Chapter 10

Arms Trade and Arms Races: A Strategic Analysis

by

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* The authors have profited from comments provided by Keith Hartley, Todd Sandler, Ron Smith and Asher Tishler on an earlier draft. The usual disclaimer applies.
1 Introduction

Within the Western Alliance during the Cold War military preparations had elements of a public good: the forces of one country had spillover benefits for other countries, thus arms transfers to allies could increase alliance capability and enhance inter-operability. In addition, having a domestic defence sector was seen as strategically important for home security. After the Cold War, security perceptions changed, with no clear adversaries and an increasingly costly domestic defence sector, there has been a tendency towards more concentration, rationalization and globalization of the defence industry. National champions now compete for a increasingly common exports market.\footnote{Kinsella (2003) uses social network analysis to demonstrate that increasingly weapon exporters share and compete in a common market, also see Brzoska (2004a) and Markusen (2002).} However, this process has not been identical in all countries. In some cases, such as in the former USSR, changing security needs have coincided with the difficulties in adapting to a whole new economic system.\footnote{See Davis (2002) for an analysis of the Russian defence sector.} Despite these changes, the defence industry is still unique in that arms exporters acknowledge that arms exports have a possibly negative impact on their national security. On the other hand, there is still a preference to maintain a domestic defence sector. Accordingly, the arms trade is heavily regulated with export controls and export subsidies often chasing contradictory objectives such as the promotion of a domestic defence industry and the limitation of arms exports and/or their quality so as to ensure national security. It is important to note that many weapon importers are involved in situations of conflict and arms races, another distinctive characteristic of the arms trade markets.

It is in this context that the arms trade literature has been developed. The economic analysis of arms trade described in this chapter has focused mainly on major weapon systems. The international markets in these are mainly considered to be imperfectly competitive. Accordingly, this literature has used elements of new trade theory, industrial organization and regulation theory with the added elements of security perceptions and (home biased) procurement to analyse how export control policies and industrial policies impact on national security, the structure of the defence industry and the welfare of importer countries [Anderton (1995, 1996)]. The empirical literature has contributed to provide a picture of the post Cold War evolution of
the arms trade markets and the security consequences of their existence.

The main research objectives within this literature have been (i) to provide a general framework for the analysis of arms trade markets that captures their main characteristics, such as, the strategic interaction between firms, governments of producer countries and decision makers in importing countries, (ii) to assess the impact of changes in security perceptions on variables such as the volume of arms exports, domestic procurement and the concentration in the international defence industry, (iii) to analyze the impact of the changing relationship between governments and their national champions on the ability to implement arms export controls, (iv) to examine the benefits of international coordination in security and industrial policies, and finally, (v) to analyze the impact of export controls on the welfare and proliferation incentives of importer countries.

This chapter is organized as follows. Sections 2 to 4 present the main stylized facts of the international defence industry through the main data sources and available empirical studies. Section 5 provides a general discussion of arms trade controls. Section 6 develops these regulation issues in the context of a non-technical overview of the recent arms trade models organized around research topics. Section 7 provides a technical presentation of a general model of the arms trade based on some of the reviewed papers. Finally, section 8 presents some concluding remarks and possible future lines for research.

2 Products and data: the facts

The arms trade literature is generally concerned with trade in security sensitive products. These are all those goods, services and technologies, which have potential military applications currently or in the future. They can be roughly divided into Weapons of Mass Destruction (WMD), typically nuclear; biological and chemical (NBC); major weapons systems; small arms and light weapons; dual purpose goods, which have both military and commercial applications (NBC and others); and services including intangible technology transfer, such as training of military and industrial personnel. Major weapons systems are relatively easy to monitor and measure. For instance, Congressional Research Service (CRS) (2005) reports that over the
period 2001-2004 weapon deliveries by Major Weapon suppliers\(^3\) to Near East Nations\(^4\) included 1677 armoured vehicles, 156 warships, 101 supersonic combat aircraft and 1887 surface-to-air missiles. All the other categories are very difficult to monitor and measure. The difficulties arise partly from problems of defining a product or service as military, e.g. how to classify a high powered rifle as military or sporting; partly because much of the trade is covert. Obtaining information on quantities of arms transferred is difficult enough, obtaining information on prices is even worse. Arms may be transferred free to allies,\(^5\) most contracts are very complicated including not only weapons, but also munitions, training, spares etc. and involve countertrade (barter) arrangements, financing by suppliers, and various types of offsets.\(^6\) Therefore, actual prices paid for weapons only partially reflect the real price of weapons. Arms transfers also tend to be ‘lumpy’, exports or imports may be large in a particular year just because of a particularly large delivery, so figures can fluctuate from year to year.

Two main sources have traditionally been used in the analysis of the arms trade markets, namely, the Stockholm International Peace Research Institute (SIPRI) and World Military Expenditure and the Arms Trade (WMEAT), previously provided by U.S. Arms Control and Disarmament Agency (ACDA), more recently by the Bureau of Verification and Compliance of the State Department. Both sources have advantages and disadvantages as discussed in Smith and Tasiran (2005). SIPRI provides yearly data on the volume of transfers of major weapons systems, not including transfers of small arms [SIPRI yearbook (2005)]. It is a volume measure because quantities are multiplied by trend indicator values not the prices actually paid. WMEAT provides value of transfers, therefore, taking account of prices actually paid, and includes small arms. Although WMEAT’s data reports were discontinued in 1999, the reports from the U.S. Congressional Research Service can be used as a substitute [CRS (2005)]. These reports offer up-to-date data on arms transfers to developing nations in value. The CRS report gives separate data on arms transfer agreements (i.e., arms or-

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\(^3\)These include U.S., Russia, China, European and all others, the disaggregated data can be found in CRS (2005).

\(^4\)These are Algeria, Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Qatar, Saudi Arabia, Syria, Tunisia, United Arab Emirates and Yemen.

\(^5\)Although this is now increasingly less frequent: see Brzoska (2004a).

\(^6\)For a review and examples of the defence literature on offsets see Brauer and Dunne (2002, 2004).
ders) and arms transfer deliveries, whereas SIPRI focuses on arms transfer deliveries.

Table 1 compares value, from CRS, and volume, from SIPRI, of arms transfers in the period 1997-2004. The third column gives a ratio between the two. Changes in this ratio could be seen as an indicator of changes in the price of transfers but could be treated as indicating measurement errors [Smith and Tasiran (2005)]. The ratio does not have any trend in it, ranging from 2.4 in 2000 to 1.8 in 2001. Both series tell a broadly similar story, with transfers tending to fall between 1997 and 2002, and increasing thereafter. Figures for exports or imports for individual countries tend to show larger differences.

Tables 2 and 3 give top world wide suppliers’ arms transfer agreements and deliveries and the percentage of those transfers going to developing countries. It can be seen that the majority of arms transfers go to developing nations (58.90% of total agreements and 64.60% of total deliveries). Indeed, the relative importance of the developing countries as an importer market has been increasing in the past few years. Both agreements and deliveries to developing countries in 2004 have been the highest total since 2000 [CRS (2005)]. In 2004, the United States ranked first in both arms transfer deliveries and agreements to the developing world, a market which has been jointly dominated by Russia and the U.S. since 2001. Tables 4 provides data on the leading recipients of arms transfer deliveries in the developing world. Most of those countries are either involved in conflict or an arms race with a neighboring country. To conclude, even though the available data are neither comprehensive nor perfect, it is clear that the international structure of the defence industry is such that a few developed countries are the main weapon exporters and producers and their production is at least in recent times increasingly dependent on imports from developing countries, many of which are involved in regional or internal conflicts.

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8 This could be a sign of a lesser preference for domestic production together with the increasing costs of developing new generations of weapons. It could also be the result of an increase in conflict in developing countries relative to developed countries. As will be seen later, the arms trade literature tends to represent non arms producer countries as being involved in an arms race with similar countries.

9 The data on arms agreements provides a similar set of countries.
3 Demand for arms imports

The demand for arms of various types is influenced by security perceptions of internal or external threats and by price and income, which determine what a state can afford. States then choose whether it is more cost effective to develop and produce the weapons domestically; develop and produce them in collaboration with other countries; to produce under license systems developed elsewhere; or to import the desired arms. The decision to import is not a one off: it generally implies agreement from the seller to provide technical assistance and therefore, it involves a certain dependence between importer and supplier. If they decide to import, they have to choose between competing systems available on the world market. Bribery and corruption are endemic in the arms market and a policy issue for supplier countries is to what extent they take anti-corruption measures [Gupta et al. (2001), Berryman (2000)]. However, prices matter and the main factor constraining the proliferation of major weapons systems is that few countries can afford them. Smith and Tasiran (2005) provide econometric estimates of the demand for arms imports as a function of domestic military expenditure (a proxy for the threat\textsuperscript{10}), a measure of price\textsuperscript{11} and the income of a country. On these estimates, demand is sensitive to price. For a constant threat, a one percent increase in price causes a roughly one percent fall in the quantity of arms imports demanded (also see Levine et al. (1998)).

Changes in demand side factors may affect the demand for weapons. The most common economic model used to model non producer country demand for weapons is an arms race between two antagonists. A peace agreement or a decrease in perceived threats will reduce demand for weapons.

4 Supply: the arms industry

Defence industries have the characteristics of both a military and economically strategic industry. They are economically strategic in terms of R&D intensity, spin-offs and decreasing unit costs reflecting both economies of scale

\textsuperscript{10}Domestic military expenditure will in general depend on the allies and adversaries’ military expenditure, the perceived threat and the weight given to security in the welfare function, among other variables. The theoretical models of arms trade analyze some of these issues in detail.

\textsuperscript{11}They use as a proxy for prices the ratio of value of exports (using data from WMEAT) to quantity of exports (using data from SIPRI).
and learning [Sandler and Hartley (1999), and Hartley and Sandler (2003)]. With high fixed \( R&D \) costs and decreasing unit production costs, output is a major determinant of unit total costs. Disarmament following the end of the Cold War resulted in fewer new projects and smaller national orders led to pressures for defence companies to seek export markets and reduce costs.\(^\text{12}\)

Changes in the demand for domestic procurement happened at a time when technology and government attitudes towards domestic production and ownership were already leading to changes on the supply side. There was an increase in \( R&D \) as a proportion of total production costs within the companies, as companies responded to technological imperatives (i.e., the need to maintain a technological edge with respect to competitors and potential adversaries) and contracted out component production to reduce costs. Changes in security perceptions led to the questioning of the strategic need for a domestic defence industrial base, making producer nations more willing to import, this forced defence firms to compete in an increasingly globalized arms trade market. Also, in response to cost pressures, arms producers have increasingly been using components that are commercial ‘off-the-shelf’ (COTS) products, produced by manufacturers that would not see themselves as part of the arms industry [Klein (2001), and Kulve and Smit (2003)].

As a consequence of the above changes, the structure of the defence industry also changed. Analysing the data on the major arms producers, Dunne et al. (2003) show that although at the end of the Cold War the international arms industry was relatively unconcentrated, concentration increased markedly in the 1990-98 period, although this is proven not to be associated with increases in the average size of firms. Still, as argued in Dunne et al. (2003), the defence industry remains relatively unconcentrated if we compare it with other similar civilian industries.

At the same time, there have also been changes to the nature of the relationship between governments and the defence firms. In the past, it was common for national arms firms to be almost an extension of the state, and they were often publicly-owned. There has been a trend for increasing independence between governments and national arms firms, a move that was initially taken to improve the efficiency of weapons production. Such a situation has increased the importance of the strategic interaction between firm and government and the relevance of asymmetric information issues.

\(^\text{12}\)Kirkpatrick (1995, 2004) analyzes other factors behind the cost pressures in the defence industry.
Strategic interaction between parties happens when the decisions of any one party affect the payoffs of the other party. In arms trade markets, strategic interaction happens not only between domestic firms and government but also between foreign firms and governments (foreign sales may affect both domestic firm profits and domestic security) and also between the different governments (other governments’ regulations will affect domestic welfare).

Game theory models illustrate how information differences between the different parties to a transaction (asymmetric information) can lead to a range of market failures, cases where markets cannot be relied upon to allocate resources efficiently. As governments use domestic defence procurement contracts to interact with their increasingly independent domestic defence suppliers, uncertainty over the firm’s costs and the quality of their production becomes an obstacle in the achievement of efficiency. Of course, even when the firm is owned by the state, the firm may capture the part of government nominally controlling it and producer interests come to determine policy. Also, there is still an asymmetric information problem between the public firm manager and the government. But, uncertainty becomes more of an issue as competition in the international arms market grows, defence firms become more internationalized, and collaborative projects between countries become more common. The relevance of uncertainty is then extended to the costs and quality (both produced and exported) of foreign firms and the weighting that other governments might give to security or firm profits when choosing their regulation tools.

It is these different interactions and the trade-offs with governments having to choose between support for their domestic defence industries and their concern with the possible impacts of arms exports on national security that makes the arms industry unique. The following section discusses such trade-offs.

5 Regulation

The arms trade is subject to more extensive controls than trade in most other goods. Producer countries use a number of instruments to regulate the arms trade: these are basically either arms export controls and industrial policies such as production, R&D and export subsidies.

Unilateral national export control systems are the foundation for multilateral controls, which vary from relatively informal clubs of suppliers, to
very formal systems embodied in treaties and involving extensive monitoring systems like that associated with the nuclear Non-Proliferation Treaty (NPT).\textsuperscript{13}

We can divide export controls into quantitative and qualitative controls.\textsuperscript{14} Quantitative export controls include total or partial restriction of weapons exported to a single country or a group of countries. Qualitative export controls include controls on the transfer of state-of-the-art technologies that allow exporter countries to maintain a technological edge over potential adversaries, and controls on the transfer of very sensitive technologies.\textsuperscript{15}

When regulating the arms industry, weapon producers have a variety of security and economic objectives, which are often in contradiction. Producer countries may see the exports market as a means of achieving profits that may help cover part of the increasingly high development costs of new weapons and retain a domestic defence sector. As security sensitive goods are exempted from WTO rules, countries are free to set whichever trade policies maximize their own objectives [Markusen (2002)]. The imperfectly competitive nature of the market in major weapon systems provides unilateral incentives to set strategic trade policies that often involve export subsidies. In addition, domestic procurement can also act as an indirect export subsidy by itself in the presence of increasing returns to scale. In other words, domestic production and exports would be complements rather than substitutes [García-Alonso (1999)]. However, the very existence of the arms exports market generates a potential negative impact on the national security of the exporter countries. For instance, an importing nation might be a future threat to the exporting nations either directly or through regional conflicts which involve the exporting nation (Iraq is just a recent example). In addition, arms transfers may create internal conflict and poverty that requires international help involving exporting nations [Blanton (1999), Craft and Smaldone (2003), Sanjian (2003), and Wang (1998)]\textsuperscript{16}.

\textsuperscript{13}The SIPRI yearbooks provide updates on existing export control agreements. García-Alonso and Smith (2006) provide a non-technical review of the subject.

\textsuperscript{14}See Panofsky (1990) for a similar classification.

\textsuperscript{15}An example of this is that, when exporting advanced systems, the US often ‘black-boxes’ the software, not providing the source code, so the buyer cannot find out how the system works or change it. The UK Ministry of Defence could not use the Chinook HC3 helicopters because it was unable to verify the software (NAO, 2004).

\textsuperscript{16}Kinsella (1998) argues that the dependency generated between client and supplier of weapons may counteract the negative effect of arms exports on regional conflict. However, as Kinsella himself acknowledges the post-Cold War common exports market predict a
The quality of the exported weapons, not just the quantity, may become a security issue for exporter countries. Already during the Cold War adversary powers extended their technological rivalries to the importers they chose to support, even though state of the art weapons were not transferred. The situation in the post-Cold War era has changed in many respects: arm suppliers face an economic profit incentive to compete for the now more globalized exports market. The 'unintended' security consequence of this situation is that competition in quality for export markets generates a further incentive to improve military technology so as to preserve the gap between domestic state of the art technology and exported technology. Buzan and Herring (1998) refer to the forces behind this process collectively as the 'technological imperative' (see also Kinsella (2001)). In this sense, the restriction of exported quality is often chasing a moving target: the state-of-the-art technology. This makes the regulation of the arms trade ever more complex. In addition, the increasing use of dual-use technologies and military-civilian partnerships so as to rationalize arms production is making military goods more difficult to define and therefore, export controls more difficult to design and implement. A significant example is that of digital information technology. Most of the recent military developments in this field actually derive from initial civilian innovation, dissemination of this dual use technology is fast and difficult to control [Smith and Udis (2001), and Stowsky (2004)].

There has been a substantial debate about the extent to which arms export sales have been subsidized by supplier governments or in other words, how much the profit objective of producer countries has been given more weight than their security objectives. Ingram and Isbister (2004) argue that arms exports are bad for Britain, both because of the subsidies and the distortion of procurement choices. Chalmers et al. (2002) provide a detailed estimate of the benefits and costs of maintaining UK defence exports and suggest that even the economic effect of a reduction in arms exports are rather small and mainly a one-off (also see Martin (1999)). However, Chalmers et al. (2002) argue that the impact of the arms exports industry on national welfare should include not only economic factors but also the impact of exports on security, and this empirical analysis is a much harder task to perform.

As already mentioned, industrial policies that aim to increase domestic
firm export profits and export control policies that aim to increase domestic security are often in contradiction: whilst export controls tend to increase the cost of imports to the potential acquiring country, export and production subsidies do the opposite, therefore, encouraging arms exports. Also, R&D subsidies may exacerbate the technological imperative problem. However, there may be circumstances in which policies that aim to limit arms exports also enhance firm profits. Supplier cartels may have a positive impact on both export profits and the exporter security (via a reduction in exports). These issues will be further explored in sections 6 and 7.

6 An non-technical review of the arms trade models

As discussed in section 5, the arms trade problem involves a number of agents interacting in pursuit of different, sometimes contradicting, objectives. Whereas governments care for their domestic firms they also have security objectives. The existence of intra-country and intra-firm strategic interaction usually leads to the global first best not being achieved, therefore, resulting in a need for the international coordination of national policies. Such coordination is difficult to achieve since enforcement of agreements is required but punishments are not always credible.

The New Trade literature illustrates the problems involved in countries independently aiming to support their own domestic imperfectly competitive industries. Multiple stage games portray governments that commit to a policy tool (e.g., an export subsidy or a production subsidy) prior to firms competing in the international market. The arms trade literature has tended to take this as a suitable framework for the analysis of markets for major weapon systems and possibly some dual use goods. There is the added difficulty involved in having a more complex imports demand side, often characterized by regional arms races, and also, by there being an added layer of strategic interaction between exporter governments who also want to optimize their security objectives.

The majority of arms trade models are characterized by multiple stage games in which first governments commit to arms control and industrial policies, second, firms aim to maximize profits by choosing either, prices, quantities or R&D investments and finally importer countries choose their
imports, the market clears and world prices would be determined. Different models tend to focus on different aspects of the arms trade: the benefits of coordination, the impact of changes in the country’s security perception on the arms trade and security itself, R&D policies, the impact of the exporter policies on importer governments welfare and decisions on home production or the determinants of the structure of the industry itself.

To summarize, global arms trade models covering industry exports and arms races must address and specify a large variety of model characteristics. Among them are: (i) the definition of security, (ii) the definition and scope of adversaries in the model, (iii) the relations between the governments and the defense firms in the arms-producing countries, (iv) the scope of the arms races among countries other than the arms-producing countries, (v) the procurement rules (methods of pricing of the defense goods) in arms-producing countries, (vi) the nature of the international market interaction between exporter firms, (vii) the variety of defense goods, and (viii) the decision rule that governments follow in determining their security level. In what follows, we provide a non-technical review of recent arms trade models organized around their research topics.

6.1 Supplier objectives and the benefits of coordination

Recent papers that study the arms trade tend to represent the welfare of supplier governments as a function of security, itself a negative function arms exports and/or their quality. Arms exports are presented as generating a negative security externality on the exporter country and also a negative externality on other countries, although exports to allies may have positive externalities. Depending on the type of product to be studied, the arms trade models use different functions of international weapon exports and their quality to give a representation of security for the exporter country; also, security concerns may vary among exporters.

When producer countries decide on the amount or quality of weapons exported in a non-cooperative way, even if they share the same antagonists, they each export more than they would jointly have decided to export if they could have implemented cooperation. The reason is that countries only care about the negative impact that the exports have on their own security, in other words, they maximize their individual welfare functions. This is
A typical characteristic of negative externalities which also arises in other contexts such as CO$_2$ emissions.\textsuperscript{17} The added difficulty in the arms exports market is that these strategic interactions between exporters happen not only at the security level but also at the purely market competition level.

Countries competing in the exports market have unilateral incentives to give export or R&D subsidies so as to increase their market share. This may result in both less security and less welfare for both exporter countries and recipients. Dunne et al. (2005), García-Alonso (1999, 2000), García-Alonso and Levine (2004), and Levine and Smith (1995, 1997a, 2000b) provide examples of models that capture these interactions. An exporter may even create a technological arms race with itself, having to develop new generations of weapons that are superior to the ones that it previously exported. The inability of producer countries to coordinate in setting of export controls can sometimes lead to almost counter-intuitive situations. For example, a security concerned country might want to subsidize the development of sensitive technologies and then prohibit their exports. This would give their domestic firms a quality edge over firms in less security concerned countries. This quality edge would decrease the competitors’ incentive to invest in new technologies since they would be likely to be “beaten” in the exports market should they decide to develop them anyway [García-Alonso (2000)].

Although the noncooperative equilibrium among exporter countries is inefficient, cooperative agreements are often difficult to enforce. There are a number of specific factors affecting the incentives of individual countries to defect from multilateral export control agreements such as information asymmetries (within and between countries), the structure of the arms exports market (profits to be made out of weapons exports), asymmetry of security concerns among exporters, different discount rates of long-term security consequences, the number of countries having access to the restricted military product, the type of weapon to be controlled, the monitoring capability of the control system or the credibility of punishment strategies on defecting firms/countries [García-Alonso and Hartley (2000), Smith and Udis (2001), and Sandler (2000), (2004)].

As mentioned in section 5, agreements that decrease the quantity of weapons exported are not always export control agreements as such. Cooperative agreements among exporters such as cartels and international mergers

\textsuperscript{17}The externality discussed is also analogous to those associated with counterterrorism as shown in the Sandler and Arce Chapter 6 of this handbook.
would tend to increase export prices and therefore decrease exports in the same way as export taxes or direct export controls. Levine and Smith (1995, 1997a) provide an analysis of cartel agreements (see section 7 for a technical presentation of these models). Mergers and cartelisation also reduce the number of potential deviators and decrease asymmetric information issues therefore reinforcing export control agreements. However, it is important to note that these and other collaborative agreements among weapon producers, such as research joint ventures, might result in higher R&D investments. We then have higher levels of potential quality that could be exported. Therefore, cooperation between firms alone could result in more quality being exported unless combined with direct qualitative export controls [Dunne et al. (2005)].

Another example of an agreement that could in principle help export controls is for arms trade to be included within WTO rules prohibiting export subsidies. The fact that the arms industry has been exempted from WTO rules would tend to produce more arms exports than otherwise, as individual producer countries have incentives to give export subsidies. In addition, these subsidies may increase the incentives that individual producer countries would have to defect from standard export control agreements as a given deviation may then result in higher increases in profits [García-Alonso and Levine (2005)]. Finally, Brzoska (2004b) discusses the use international taxation of arms exports as a means of reducing the arms trade. A multilateral exports tax will have similar effects to that of a cartel or a prohibition of export subsidies; higher export prices and therefore, less exports. The elimination of export subsidies may be the easiest to rationalize from the suppliers’ perspective, since it would also increase export profits, if done multilaterally, and would be consistent with already well established trade rules. The arms export’s tax suggested by Brzoska (2004b) would go a step further as revenues from taxation would go to an international fund. Such fund would be used to palliate some of the negative effects of conflict. This arrangement would be more difficult to implement as it would require a credible commitment to both taxation and revenue transfer to the fund. However, it exemplifies the idea that, like pollution, arms trade generates a negative externality on all countries, which the exporter countries must acknowledge.

Still, as we will see in the following section, supply side agreements will often not be enough to control arms proliferation.
6.2 Demand for imports and responses to regulation

The overall effect of export controls on the welfare of an importing country is complicated. Although qualitative or quantitative export controls may reduce conflict,\footnote{Levine and Smith (1997b) show that the price of arms exports has an important influence on the stability of regional arms races among importers.} if applied to all parties involved, the increase in the cost of acquiring these military products (sometimes prohibitory) will reduce consumption not just of weapons but also of other goods, especially if the price elasticity for weapon imports is low. However, the positive impact on security can offset the negative impact on consumption, so resulting in a positive welfare effect even though in some cases it must be combined with income transfers to importer countries [Levine and Smith (1995, 1997a, 2000b) and Dunne et al. (2005)].

Even if the welfare of importer countries was increased via export controls or exporter cartels, importer countries may still have an incentive to unilaterally search for alternative ways to build military capability that would give them an edge with respect to their adversaries. The problem of course being that their adversaries would do exactly the same resulting once again in conflict escalation. It is this situation that explains why export controls can sometimes have unintended consequences. States subject to embargo or control, or who fear that they may be subject to embargo in the future, may develop their own arms industry to produce the weapons that they cannot import. In addition, other potential exporters with less security concerns might have incentives to develop their own exports industry in face of other countries’ export controls. For instance, the US embargoes on Latin American countries during the Carter Presidency proved a major incentive for countries like Brazil to set up their own industries, partly financed by exports. To try and avoid this, export control regimes are usually associated with measures to prevent the diffusion of the relevant technology to other states (e.g. the Missile Technology Control Regime). This raises the cost of acquiring domestic production, but rarely makes it completely impossible. Levine and Smith (2000a), Levine et al. (2000) and Mouzakis (2002) discuss the interaction between export controls and proliferation (see section 7 for more details). Also, Golde and Tishler (2004) and Mantin and Tishler (2004) argue that an increase in world prices could crowd-out countries in the developing world from the market for modern weapon systems and may force them to develop and use 'cheap and dirty' weapon systems. The concern
over the limited ability of export controls alone to deter proliferation is also voiced by Brauer (2000) who suggests that supply side controls alone are not enough to avoid proliferation: they must be combined with measures to reduce the demand for weapons.

6.3 The arms industry

The arms trade literature has analyzed the changing security needs of exporter countries which have affected the characteristics of the international arms market and the ability of producer countries to implement export controls. Governments in exporter countries are increasingly treating defence providers as any other procurement provider. Arms trade models have reflected this by treating governments and defence firms as independent decision makers who interact strategically with both competing firms and governments. Also, as previously said, governments now often face an information asymmetry, not only with respect to its own firms but also with respect to the firms and governments of other exporter countries. This issue has also been studied in the literature. The lack of transparency between governments and national champions over the quality exported generates incentives on the side of profit maximizing firms to export forbidden technologies or export to forbidden countries. This would force governments to introduce a penalty system strong enough to discourage firms from infringing export controls. However, the existence of limited liability on the side of possible infringers of export control regulations imposes constraints on the implementation of such punishments. Governments may be unwilling to drive firms into bankruptcy: therefore the expected value of cheating to the firm is increased, because the penalty if they are caught is smaller. Asymmetric information may not always have negative effects on the implementation of export controls. If the source of asymmetric information is the procurer government being unsure about the cost-effectiveness of the domestic firm, the quantity of exports may decrease. The reason for this is that it will be more difficult for the government to give incentives for firms to behave efficiently.

\footnote{As an example of this, we have the French embargo on Israel, announced in 1967, as one important catalyst to the development of the Israeli defense industry [Shefi and Tishler (2005)].}

\footnote{See Laffont (1995) for an analysis of this issue in the environmental literature context.}

\footnote{This is an important issue for the defence sector where maintaining a domestic defence base is still seen as a matter of strategic importance, although increasingly less so.}
This will result in costs being higher and therefore, optimal prices going up and equilibrium exports going down [García-Alonso and Levine (2005)]. Another example of a positive effect of asymmetric information on export controls (broadly defined) would be the case when the importer government is unsure about the quality of the imported military product or whether future replacement needs will be covered [García-Alonso, Levine and Morga (2004)]. In principle, this will reduce imports demand, however, it may also increase the incentive to develop a domestic defence industry.

The changes in the concentration in the defence industry have also been studied in the arms trade literature. Dunne et al. (2005) construct a model of the global arms industry linking concentration, military procurement, international trade and regional conflict with endogenous market structure and quality. Concentration is proven to depend on the willingness of producers to import for their military needs and on the relative size of the external market of non-producers. Increases in concentration can be explained by either increases in openness or increases in the importance of the external market. In the data section, we observed an increase in the proportion of arms imports by developing countries, mainly nonproducers, this could be identified with an increase in the importance of the external (nonproducer) market relative to the developed producer countries, the decline in the demand for weapons could be one of the reasons behind this trend. The paper also analyzes other factors that influence the number of firms such as cooperation among producer countries and changes in R&D costs.\footnote{A version of this model is presented in Section 7.4 of this chapter.}

Other papers analyze the structure of the global arms industry. Golde and Tishler (2004) analyze the international military markets with exogenous market structure. They conclude, using a two producer bloc multiple stage game model that net defence costs are lower when the number of defence firms is lower. Blume and Tishler (2000) provide a simple model of endogenous market structure for the military sector where firms produce homogeneous goods and the government exogenously decides to procure identical quantities from all domestic firms. They analyze the impact of different procurement pricing rules on world arms trade, net defence costs and government defence expenditure. They also conclude that a lower target security level results in a smaller number of defence firms. Mantin and Tishler (2004) model the interactions between the defense needs of the USA and Western Europe, which produce several heterogeneous defense goods and the defense industry
market structure. They show that net defense costs of the USA and Europe are lower when the number of defense firms is small and when the world prices of the defense goods are high.

The papers reviewed in this section have illustrated the complexity involved in studying the arms trade. We have seen that the nature of the exporters interaction in setting export controls and export policies raises the benefits of coordination in both export control and industrial policies. We have also seen that a failure to coordinate in one of these two policies tends to increase the incentives to deviate from an agreement to coordinate in the other policy, therefore, highlighting the importance of a unified approach to arms trade regulation. Issues such as, differences in the security perceptions of exporters, the home bias and the characteristics of the competition between exporter firms may all make the implementation of export controls ever more challenging. Interestingly, although uncertainty will generally make matters worse, it may not if it decreases the effort that exporter firms put into producing higher quality weapons.

We have also argued that supply side regulation will not be enough to prevent arms proliferation among initially non-producer countries, even if, supply side controls may have a positive impact on the importers’ welfare.

Finally, we have seen how some of the reviewed models provide a rational for the evolution of the arms trade markets in the last few decades. A formal analysis is provided in the following section.

7 A formal model of the arms trade

Drawing upon the non-technical overview of the literature in the previous sections, we now present a formal model mainly based on work by Levine and Smith (1995, 1997a) and Dunne et al. (2005). We describe the process by which optimization by buyers and sellers within a particular supply regime will result in the determination of prices and quantities. Then the collective action problems suppliers face in establishing an arms export control regime are discussed. Finally, we generalize the model to allow for an endogenous number of firms producing distinct military technologies and we use this to examine the determinants of market structure in the military sector.
7.1 The basic model

Suppose the world can be divided into two groups of countries. There are a large number of buyers, each of whom are involved in a local arms race with a neighbor (e.g. India and Pakistan, Greece and Turkey). Buyers involved in arms races are indexed by \( b = 1, 2, ..., r \). There are a small number of suppliers, indexed \( s = 1, 2, ..., \ell \) who have the capability to build major weapons systems. The suppliers also have global security interests (e.g. through their foreign direct investment).

7.1.1 Demand side

On the demand side buyers maximize an multi-period discounted welfare \( U_{bt} \) from time \( t \) into the future:

\[
U_{bt} = \sum_{i=0}^{\infty} (1 + r_b)^{-i} W(C_{b,t+i}, S_{b,t+i})
\]

where \( W(\cdot) \) is a single-period utility function of security, \( S \), and consumption, \( C \), and \( r_b \) is their discount rate. Their antagonist in the \( b \)th arms race, denoted by a star, has a similar welfare function determining \( U_{bt}^* \). Security depends on the the buyer's military capability and that of its antagonist. In general military capability is a function of military personnel and the accumulated stock of arms. If there is little substitution between labour and arms then military capability is simply a function of the the stock of arms and we can write the security function as:

\[
S_{bt} = S(K_{bt}, K_{bt}^*),
\]

with \( \partial S/\partial K > 0 \), \( \partial S/\partial K^* < 0 \). The stock of arms depends on investment in imported, \( M_b \), and domestic weapons, \( D_b \), and depreciated previous stock:

\[
K_{bt} = f(D_{bt}, M_{bt}) + (1 - \delta)K_{b,t-1}.
\]

\( f(D_{bt}, M_{bt}) \) measures the contribution to the military stock from imported and domestic arms, respectively.

A convenient general form of the military stock function is a CES form:

\[
f(D_{bt}, M_{bt}) = \left[ w_b D_{bt}^{\sigma-1} + (1 - w_b)M_{bt}^{\sigma-1} \right]^{\frac{\sigma}{\sigma-1}}
\]

\[23\] A similar model is used in chapter 9 in this handbook.
where $\sigma \in (0, \infty)$ is the elasticity of substitution between domestically produced and imported arms. As $\sigma$ approaches zero we tend to a Cobb-Douglas function $f(D_{bt}, M_{bt}) = D_{bt}^{w_{b}} M_{bt}^{1-w_{b}}$, indicating that they are imperfect substitutes, while as $\sigma$ approaches unity they become perfect substitutes with $f(D_{bt}, M_{bt}) = w_{b} D_{bt} + (1 - w_{b}) M_{bt}$. The budget constraint is:

$$Y_{bt} = C_{bt} + p_{bt} D_{bt} + P_{t} M_{bt}$$  \hspace{1cm} (5)$$

where $Y_{bt}$ is total output, $p_{bt}$ and $P_{t}$ are the per-unit cost of domestic and imported arms, respectively. The binding participation constraint for the domestic firm is:

$$p_{bt} D_{st} - c(D_{st}) = 0$$  \hspace{1cm} (6)$$

where $c(\cdot)$ is the cost function.\textsuperscript{24}

The optimizing choices of the buyer and its antagonist, described in a similar way, then jointly determine a Nash equilibrium in arms subject to their available output and the price of imported and domestic weapons. This is discussed in Levine and Smith (1995) where following Anderton (1990), it is assumed that (2) is linear, and there is no domestic production by buyers engaged in local arms races. The steady state of the Nash equilibrium in this dynamic game is illustrated in Figure 1 for the case where there are positive fixed benefits from defence (i.e., the defender has an inherent advantage). BN and AN are the linear reaction functions\textsuperscript{25} for countries 1 and 2 respectively, and N is the unique Nash equilibrium. The indifference curves of country 1 corresponding to the highest utility given $K_{b}^2$ are shown which map out BN. Similarly the indifference curves of country 2 corresponding to the highest utility given $K_{b}^1$ map out AN. The shaded area under the indifference curves of the two countries passing through N are points that raise welfare for both countries (i.e., are Pareto-improving) and the welfare-maximizing levels of military stock is zero at 0 in Figure 1, or total disarmament.\textsuperscript{26}

\textsuperscript{24}This specification of the cost function assumes the same good is produced for domestic use and exports, and that factor prices are given to suppliers when making decisions affecting arms production and trade (i.e., the model is of a partial equilibrium variety).

\textsuperscript{25}If the reaction functions are non-linear there may be multiple equilibria

\textsuperscript{26}Complete disarmament is only the efficient outcome if there are fixed benefits from defence. If there are fixed benefits from attack so that the attacker has an inherent advantage, then although the Nash equilibrium still sees the country spending too much on arms, total disarmament is no longer the efficient outcome (see Levine and Smith, 1995).
Thus the Nash equilibrium will in general be inefficient because of coordination failure. Countries can increase their security by increasing military capability; but one country’s security is its rival’s insecurity. Security is a negative externality which both countries appreciate. The countries can do nothing to avoid this externality in the absence of a credible coordination mechanism. An arms control regime between regional rivals that jointly agreed on levels of military capability would internalize this externality and result in lower military expenditure and imports of arms, but given their antagonism they cannot agree to such a regime. With multiple equilibria there may be possibilities of moving from the highly armed to a lower armed Nash equilibrium.

This game generates a demand function by the buyers for imported arms as a function of price, the threat from the antagonist, and available output. Econometric estimates of such demand functions in Levine, Mouzakis, and Smith (1998) using cross-section data estimate a significant negative price elasticity of demand. Price is also important for the dynamics of the arms race. If increasing demand increases price, the usual case, the feedbacks would tend to stabilize the arms race. If there were significant increasing returns to scale in weapons production, increased demand could reduce price causing destabilizing feedbacks or the multiple equilibria discussed by Brito and Intriligator (1999).

7.1.2 Supply side

On the supply side, seller governments maximize a similar welfare function:

\[ U_{st} = \sum_{i=0}^{\infty} (1 + r_s)^{-i} W(C_{s,t+i}, S_{s,t+i}). \] (7)

However, because of their global rather than regional concerns, their security depends on stocks of arms throughout the world (i.e. the stocks of each pair of buyers, \( b = 1, 2, ..., r \) and each of the suppliers, \( s = 1, 2, ..., \ell \) including itself:

\[ S_{st} = S(..., K_{bt}, K_{bt}^*, ..., K_{st}, ...). \] (8)

In many post-Cold War situations (e.g. the Gulf War and former Yugoslavia) increased regional stocks of arms have a negative effect on supplier security, \( \partial S_s/\partial K_b < 0 \), and other suppliers are allies whose arms stocks have a positive effect, \( \partial S_s/\partial K_s > 0 \). In this case, from the suppliers point of view both arms
exports and military expenditure, by itself and by the other suppliers, have security externalities. The decisions of producers involving domestic military capability and the exports of arms results in a public good in the form of their common regional security. It is non-excludable (no country can be excluded from ‘consuming’ high regional security) and it is non-rival (its ‘consumption’ does not reduce the amount available for others).

Suppliers can also import arms so, as for buyers, stock is given by:

\[ K_{st} = f(D_{st}, M_{st}) + (1 - \delta)K_{s,t-1}. \] (9)

The budget constraint is:

\[ Y_{st} = C_{st} + p_{st}D_{st} + P_tM_{st}. \] (10)

Notice that the budget constraints (5) and (10) are balanced trade conditions.

Unlike buyers, suppliers export arms choosing a level of exports, \( X_{st} \), and set the domestic price of arms, \( p_{st} \), to maintain domestic production capability given their demand, export demands and costs. The participation constraint of the domestic firm is then

\[ p_{st}D_{st} + P_tX_{st} - c(D_{st} + X_{st}) - F = 0, \] (11)

where \( c(\cdot) \) is the variable cost function and \( F \) are fixed costs. For buyers exports of the consumption good finance arms imports; for sellers arms exports finance imported consumption. Suppliers then jointly determine \( X_{st} \) and \( D_{st} \), \( s = 1, 2, ..., m \) subject to their outputs, demand and market structure. The world price of arms, \( P_t \), then adjusts to clear the market so that

\[ \ell + r \sum_{b=1}^{\ell+r} (M_{bt} + M_{bt}^*) = \sum_{s=1}^{\ell} X_{st}. \] (12)

This framework is too general to get explicit analytical solutions, but a number of special cases have been considered in the literature. These use specific forms for the various functions and can be solved numerically for particular values for the parameters of those functions.

### 7.2 Collective action problems

Within the framework set out in the previous section a central issue is the form of market structure or international regime, which influences the determination of \( X_{st} \) and \( D_{st} \). The form of regime is determined by the suppliers
choice to cooperate or not to cooperate along three dimensions. Firstly, suppliers may or may not jointly regulate arms exports, operating as a suppliers cartel. Secondly, suppliers may or may not operate as allies, jointly determining their military expenditures. Thirdly, suppliers may or may not collaborate in production reducing \( c(D_{st} + X_{st}) \) by benefiting from learning curves, increasing returns to scale, and sharing fixed costs.

Under the assumptions above, \( \partial S_s/\partial K_b < 0 \), arms exports are a ‘bad’ within this framework, therefore monopoly (arms export control) is good, since it restricts supply and raises prices. This has two effects on the buyers. The first is a terms of trade effect which clearly reduces the buyers welfare: they pay more for their arms and have less for other uses. The second effect is for the higher price of arms to cause a switch from military expenditure into civil consumption. The reduction in arms stocks in response to the price rise shifts the reaction functions in the arms race. This moves the Nash equilibrium closer to the efficient consumption-military expenditure mix that pairs of buyers would choose if they could cooperate through some process of arms control. Such effect could outweigh the terms of trade loss, making the buyers better off as a result of the formation of the cartel and the higher prices. Suppliers also benefit from internalizing the regional stability externality if \( \partial S_s/\partial K_b < 0 \). These results suggest that the optimal market structure for the arms industry could be a cartel of cooperating producer countries. Under these assumptions, arms suppliers clearly have a common interest in forming a cartel. The results in Levine and Smith (1995) indicate that this could also be beneficial for recipients, particularly if combined with a tax on arms exports redistributed to recipients. Of course the proposal for a supplier cartel plus transfers to recipients is both dependent on the specification of the model, particularly the form of the supplier security functions, and subject to obvious practical difficulties. Besides, any proposal for cooperation must inevitably address the collective action cartel stability problem of sustaining such a regime given the short-run incentives of any particular supplier to defect. Sandler (2000) discusses the collective action problem involved in verifying compliance and enforcing the rules of any cooperative regime. He discusses that while verification of compliance may improve over time, enforcing compliance will always remain as an issue to be addressed.

Suppose suppliers do solve the collective action problem and do cooperate in controlling the export of arms, acting as a joint monopolist. Then they face the credibility issues analyzed in Levine, Sen and Smith (1994). If buyers are forward looking as implied by equation (1), and if some commitment
mechanism\textsuperscript{27} is in place so that the suppliers can credibly precommit to the quantities that they will export in the future, they can use these announcements to change the recipients behavior. However if they cannot precommit, they are forced to adopt the less efficient time-consistent strategy: doing what is optimal in each period. In the arms trade the credibility of commitment to future supply or embargo is particularly important for the case of resupply of spares and munitions in a future conflict.

Finally, even if suppliers solve both the collective action and credibility problems, they face the problem that to the extent export controls are effective, driving up price or reducing quantity, they provide incentives for the buyers to create their own defence industrial base.

\textbf{7.3 Domestic production}

Using a static version of the framework from section 2, Levine et al. (2000) show that there is a threshold at which countries switch from depending completely on imports to establishing a domestic capability. A sufficiently high price can induce a pair of identical antagonistic buyers to switch from importing arms to domestic production. This switch causes higher levels of military expenditure, military capability, and inefficiency than had the antagonists relied on importing arms. Higher fixed costs of establishing domestic production increase the threshold level of military capability at which it is efficient to set up military production. The model assumes that domestic and imported arms are imperfect substitutes. The incentives for establishing a domestic industry also depend on the substitution between security and consumption. Levine and Smith (2000a) extend this analysis by introducing uncertainty and irreversible investment. Using real option theory\textsuperscript{28} they find that greater uncertainty about future military demand and costs actually reduces the likelihood of a country investing in domestic production capability.

\textsuperscript{27}These commitment mechanisms need careful consideration. One possibility is the desire to maintain a \textit{reputation} for commitment in a world where there exists two types of policymaker: those (the vast majority) who behave opportunistically and seize the chance to improve their situation by reneging on any commitment promise and those who like to commit as a matter of principle. Reputational equilibria are then those where the first type of policymaker mimics the second.

\textsuperscript{28}See Dixit and Pindyck (1994).
7.4 Industry and market structure

Up to now we have assumed that each supplier country produces a single homogeneous military good and different market structures only arise insofar as supplier countries collude in the production and exports of these goods. Following Dunne et al. (2005), we now extend the analysis by introducing differentiated goods and to allow for the free entry and exit of firms. Market structure now becomes endogenous. In this section we assume 100% depreciation per period ($\delta = 1$) so the model becomes static. For this reason the time subscript is superfluous.

Consider the supplier country $s = 1$ which procures $D_{1j}, j = 1, 2, \cdots, n_1$ domestically produced military goods with quality $q_{1j}$ and $M_{1j}, j = n_1 + 1, n_1 + 2, \cdots, N$ imported goods with quality $u_{1j}$. The latter can be less than the quality of the variety produced by the exporting country for internal use and this is one form that arms export controls can take. Military strength takes the form of a generalized Dixit-Stiglitz CES utility function of the form:

$$\left[ w_1 n_1 + (1 - w_1) (N - n_1) \right]^{\nu} \left[ w_1 \sum_{j=1}^{n_1} (q_{1j} D_{1j})^{\frac{\sigma - 1}{\sigma}} + (1 - w_1) \sum_{j=n_1+1}^{N} (u_{1j} M_{1j})^{\frac{\sigma - 1}{\sigma}} \right]^{\frac{1}{\sigma}}$$

where $\sigma > 1$ is the elasticity of substitution and $\nu > 0$. In (13), which generalizes $f(D_{bt}, M_{bt})$ above, if we put $\nu = 0$ and $w = \frac{1}{2}$, (13) reduces to the familiar Dixit-Stiglitz utility function used in the new trade and endogenous growth literatures. But as Benassy (1996) points out, this form of utility is restricted in that it implies a one-to-one correspondence between the taste for variety and the elasticity of substitution. Introducing the extra parameter breaks this link. In addition, the parameter $\nu$ represents in a simple way the concept of integrative technology which refers to the ease with which different weapon systems work together to provide military capability (Setter and Tishler, 2004).

The budget constraint for government in producer country 1 now be-

\[\text{29}\]

\[\text{Setter and Tishler (2004) define integrative technology as ‘information and communication technologies that enable separate individual systems to work in a joint, coordinated, and synergistic fashion as a single holistic system’. In their paper, they endogeneize the choice of integrative technology, they also use a different functional form. For simplicity, we keep it exogenous.}\]
comes:
\[ Y_1 = C_1 + \sum_{j=1}^{n_1} p_{1j} D_{1j} + \sum_{j=n_1+1}^{N} P_j M_{1j} \]  
(14)

and the binding participation constraint for each firm producing a single variety \( j \) of quality \( q_{1j} \), of which \( D_{1j} \) is domestically procured and \( X_{1j} \) is exported is:
\[ p_{1j} D_{1j} + P_{1j} X_{1j} - c(D_{1j} + X_{1j}) - F - f q_{1j}^\beta = 0 \]  
(15)

As before with (11), the first two terms in (15) consist of revenue from domestic procurement at price \( p_{1j} \) and from exports at price \( P_{1j} \), respectively for producer \( s = 1 \). The third term and fourth terms are variable and fixed costs respectively. The final term is new and represents the costs of providing quality \( q_{1j} \). We assume the R&D cost parameter \( \beta > 1 \) so these latter costs are convex. The model is then completed with a world market clearing condition for the exports and imports of each variety:
\[ \ell + r \sum_{b=1}^{t+r} (M_{bj} + M^*_b) = \sum_{s=1}^{t} X_{sj}. \]  
(16)

To solve for the equilibrium of this model we need to specify the sequence of events:

**1. Domestic Procurement by Producers.** Given military expenditure, the government in producer country 1 sets and procures domestic goods of quantity \( D_{1j} \) and quality \( q_{1j} \) at price \( p_{1j} \), for \( j = 1, 2, \ldots, n_1 \). It also formulates a plan to import goods \( M_{1j} \) of quality \( u_{1j} \), for \( j = n_1 + 1, n_1 + 2, \ldots, N \) at the world market equilibrium price \( P_{1j} \). All decisions are subject to a budget constraint and a non-negative profit participation constraint for domestic firms. The procurement price may be greater or less than the international market price. Firms already participating in the international market will always accept domestic procurement as long as the procurement price exceeds the marginal cost. Given the procurement price, the participation constraint for each domestic firm then determines the number of such firms. Thus in setting the procurement price the government in effect are choosing the number of domestic firms which is *endogenously determined* at this first stage of the game.

**2. Monopolistic Competition between Firms.** With a commitment to producing \( D_{1j} \), in a price-setting equilibrium of this stage of the game,
firms in producer country 1 set world prices $P_{1j}$ and export quantity $X_{1j}$ of quality $u_{ij}$ to countries $i = 2, \cdots, \ell + r$. In general, the world market price can depend on procurement decisions at stage 1, but for large $N$ (assumed in the analysis) we have monopolistic competition with the price given by $P_{1j} = P = \frac{\sigma c}{\sigma - 1}$ which depends only on the marginal cost $c$ and the elasticity $\sigma$. Note that decisions on quality have been decided at stage 1 by the procuring governments.

3. Military Spending by Non-Producers and Demand for Imports by all Countries. Given the world market price $P_j$ and quality $u_{ij}$, and military expenditure, governments in both producer and non-producer countries $i = 1, 2, \cdots, \ell + r$ procure imports of good, $M_{ij}$, $j = 1, 2, \cdots, N$ of quality $u_{ij}$, where $i \neq j$ for producer countries $i = 1, 2, \cdots, \ell$. Non-producers anticipating these decisions allocate resources between consumption and military expenditure.

This framework can be used to examine how the size of the defence industrial base is influenced by the degree of home bias for domestic production (the parameter $w$), R&D costs which determine the quality $q_{sj}$ of system $j$, export controls captured by $u_{sj}$ and the nature of regional arms races. Collective action problems relating to possible cooperation between suppliers in procurement, R&D and export control decisions can also be addressed with this framework. Figures 2 and 3 taken from Dunne et al. (2005) illustrate some insights provided by this model. We examine in these results a symmetric equilibrium in which all producer countries are identical in every respect and similarly for non-producers. The utility function across producers and cost conditions for firms are identical. The consequence of this is that procurement prices and firm numbers in each country are all equal.

In Figure 2 the endogenously determined number of firms in this symmetrical equilibrium is shown as a function of the R&D cost parameter $\beta$. This figure shows how there exists a trade-off between quality and variety: an increase in a cost parameter $\beta$ increases barriers to entry and inhibits the emergence of new firms and varieties (since each firm produces a single variety in our set-up). Quality and R&D costs as a percentage of total costs falls with firms switching from quality to quantity. Figure 2 also demonstrates two effects of cooperation: the reduction of duplication in R&D investment and the increase in varieties. The latter occurs under cooperation because variety produced in each supplier country enters the utility of other producers as a positive externality.

In Figure 3 the endogenous number of firms in a symmetric equilibrium
is plotted against the home bias parameter \( w \in [0.5, 1] \). The fall in \( w \) from its value under autarky, \( w = 1 \), to the no home bias case, \( w = 0.5 \), can be seen as one aspect of the globalization of the international defence industry as countries are more willing to look to imports to provide for their military needs. Again procurement cooperation increases variety and reduces R&D investment compared with non-cooperation. Furthermore under cooperation, changes in home bias has no effect as it is internalized in the cooperative decision. With non-cooperation, as home bias increases the willingness to invest in both quality and variety rises (since there is less scope for importing these features). However in the vicinity of the no bias value \( w = 0.5 \), the R&D-variety trade-off sees more R&D investment at the expense of variety so firm numbers initially fall. As \( w \) increases further, the convex nature of R&D costs means that at some value (around \( w = 0.7 \)) the increase in R&D drops off and variety starts to increase. The prediction of the model then is for values of home bias \( w \) near the autarky value, globalization (a reduction in \( w \)) causes firm numbers to fall and thus international market concentration to increase.

The model can also predict that if quality and R&D expenditure are held fixed or indeed rise, then globalization in another sense of an increased relative size of the external market and greater willingness to export higher quality weapons will reduce the number of firms. Taken together our results then provide an explanation for the driving forces behind the recent increases in concentration in the defence industry (see Dunne et al., 2003).

8 Concluding remarks

Recent developments in the arms trade literature have attempted to provide a suitable framework to analyze the strategic interactions of the arms trade. Elements of strategic trade theory and procurement theory have been brought together to capture a market structure which is complex for a number of reasons such as the insistence of producer governments in retaining a home defence industry, the web of subsidies and controls characteristic of this industry, the sometimes diverse security concerns of exporter countries and the arms race aspect of the demand for weapons in many importing countries.

Different models of the arms trade have focused on different aspects of the problem such as the impact of arms exports and arms export controls
on arms races and arms proliferation, the importance of security perceptions for the structure of the defence industry and the benefits of coordination. The forces behind recent changes in the defence industry such as changes in concentration and asymmetries of information have also been analyzed.

We have also given a presentation of some of the formal models to provide an illustrative framework, integrating economic and security objectives, that allow the analysis of the institutions of the arms trade, particularly its national and international regulatory regimes and market structures. Of course, in any rational actor model such as those set out above, specifying the preferences or objectives of the actors is crucial. In this respect the specification of security is central. For buyers, the specification in terms of an arms race seems to capture very many important cases; though it does not cover actual war or internal threats. Supplier security is more problematical, but a specification which recognizes that they may come into conflict with buyers, perhaps in alliance with other suppliers, captures many important reasons for arms export controls.

The models include factors which are important but are often ignored. Budget constraints are clearly important as the fall in demand for arms after the 1985 oil price collapse and the 1997 East Asian crises indicates. Prices are important, as indicated both by econometric work and by the drop in prices for major weapon systems when demand fell in the 1990s for strategic reasons while supply did not. The formal models highlight a number of ways in which the military sector is fundamentally different from other industries. First, for buyers of arms involved in regional arms races price increases can actually be welfare enhancing by dampening arms races. From the viewpoint of these consumers price competition between arms producers can therefore be detrimental and monopolistic market structures can be optimal. Second, home bias has been very high in this industry. A recent trend towards globalization (a reduction in home bias) can help to explain the observed drop in firm numbers in the military sector and the increase in concentration. Third, R&D plays an increasingly crucial role in the capability of major weapons systems. The trade-off between R&D and varieties then points to another factor that can explain the fall in firm numbers in this sector. Finally, the sector and the arms trade in particular, is subject to far more controls than other industries. However, regulatory regimes can generate perverse incentives. Controls can promote proliferation: by raising the price they increase the incentive for domestic production. By contrast uncertainty about the future supply of imported weapons, prices or quantities available, can reduce
the probability of proliferation. This is a feature that does not seem widely recognized in the literature which has been more concerned with the need for sending clear signals.

Regarding future lines of research, it is apparent from our review that there is plenty of scope for empirical research that tests many of the hypotheses suggested in the theoretical literature. As seen in the product and data section, the lack of good and reliable data for arms trade could explain the relative lack of empirical studies in the area (with exceptions already quoted). A second reason though might be the difficult in measuring concepts such as the security of exporter countries or the degree of home bias or even the definition of arms product itself. This conceptual challenge has been enhanced by the emergence of terror and the decline in the prospect of inter-state wars. Related to this is the rise in importance of the so called dual use goods [Klein (2001), García-Alonso (2003), Kulve and Smit (2003), and Stowsky (2004)]. It is both in the understanding of the implications of these new trends and their implications for the defence industry, security and international cooperation that there lie a number of pressing issues for future research.


9 References


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Table 1. CRS (in value, millions constant 2004 US $) and SIPRI (in volume, millions constant 1990 US$) arms transfer deliveries 1997-2004.

<table>
<thead>
<tr>
<th>Year</th>
<th>CRS</th>
<th>SIPRI</th>
<th>Ratio</th>
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<tr>
<td>1997</td>
<td>51581</td>
<td>24832</td>
<td>2.08</td>
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<td>2004</td>
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Table 2. 2004 top worldwide suppliers’ arms transfer agreements (millions of constant 2004 US $)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Worldwide Agreements</th>
<th>Developing World (% of total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>12,391</td>
<td>55.5</td>
</tr>
<tr>
<td>Russia</td>
<td>6,100</td>
<td>96.7</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>5,500</td>
<td>58.2</td>
</tr>
<tr>
<td>France</td>
<td>4,800</td>
<td>20.8</td>
</tr>
<tr>
<td>China</td>
<td>600</td>
<td>100</td>
</tr>
<tr>
<td>Italy</td>
<td>600</td>
<td>100</td>
</tr>
<tr>
<td>Germany</td>
<td>200</td>
<td>0</td>
</tr>
<tr>
<td>All other European</td>
<td>4,300</td>
<td>30.2</td>
</tr>
<tr>
<td>All others</td>
<td>2,500</td>
<td>92</td>
</tr>
<tr>
<td>TOTAL</td>
<td>36,991</td>
<td>58.9</td>
</tr>
</tbody>
</table>
Table 3. 2004 top worldwide suppliers’ arms deliveries (millions of constant 2004 US $)

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Value 2004</th>
<th>Developing World (%) of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>18,555</td>
<td>51.5</td>
</tr>
<tr>
<td>Russia</td>
<td>4,600</td>
<td>97.8</td>
</tr>
<tr>
<td>France</td>
<td>4,400</td>
<td>95.5</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1,900</td>
<td>68.4</td>
</tr>
<tr>
<td>Germany</td>
<td>900</td>
<td>55.6</td>
</tr>
<tr>
<td>China</td>
<td>700</td>
<td>85.7</td>
</tr>
<tr>
<td>Italy</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>All other European</td>
<td>1,200</td>
<td>41.7</td>
</tr>
<tr>
<td>All others</td>
<td>2,400</td>
<td>50</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>34,755</strong></td>
<td><strong>64.6</strong></td>
</tr>
</tbody>
</table>

Table 4. Arms deliveries of developing nations in 2004 by leading recipients (in millions of current U.S. $).

<table>
<thead>
<tr>
<th>Rank</th>
<th>Recipient</th>
<th>Agreements Value (2004)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>U.A.E.</td>
<td>3,600</td>
</tr>
<tr>
<td>2</td>
<td>Saudi Arabia</td>
<td>3,200</td>
</tr>
<tr>
<td>3</td>
<td>China</td>
<td>2,700</td>
</tr>
<tr>
<td>4</td>
<td>India</td>
<td>1,700</td>
</tr>
<tr>
<td>5</td>
<td>Egypt</td>
<td>1,700</td>
</tr>
<tr>
<td>6</td>
<td>Israel&lt;sup&gt;30&lt;/sup&gt;</td>
<td>1,500</td>
</tr>
<tr>
<td>7</td>
<td>Taiwan</td>
<td>1,100</td>
</tr>
<tr>
<td>8</td>
<td>Pakistan</td>
<td>900</td>
</tr>
<tr>
<td>9</td>
<td>South Korea</td>
<td>800</td>
</tr>
<tr>
<td>10</td>
<td>South Africa</td>
<td>500</td>
</tr>
</tbody>
</table>

<sup>30</sup>The CRS classification of Israel as a developing nation could be argued, at least in terms of its defense industry. Israel is a major weapons exporter and produces high tech weapon systems comparable to those of European countries and US [Shefi and Tishler (2005)].
Figure 1: Nash Equilibrium for Importing Countries.
Figure 2: Number of Firms per Country as R&D cost parameter $\beta$ increases: Non-Cooperation compared with Cooperation.
Figure 3: Number of Firms per Country as home bias parameter $w$ increases: Non-Cooperation compared with Cooperation.