but there are great dangers inherent in the current unstable political, economic, and social situation in Russia. The result could be a loss of effective control of weapons of mass destruction, with the possibility of an accidental or inadvertent launch of such weapons. The disquieting similarities between Russia today and Germany in the Weimar Republic period between the wars, including loss of empire, inflation, depression, and the destruction of the middle class, suggest the possibility of the emergence of a new authoritarian leader in Russia, which would create additional instabilities.

Another major threat to stability at both global and regional levels is the proliferation of weapons of mass destruction. There is now much greater worldwide access to technology and required material for nuclear, chemical, and biological weapons stemming, in part, from the collapse of the Soviet Union and the desperate situation of its military and scientific establishment. There is also the continuation of chains of proliferation that started with the United States and continued with the Soviet Union, the United Kingdom, France, China, India, and Pakistan and that could continue to other nations, including those of the Gulf region.

Yet another threat to stability in the post-Cold War world is that of terrorists using various weapons of mass destruction. Subnational groups, motivated by extreme ideologies, religious fanaticism, or other causes, have much greater access to such weapons on world markets. Large urban

centers and freedoms of speech, travel, assembly, and the press have made modern societies highly vulnerable to possible terrorist attack.

5. The Future of Arms Race Theory

The classic Richardson model of arms races has dominated the theoretical work on this topic. In our own work, both individually and jointly, we have expanded this model to deal with the realities of arms races. It was necessary for us to start from the foundations of why nations would seek weapons and how wars do occur in order to develop a theory that would take account of behavioral decisions of defense decision makers seeking either to deter or to attack the other side. Our work in reformulating the Richardson model with a theoretical foundation has addressed such factors as maximizing behavior, bureaucratic decision making, alliance formation, multicountry stability, the balance of power, and proliferation. Our dynamic-economic model of the arms race has four components: a *technology* that describes the economic constraints faced by the country in terms of choices between consumption and investment in weapons; a *defense technology* that determines the level of defense capability in terms of the weapons held on both sides; a *learning technology* that describes how a country updates the information available to it, and a *choice function* that characterizes the choices made by the country, given the technology and information available to it, such as through the maximization of a utility function. Assuming that the updating process and the choice function are both continuous and that the choice sets are compact (closed and bounded for finite dimensional spaces), then it follows that there exists at least one equilibrium for the arms race, a result that follows from standard results of optimization theory.

The Richardson model has been the dominant paradigm for both theoretical and empirical studies of the arms race. However the Richardson paradigm may no longer be appropriate. Increasing returns to scale in the technology of arms production, as discussed earlier, and newer types of "smart" weapons that rely heavily on information, electronics, computers, and software, could change the dynamics of the arms race. Since information is a public good in the sense that its marginal cost is zero, producing weapons with a large informational component possibly implies an increasing returns to scale technology.

Recent developments, including the large-scale mergers of arms-producing firms, such as those producing military aircraft, highlight the importance of increasing returns in weapons production as these firms try to establish longer production runs to exploit these economies. Increasing returns technology in arms production, however, has rather different implications than a diminishing returns to scale technology that is typically assumed in economic models of the arms race. Increasing returns technology in an arms race implies there may not be a unique equilibrium. Rather, there may be multiple stable equilibria. One implication of such multiple stable equilibria is the possibility of a choice between equilibria. Thus, institutions such as arms control agreements that reduce weapons stocks to a lower equilibrium point should be incorporated in the modeling process.

Overall, arms races with increasing returns technology exhibit very different phenomena than those with constant or diminishing returns to scale technology. The assumption of constant or diminishing returns to scale technology results in choices that are marginal, as in the traditional choice between "guns and butter." In an economy where the technology is

characterized by increasing returns to scale and information, however, the production possibility set may be non-convex, and the important choices may be discrete. For example, in an arms race with multiple stable equilibria, the choice of equilibrium becomes an important question that may require consideration of the possibilities for arms control. Increasing returns to scale also creates the possibility that trade in weapons may be a Pareto dominant outcome in the arms race, again implying discrete choices.

We believe that much more will have to be done concerning the role of predictions or projections that each side in an arms race makes as to the opponent's changes in weapons stocks. It is necessary to investigate whether such predictions make an arms race more or less stable, and it will probably be necessary to bring to bear on this question some of the newer results of game theory, such as rational learning, subjective games, and evolutionary games. The behavioral assumption used in our early reformulations of the Richardson model that both countries behave in a myopic manner, without extrapolating changes in weapons stocks, made it easy to analyze the stability of the equilibrium. Under this assumption there exists an equilibrium level of armaments that is stable, while the disarmed state is unstable except under some very special circumstances in which behavior very similar to that of the Prisoner's Dilemma game will be observed. The assumption of myopic behavior is, however, very unrealistic. Clearly, military expenditures are based not only on the current arms level of the potential enemy but also on its projected levels.

A more realistic assumption would treat each country as using information about the current arms level and its rate of change to predict future levels. This projection, that can be revised periodically or

continuously, would then be used to plan current weapons acquisitions. Important recent developments in game theory, such as rational learning, subjective games, and evolutionary games, would permit the study of such issues. Much of this recent work uses repeated games with a finite strategy space. There are two changes that must be made to the basic model to use these results. First, the choice set of the players must be discrete. In the context of the arms race, this assumption is, in fact, more realistic than the previous assumption that the choice set is continuous. The other limitation of these models is that they are not Markov games and thus do not permit stocks. This is a more serious problem in that stocks appear to be an essential element of an arms race. The question is then whether the model can be reformulated in a fashion that is meaningful and yet permits one to use these new results.

If the parties of an arms race are Cournot/Nash players in that they are myopic with respect to the behavior of the other party, then they take this behavior as given. We have shown that in this case the dynamic equations for the arms race are given by generalized nonlinear Richardson-type equations that have a stable equilibrium. The nature of this equilibrium depends crucially on whether it is stable or not, and we have determined sufficient conditions for an equilibrium to be stable. To do so, it is necessary to specify how each of the two countries will react when the weapon stocks are not in equilibrium. The simplest assumption is that of myopic behavior, where each country reacts only to the current levels of weapons stock, disregarding information about the history of the levels of weapon stocks and the current rate of investment in weapons. This assumption was used by Richardson and others, and it is similar to the Cournot/Nash solution of the duopoly problem. We have proved that the

equilibrium point is stable if each country attempts to behave in such a myopically optimal manner. An open question is what assumptions are sufficient to transform this dynamic-economic model into a repeated game and what implications these assumptions would have on the properties of the model. If these assumptions do not change the essential dynamics of the arms race in the dynamic-economic model under the assumption of myopic behavior, then the new results in repeated games literature have the potential of providing insights into sophisticated behavior in arms race models. A sufficient set of assumptions that would transform the dynamic-economic model of an arms race into a repeated game is, first, that the choice set is discrete; second, that there are no income effects; and, third, that investment in weapons is reversible, i.e., that capital in weapons is putty-putty. The assumption that the choice set is discrete is not a serious issue as there is no limit to how fine the choice set need be. The defense budget could be specified to the nearest dollar. Thus, for any game with a bounded continuous choice set, there exists an equivalent game with a discrete choice set that approximates it.

The assumption of no income effects is less innocuous, yet this is an assumption that is commonly used in the cost-benefit and applied public finance literature. It is impossible, for example, to use consumer surplus unless a dollar is a dollar for everyone. The assumption of putty-putty capital is one that has been common in capital theory, and our conjecture is that this is not a very serious restriction in the proposed new paradigm for the arms race. Increasing returns to scale and the special role of information in weapons technology imply that it will be necessary to go beyond marginal analysis in the allocation of resources in acquiring or transferring weapons.

Overall, recent results from the theory of repeated games may provide the needed foundation for a new paradigm for the arms race for the twenty-first century in much the same way that the Maximum Principle and dynamic games provided a way of taking Richardson's equations from a heuristic explanation to a well-developed theoretical model that reflected the conditions of the twentieth century.

6. Conclusion

Overall, a great amount of work has been done in furthering our knowledge of arms races, but much remains to be done. Future work should extend insights into the nature of arms races and determine the nature of the interactions among the nations involved. In this paper we have defined the arms race and discussed related issues and questions; treated the changing nature of arms races in the last ten years; identified areas of both continuity and change in regional arms races; suggested that the implications of these changes has probably been greater instability than that of the earlier Cold War period; and, finally, discussed some gaps in the literature and some possible future theoretical developments for this subject. Of the possible future developments in this area, we believe that the most important are probably the applications of some of the recent developments in game theory such as rational learning, subjective games, and evolutionary games.

References

- Anderton, Charles H., 1985, "A Selected Bibliography of Arms Race Models and Related Subjects," *Conflict Management and Peace Science*, 8, 99-122.
- Brito, Dagobert L., 1972, "A Dynamic Model of an Armaments Race," *International Economic Review*, 13:359-375.
- Brito, Dagobert L. and Michael D. Intriligator, (1999), "Increasing Returns to Scale and the Arms Race: The End of the Richardson Paradigm?" *Defence and Peace Economics*.
- Brito, Dagobert L. and Michael D. Intriligator, 1996, "Proliferation and the Probability of War: A Cardinality Theorem," *Journal of Conflict Resolution*.
- Brito, Dagobert L. and Michael D. Intriligator, 1995, "Arms Races and Proliferation," in Keith Hartley and Todd Sandler, Eds., *Handbook of Defence Economics*, Amsterdam: North-Holland Publishing Co.
- Downs, George W. and David M. Rocke, 1990, *Tacit Bargaining, Arms Races, and Arms Control*, Ann Arbor: University of Michigan Press.
- Gleditsch, Nils Petter and Olav Njølstad, Eds., 1990, *Arms Races: Technological and Political Dynamics*, London: Sage Publications.
- Intriligator, Michael D., 1975, "Strategic Considerations in the Richardson Model of Arms Races," *Journal of Political Economy*, 83: 339-353.
- Intriligator, Michael D., 1982, "Research on Conflict Theory: Analytic Approaches and Areas of Application," *Journal of Conflict Resolution*, 26: 307-327.
- Intriligator, Michael D. and Dagobert L. Brito, 1984, "Can Arms Races Lead to the Outbreak of War?" *Journal of Conflict Resolution*, 28: 63-84.

Isard, Walter, 1988, *Arms Races, Arms Control and Conflict Analysis*, New York: Cambridge University Press,

Isard, Walter and Charles Anderton, 1985, "Arms Race Models, A Survey and Synthesis," *Conflict Management and Peace Science*, 8, 27-98.