EXPORT CONTROLS, MARKET STRUCTURE AND INTERNATIONAL COORDINATION

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Abstract

We look at the different ways of aggregating the exports of dual use products to give the security perception of exporter countries and their consistency with the relevant export control regimes. Also, we analyze different models of export controls highlighting the role of the perception of security, market structure and competition between exporting firms in determining the existence of multiple equilibria and therefore, the need for coordination between countries in setting export controls.

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1. INTRODUCTION

In the Post Cold War era, the perceived security requirements of the main producers of weapons have changed significantly[1]. Among these concerns, we have civil strife and ethnic conflict (e.g. Kosovo), terrorism, regional threats, the proliferation of weapons of mass destruction and even the environmental consequences of improper storage or disposal of military related material, especially nuclear technologies.

In 1992, the Security Council of the United Nations (UNSC) determined that the "proliferation of all weapons of mass destruction constitutes a threat to international peace and security" and the member countries committed "to working to prevent the spread of technology related to the research for or production of such weapons and to take appropriate action to that end". The fact that among the members of the UNSC we find the most important exporters of weapons highlights the importance of this commitment. Indeed, prior to 1992 Western industrialized countries had already started to organize supply-side controls on transfers of weapons-related technologies.

At present, there are a number of multilateral export control regimes which include the nuclear suppliers group (NSG) and the Zangger Committee (ZC) which address nuclear technology, the Australia Group (AG) which deals with chemical and biological military-related material, the Missile Technology Control Regime (MTCR) and the Wassenaar Agreement (WA) which refers to conventional arms and dual use goods and technologies. Also, extreme export controls in the form of embargoes have been monitored by the UN and NATO (e.g. Iraq).

As the spin-offs between the civil and the military sector now flow in both directions and the speed of technological innovation is very high in these sectors, the scope of the above mentioned export controls extends to goods or technologies which have a direct or potential military applications, the so called *dual use products*.

In this paper, we present different ways of aggregating the exports of dual use products to give the security perception of exporter countries and their consistency with the relevant export control regimes. Also, we analyze different models of export controls highlighting the role of the perception of security, market structure and competition between exporting firms in determining the existence of multiple equilibria and therefore, the need for coordination between countries in setting export controls.

There is some literature which analyzes the issue of arms control (Hartley and

Sandler (1995) and Sandler and Hartley(1995)). This has been in part motivated by the arms control treaties between the US and the former Soviet Union in the 1980s. At that time the security perception of those countries was highly influenced by their involvement in an arms race. This situation resulted in an extensive literature that focused on the analysis of defence expenditure in defence alliances with defence expenditure considered as a public good to which the members of an alliance contribute (Hartley and Sandler 1999). In addition to arms races, the trade in arms affects perceptions of security and raises the related issue of export controls.

A number of recent papers have introduced the trade in dual use products as an important factor in the study of security among the main exporters. The common feature is that these models introduce arms and dual use products exports as having a negative effect on the suppliers security-i.e. these exports generate negative externalities on exporter countries. This idea approaches the problem of export controls for dual use products in the same way as some environmental problems like global warming and nuclear waste anti-dumping (Rotillon et al. (1996) and Moody-O'Grady (1995)). Both issues have generated a need for agreements at the international level and discussions over the concept of security: military security or environmental security. The key difference between them is the importance that the market structure and competition between exporter firms has on the ability to control the exports of dual use products exports: this creates a double interaction between countries at the security level and at the exports profits level which sometimes generates a need for the design of specific mechanisms that help multilateral agreements to be implemented.

In the arms trade literature, Levine et al. (1994) and Levine and Smith (1995) present a model that specifies not only the economic features but also political characteristics of the arms trade. They provide a formal model of trade which allows for competing forward looking suppliers whose welfare depends on both the economic benefits from the sales and the security repercussions of the recipient's behavior.

In García-Alonso and Levine (1997) and García-Alonso (1998a), the consideration of military firms and exporting governments as different decision makers is introduced and strategic effects involved in the decision on domestic weapons procurement and arms exports are analyzed. Also, Levine and Smith (1997) and García-Alonso (1998b) introduce the issue of exports controls for dual use technologies in two different ways. The first paper studies different forms of cooperation between arms exporters deciding on domestic procurement and arms

exports and compares, among other things, the equilibrium quantities in each case. García-Alonso (1998b) examines the relationship between the optimal subsidization policies of $R\&D$ investments of exporters of dual use technologies with the existence of a unilateral or multilateral concern for security in exporter countries.

A key difference between the various papers is the way each of them models the effect of exports on security. Whilst they all contemplate the negative effect of exports on the suppliers security, the way in which these exports are aggregated differs depending on whether or not product quality is considered.

The issue of aggregation technologies has also been raised in the context of public goods. Conybeare et al. (1994) discussed different ways of aggregating military capabilities of the members of a military alliance. Also, it has been applied to international environmental agreements in Sandler and Sargent (1995). Cornes and Sandler (1996) provide a detailed review of the relevant literature. However, export control agreements have not yet been analyzed under this perspective.

The paper is organized as follows. First, it presents some stylized facts of arms exports. Second, it examines the different ways of aggregating dual use products exports to give the security perception of exporter countries and their consistency with the relevant export control regimes. Third, it analyzes different models of export controls highlighting the role of the perception of security, market structure and competition between exporting firms in determining the existence of multiple equilibria and therefore, the need for coordination between countries in setting export controls. Finally, it describes the most significant characteristics of the existing dual use export controls.

2. SOME STYLIZED FACTS

This section describes some of the main features of the international arms trade which our model seeks to address. Arms exports are big business in a market dominated by relatively small numbers of supplying and buying nations. Over the period 1993-1997, the USA was the world's leading supplier accounting for 47% of total weapons deliveries; and the top 5 suppliers, including Russia, UK, France and Germany, accounted for 82% of total deliveries. Over the same period, the top 10 recipients of defence equipment accounted for over 50% of total imports (ranked by value of imports, these were Saudi Arabia; Taiwan; Turkey; Egypt; South Korea; China; Japan; Greece; Kuwait: SIPRI 1998). It might be expected that small numbers of nations, especially as suppliers, are more likely to reach an international agreement on arms export controls.

Participation in the world arms market will partly reflect the different comparative advantages of both buyers and sellers with the market reflecting vertical differentiation. Some nations will specialize in supplying costly, high technology arms exports (e.g. France; UK; USA); others will specialize in supplying cheaper, low technology arms exports (e.g. Brazil; China). Similarly, buying nations will have different income levels affecting their ability to pay with poorer nations demanding cheaper and hence lower technology arms, with such demands reflecting the comparative advantage of their national armed forces (e.g. labour-intensive conscript forces with limited human capital will require "simple technology" weapons).

Arms exports are determined by the usual price and non-price variables, but they are 'different' in their dependence on political variables. Governments dominate the market through support for their national defence industries and their role in allowing arms exports and determining the terms of trade (e.g. R&D levies; favourable financial terms). Governments might also favour certain nations (e.g. allies; former colonies; friends) which might then be viewed as "captive markets"). 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 cost reflecting both economies of scale and learning (Sandler and Hartley, 1999). 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 has resulted in fewer new projects and smaller national orders leading to pressures for defence companies to seek export markets. For national governments, arms exports are a means of maintaining their defence industries in an era of disarmament with exports resulting in 'wider economic benefits' (Hartley, 2000). But there are 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 (e.g. importing nation might be a future threat to the exporting nations either directly or through regional conflicts which involve the exporting nation).

This concern with both national defence industries and national security might affect the exporting nation's attitude to the form of export controls where these vary between quantitative and qualitative. At the limit, there might be a complete ban on arms exports, but such a policy is not costless and the nation has to estimate the economic impacts of a ban, including the costs of retaining any defence industrial capability for national defence needs. Obvious costs from an export ban include losses of jobs and exports, higher prices for national defence equipment and the costs of either retaining capacity or shutting it down and

re-starting between gaps in orders (Martin, Hartley and Stafford, 1999; Hartley, 2000). An alternative to a complete ban might be to control the quantity of arms exports to certain nations or to control their quality. Restrictions on quality mean that the exporting nation would refuse to supply the latest high technology equipment to foreign buyers. For example, combat aircraft and helicopters might be exported but without the latest radar, avionics and stealth features; conventional submarines might be exported but not nuclear-powered submarines. Of course, importing nations might respond to these various forms of export controls by buying from other nations or developing their own national defence industry (c.f. Israel and South Africa).

Policies on arms exports can be either national or international, with international agreements offering the prospects of a public good in the form of peace. But international collective agreements involve substantial transaction costs in identifying participating countries, negotiating an agreement and then monitoring and enforcing it. Collective decisions are needed on the definition and range of weapons to be included in the agreement, the target importing nations to which the agreement applies, the policing and monitoring arrangements, the penalties for non-compliance and the incentives created for illegal trading. Even the definition of weapons causes problems, especially for dual use equipment (e.g. helicopters can be used as civil passenger transports or as military transports and observation posts). And, in the final analysis, actual arms export controls are implemented by nation states. These stylized facts form the background for our formulation of models of export controls.

3. TECHNOLOGIES FOR AGGREGATION OF INTERNATIONAL NEGATIVE EXTERNALITIES

This section examines different ways in which negative externalities caused by exports of dual use products can be aggregated to give a perception of the security consequences for the suppliers of this trade. Also, we discuss which fits better with each of the current export control arrangements. The discussion ignores the effect on security of domestic procurement in each of the exporter countries[2]. Let q_i denote the military capability exported by country i and S_i represent the overall effect of exports on supplier i's security:

$$S_i = S_i\left(q_1, ..., q_n\right), \tag{3.1}$$

where, n is the number of exporters and S_i is decreasing in all arguments.

The specific aggregations we now propose resemble those used in the public good literature for aggregating individual contributions in the supply of public goods. However, the interpretation is somewhat different; we obtain the aggregate negative externality on suppliers produced by exports of dual use equipment.

The constant elasticity of substitution (CES) function is extensively analyzed in Cornes and Sandler (1996) as a generalized technology of public good supply aggregation. The arms trade literature has also made use of the CES function[3] for the aggregation of arms exports (García-Alonso (1998a) used it as part of a general security function in which the effect on security of domestic procurement was also considered):

$$S_i = -\left(\sum_{i=1}^{n} (q_i)^{\sigma}\right)^{\frac{1}{\sigma}}, \tag{3.2}$$

where $\frac{1}{1-\sigma}$.is the elasticity of substitution between the different countries exports in the exports security function. In our context, the elasticity of substitution determines the impact any country's exports has on security. When $\sigma = 1$, all countries' exports are perfect substitutes on the final negative impact on security:

$$S_i = -\sum_{i=1}^{n} q_i. \tag{3.3}$$

This aggregation fits best with military capability being related to quantity exported of homogenized dual use products and provides a rationale for quantitative export controls. Also it could be applied to global warming where products are homogenized in terms of the units of CO_2 they produce.

When σ approaches ∞, we have a technology of aggregation in which what determines the global negative externality is the maximum of the exported military capabilities:

$$S_i = -\max(q_1, ..., q_n). \tag{3.4}$$

An interesting property of this aggregation is that increases in any of the countries' exported military capability do not affect security unless it goes beyond the level exported by any of the other countries. In this case, we get close to the best-shot technology for aggregating individuals' contributions to public goods. This was used first in Hirshleifer (1983) for public goods. García-Alonso (1998b)

used it for the aggregation of dual-use goods exports to give a perception of security on exporter countries. This method fits well when the quality and not the quantity of the product exported is what really affects security. However, note that with this type of aggregation, only the highest exported quality affects security. One could also consider the case in which other lower exported qualities also affect security[4], however, the best shot aggregation provides a good index of security perception of countries that set qualitative export controls which specify lists of products which cannot be exported, based on their applicability to military purposes (e.g. AG).

Let us now discuss which definition of military capability seems to correspond best with the existing dual use export controls. In general, military capability is a function both of the quality and quantity of exports. Export controls could be either *quantitative* or *qualitative.* The first term would embrace controls which set a numerical ceiling on permitted classes of the amount of exports. The second term would imply limits on the performance or quality of exports of dual use products (this classification is similar to the one proposed in Panofsky (1990)). In practice, the existing export control agreements refer to the quality or powerfulness of dual use technologies exported. It does not seem that the countries taking part in these agreements perceive quality and quantity as being substitutes for each other. For instance, in the U.S., The National Defense Authorization Act on High Performance Computers (HPC)[5]controls and restricts the exports of powerful computers to a group of 50 countries including Russia, China and Israel. It is obvious that in this case quality and quantity are not substitutes for each other. In other words, having a computer which is able to simulate a nuclear experiment is not at all the same as having many computers which don't have enough power to do it. It could be argued though, that, in terms of security, it should not be the same one restricted country having access to a higher quality than several restricted countries managing to acquire it. For instance, if India had access to HPC and Pakistan did not, would it be better or worse for the exporters security than both getting it?. There is no clear answer. In principle, one the two countries having HPC should be worse, but, Pakistan and India (as most of the importers of restricted dual use goods) are involved in an arms race. Under this consideration, exporting a high tech good to India only could dangerously destabilize the arms race, besides, the willingness to pay of Pakistan to pay for the high tech would increase making it even more tempting for producer countries to export it to Pakistan too. We can then conclude that quality alone gives a good index of the definition of military capability for countries who are interested in

implementing export controls.

In the following section, we use the best shot technology in presenting different noncooperative games that attempt to explain the strategic interaction between countries involved in export control arrangements and how their decisions are affected by the exports market structure. We first use a discrete choice model in which governments are faced with the decision of whether or not to restrict a domestic firm's export quality. We then extend the discussion to a continuous choice and general security function situation.

4. THE RESTRICTION GAME

4.1. Discrete choice model

One of the distinguishing characteristics of the exports control problem is the two level interaction between governments deciding their optimal export controls and still caring about their domestic firms which compete in the international market for dual use products. The decision faced by exporting countries can be presented in the following way:

$$W_i = \pi_i + \theta_i S_i, \tag{4.1}$$

where W_i is social welfare, π_i is the domestic firm's profits, $S_i = -\max(q_1, ..., q_n)$ and θ_i is the degree of security concern of the government so if $\theta_i = 0$ the government's and the firm's problem would be equivalent.

Consider now an export market composed of two countries with one firm each exporting dual use products to the rest of the world. Firms compete in qualities and governments face the decision on setting export controls on the quality that the home firm exports or not. It is very helpful at this point to start with a discrete choice model and a best shot technology for aggregation. In this case, the problem faced by governments is indeed a two choice game and it is presented in figure 1. As can be seen, the profit of each firm depends on the quality that both export, $\pi_i(q_1, q_2)$, the first quality is the quality exported by firm in country 1 and second term is quality exported by firm in country 2.

The game we present in this section is a version of García-Alonso (1998b). That paper presented a three stage game in which governments commit to an $R\&D$ subsidy for the domestic firm before firms choose their $R\&D$ investment. Once governments know the outcome of the $R\&D$ process, they choose the optimal technology security policy which takes the form of a maximum exportable quality.

This policy becomes relevant when the domestic firm is successful in $R\&D$ and it consists of allowing or not the domestic firm to export the innovation depending on the quality available to the competitor. Given this policy, firms make their quality choices and, finally, compete in prices.

Our intention is to focus on the game theoretical interaction between exporter countries whose firms have been successful in developing a higher quality. The fact that governments are not able to commit on export controls before firms invest in $R\&D$ makes our simplified game valid for our purposes. All $R\&D$ costs are sunk and governments know the quality that competitors are able to sell. It is then left with the exports control decision. Our objective is to analyze the problem involved in implementing a multilateral export control regime given that member countries already have access to the technologies whose exports they intend to restrict

There are two qualities that firms are able to produce: q_H and q_L, with $q_H > q_L$. The dilemma faced by governments consists of deciding whether or not to allow the higher quality to be exported. The result of this game will depend crucially on the kind of competition between exporting firms and on the degree of concern for security, θ_i, of each government.

Consider a situation in which importer countries care about quality but they also perceive the product offered by each firm as different: in other words, we consider a model of horizontal differentiation in which quality matters (see Economides (1989) for an example of this). In this case, the profit functions of each firm would be increasing in its own quality so that $\pi_1(q_L, q_H) < \pi_1(q_H, q_H)$, $\pi_2(q_H, q_L) < \pi_2(q_H, q_H)$. Also, if both firms export the same higher level of quality, their profit is not smaller than they would obtain if none of them could export the innovation- i.e., $\pi_i(q_L, q_L) \leq \pi_i(q_H, q_H)$, $i = 1, 2$. Finally, profit is a decreasing function of the competitor's quality- i.e., $\pi_1(q_L, q_H) < \pi_1(q_L, q_L)$, $\pi_2(q_H, q_L) < \pi_2(q_L, q_L)$, $\pi_1(q_H, q_H) < \pi_1(q_H, q_L)$ and $\pi_2(q_H, q_H) < \pi_2(q_L, q_H)$.

Under these conditions, given that government 2, for instance, restricts its firm export's quality to q_L, government 1 will restrict its firm too if and only if when it restricts, welfare is higher, $W_1(q_H, q_L) < W_1(q_L, q_L)$. For this to be the case the degree of security concern of government 1 should be higher than:

$$\frac{\pi_1(q_H, q_L) - \pi_1(q_L, q_L)}{q_H - q_L} \equiv \theta_1^*. \tag{4.2}$$

This provides a cut-off line between security concerned and unconcerned governments. In this context, a security concerned government would be that which

would restrict the exported quality if it were the only one to have the high quality.

If both governments are security concerned (i.e., $\theta_1 > \theta_1^*$ and $\theta_2 > \theta_2^*$), we have two Nash equilibrium in pure strategies[6]in the game presented in Figure 1: Either both governments restrict (R) or neither of them restricts (NR) the domestic firm. This is because restricting one's own firm only affects security if it lowers the maximum exported quality. If the high quality level is available from the other country's company then it is better for the government not to restrict its home firm so that it can compete effectively. These two possible equilibria can be ranked by comparing the welfare that the governments achieve in each of them. It is easily shown that governments prefer the equilibrium in which both restrict if their concern for security is higher than:

$$\frac{\pi_i(q_H, q_H) - \pi_i(q_L, q_L)}{q_H - q_L} \equiv \theta_i^{**}. \tag{4.3}$$

Note that, since the profit functions are decreasing in the competitor's quality, the degree of security concern for which governments prefer a global restriction is smaller than the degree of security concern for which one government decides to restrict when it is the only country to have the high quality - i.e., $\theta_i^* > \theta_i^{**}$.

Figure 1

$1,2$	R	NR
R	$\pi_1(q_L, q_L) - \theta_1 q_L, \quad \pi_2(q_L, q_L) - \theta_2 q_L$	$\pi_1(q_L, q_H) - \theta_1 q_H, \quad \pi_2(q_L, q_H) - \theta_2 q_H$
NR	$\pi_1(q_H, q_L) - \theta_1 q_H, \quad \pi_2(q_H, q_L) - \theta_2 q_H$	$\pi_1(q_H, q_H) - \theta_1 q_H, \quad \pi_2(q_H, q_H) - \theta_2 q_H$

In general, the discrete choice games with two symmetric Nash equilibria one of them being Pareto dominant was first analyzed in Harsanyi and Selten (1988) and considered as a possible example of negative externalities in Dybvig and Spatt (1983). The problem with this game is that it is difficult to give a clear prediction of which of the two equilibria will result. Indeed, even if both governments get together before deciding whether to restrict or not and assure they plan to restrict we should not expect that they believe each other (Aumann, 1990). The reason is that, independently of its own choice, government 2 gains if government 1 restricts, hence, government 2 would always say it is going to restrict, even when it is not planning to restrict. This characteristic of the game is due to the fact that a firm's profits depends on both exporters quality, so that firms always prefer to have a leadership in quality with respect to the other firm. If firms had their own

captive markets the situation would be different. In the extreme case, having a captive exports market means that the firm's profit function would no longer be dependent on the other firm's exported quality. In this situation, the game would have the features of the Stag Hunt game and pre-play communication would help countries to implement a multilateral restriction.

It has been discussed (Sandler and Sargent, 1995) that, especially in coordination games in which players don't trust each other, a mixed strategies equilibrium makes sense. For the game in Figure 1, the mixed strategies equilibrium is given by the probabilities of the other country cooperating that makes them indifferent between restricting or not. For government 2 this probability is:

$$\rho_2 = \frac{\pi_1(q_H, q_H) - \pi_1(q_L, q_H)}{\pi_1(q_L, q_L) - \pi_1(q_H, q_L) + \theta_1(q_H - q_L) + \pi_1(q_H, q_H) - \pi_1(q_L, q_H)}. \quad (4.4)$$

Therefore, if both governments implement the restriction with a probability bigger than ρ_i, the *both governments restricting* equilibrium would be the predicted outcome. Note that an increase in the degree of security concern clearly favours the chances of the restricting equilibrium.

As predicted for these types of games in the literature, an increase in the number of countries which have access to the high quality and take part in a multilateral restriction game would diminish the chances of observing the restriction on quality implemented. The first reason is that, according to our definition of security, one country not restricting exported quality has the same effect on security as all countries defecting. As a consequence, ρ_i would be bigger with more countries and the chances of a multilateral restriction smaller (see Sandler and Sargent, 1995 and Fudenberg and Tirole, 1995 chapter 1)). Besides, an increase in the number of exporting countries will also increase competition and affect negatively the per country profits and therefore, the payoff matrix.

Consider now the effect of the existence of uncertainty over the degree of security concern of governments. For instance, imagine a situation in which government 1 has some uncertainty over the degree of security concern of government 2 such that, P_2 is the probability that $\theta_2 > \theta_2^*$ and $1 - P_2$ is the probability that $\theta_2 < \theta_2^*$. Rewriting the game in Figure 1 in terms of expected welfare for government 2 we conclude that, although *none of the governments restricting* remains a Nash equilibrium in pure strategies, the *both governments restricting* equilibrium might disappear if it is sufficiently unlikely that government 2 cares about security. It is also worth noting that, if government 2 does care about security, it is in its self interest to reveal it to the security conscious country.

4.2. Continuous choice model

The previous section assumed that, when restricting, countries were faced with a discrete choice. This makes sense in cases in which innovation processes are discrete and the qualitative differences between two different generations of products are significant in terms of security. In other instances, like a missile's speed or precision, it is very difficult to justify a discrete choice framework. Also, if countries were attempting to restrict quantity a continuous choice would be more suitable.

This section analyzes the restriction game in a continuous choice environment. Governments will be confronted with a continuous choice of restriction. Our objective is to see under which conditions we obtain multiple equilibria in this framework[7]. For this purpose, we will use a model in which governments must decide the amount of dual use products they allow their firms to export taking into account both the domestic firms profits and the security consequences of such exports. We use the general form of security described in equation (3.1), and the welfare function stated in equation(4.1). Therefore, the problem for government 1 is presented as follows:

$$\underset{\{q_1\}}{Max} \quad \pi_1(q_1, q_2) + \theta_1 S_1(q_1, q_2). \tag{4.5}$$

The first order condition for this problem is:

$$\frac{\partial \pi_1(q_1, q_2)}{\partial q_1} + \theta_1 \frac{\partial S_1(q_1, q_2)}{\partial q_1} = 0. \tag{4.6}$$

This is also the reaction function of government 1 to the quantity allowed to be exported by government 2. A necessary but not sufficient condition for having multiplicity of symmetric Nash equilibria is that both reaction functions have a positive slope greater than 1 at a Nash equilibrium[8]:

$$\frac{\partial q_1}{\partial q_2} = -\frac{\dfrac{\partial^2 \pi_1(q_1, q_2)}{\partial q_2 \partial q_1} + \theta_1 \dfrac{\partial^2 S_1(q_1, q_2)}{\partial q_2 \partial q_1}}{\dfrac{\partial^2 \pi_1(q_1, q_2)}{\partial q_1^2} + \theta_1 \dfrac{\partial^2 S_1(q_1, q_2)}{\partial q_1^2}} > 1. \tag{4.7}$$

The denominator of this expression must be negative for this is the slope measured at a Nash equilibrium. Therefore, a sufficient condition for the slope to be positive is that the numerator is positive. In other words, we need the government's marginal welfare of increasing the exported military capability to

rise with increases in the other governments exported capability. Note that this is a property present in the discrete choice games studied in the previous section. When the other country does not restrict, it becomes welfare improving for the government not to restrict as opposed to the case in which the other country restricts exported quality.

As by exporting military capability, countries are generating a negative externality not only to themselves but also to the other exporters we can say in general that equilibria in which the exports level is higher will imply lower welfare[9]. If there is a unique Nash equilibrium, the level of exported military capability is higher than the Pareto optimal one: in this case we would have a Prisoner's Dilemma problem. In other words, we have a unique Nash equilibrium which is Pareto inferior.

4.3. Introducing vertical differentiation

So far, we have analyzed the nature of the game played by countries that, having access to the 'state of the art' technology and, based on security grounds, aim to prevent firms from exporting it to other countries.

However, there are also countries which do not have access to the high-tech products but instead, they export low-tech products to importers who cannot afford to buy the highest quality. Using the literature on vertical differentiation (e.g. Shaked and Sutton (1982)), when importers have different incomes, low tech firms would still have some positive profits by selling a lower quality at lower prices to low income countries. An interesting feature of the vertical differentiation models is that the optimal quality for the low-tech firm is an increasing function of the quality exported by the high tech firms. Therefore, in a continuous choice environment, if countries involved in exporting high qualities manage to agree to diminish the quality of their exports, low tech exporters would also diminish their qualities in order to keep the quality gap between them. This would hold even if their governments did not care about security (as long as the restricted quality is above the technological frontier of low tech countries).

5. EVALUATION OF MULTILATERAL MILITARY RELATED EXPORT CONTROL REGIMES

This section identifies the characteristics of the multilateral military-related export control regimes which reveal the coordination problems involved in these

regimes and the coordination mechanisms designed by some of them in order to achieve an effective multilateral restriction regime[10].

Table 1 presents the membership of the different export control regimes and the year in which each was created. First note that most of the regimes were created by the end of the Cold War and therefore, the perception of military related exports as having a negative effect on security is a characteristic of the post-Cold War era. Interestingly, the last regimes to be created are those which target specifically dual use products and technologies. This can be seen as the consequence of the spin-offs between the civil and the military sector increasingly flowing in both directions.

It is a general characteristic of these export control regimes that they are implemented through national export control mechanisms. Therefore, they are all voluntary arrangements. The conditions for membership differ between them but, they have in common that the prospective member must develop or have national export controls on the relevant items. Besides, the overall approach of the country to non-proliferation issues is also taken into account.

So far, we have seen that the military related export controls are multilateral in the sense that they are implemented by a group of countries whose common characteristic is having national export controls, which signals an individual concern for security. But, these agreements do not have direct enforcement power: membership is voluntary and there is no penalty system. What then is the role they play in facilitating multilateral restrictions? The same question has been posed for other multilateral institutions that attempt to promote international trade cooperation (e.g. Maggi (1999) for the World Trade Organization). In that case, we have a Prisoner's Dilemma which, as is well known, when played repeatedly leads to a multiplicity of equilibria. This paper has used a static game structure where a multiplicity of equilibria arises and, with that, the need for coordinating on the good equilibria. Some of the suggested roles of a multilateral institution, like export control arrangements, would be to act as an information gathering agency, generate a sense of 'international obligation' and promote multilateral rule making. In doing so, these multilateral arrangements add an important feature to the individual national export controls of the security concerned countries which is the joint implementation of coordination mechanisms.

The information gathering is made in most of the export control arrangements through *agreed lists of controlled items.* These lists describe the products and technologies which are considered relevant for each specific export control arrangement. In building up these lists member countries make explicit the items

over which member countries are security concerned. This plays an important role in the national implementation of the export control because, as was seen in the previous section, uncertainty about the degree of security concern of other potential exporter countries makes it less likely that an equilibrium in which countries multilaterally decide to restrict is achieved. Also, especially for dual use goods, it is sometimes technically difficult to define which goods can have potential military application. Therefore, deciding over lists is a way for some countries to realize the military application of some dual use products about which they might not be aware.

In the case of the ZC and the NSG, the list of controlled items is called the *Trigger List*, the reason being that any potential export of a listed item to a non-nuclear weapon state triggers the need for International Atomic Energy Agency (IAEA) safeguards. The *safeguards* aim to verify that the potential importer is not using nuclear material or equipment to develop or produce nuclear weapons. In May 1997 the IAEA safeguards were strengthened and renamed as *full scope safeguards*. A key element of the new safeguards is an enhanced information system managed by the IAEA based on expanded declarations on nuclear transfers. The members of the NSG have agreed on implementing full scope IAEA safeguards over potential transfers of items in the Trigger List. Again, this makes clear the way in which countries make explicit their perception of security and therefore, it helps in achieving the multilateral implementation of export controls.

We have seen the positive aspects of the existence of *agreed lists of controlled items*. Nonetheless there might be some risks involved in relying too much on lists when dealing with dual use goods. First, there is the updating problem: for technologies in which innovation speed is high it can be difficult to have lists which react quickly to changes in the technological patterns of military related products. Encryption technology is one of the best current examples. Besides, firms competing in export markets might advance a potential restriction over the items it attempts to export and therefore, try, artificially, to change their characteristics so that they are not subject to export controls: this does not necessarily mean that their goods are not military related anymore. Maybe, this is the reason why in the WA the list of controlled items has not yet been released. Another way of avoiding the lack of flexibility of the lists system is to add discretionary mechanisms for specific cases. Here, we could include the *catch-all or know rule* used in the MTCR. The idea is that, if an exporter is aware that an item will contribute to the proliferation of weapons of mass destruction, the export should be prevented whether or not it conforms to technical parameters of the commodity

control list.

There is one final coordinating mechanism that can help security concerned countries to implement a multilateral export controls and which can be found in the regulations of the Australia Group. In June 1993, the AG adopted a so-called *no-undercut policy*[11].

The policy seeks to avoid a situation in which an AG member competing for a lucrative business deal tendered by a potential proliferator would grant an export licence under the presumption that otherwise another AG state would do so. The AG countries honour the decisions of other AG states to deny a particular export. If an AG country does not grant an export licence it notifies the other AG states of its decision and provides them with information regarding the goods, their destination and the end-user. If, however, a second AG member has doubts about or disagrees with the proliferation risk assessment on which the original denial was based, it is obliged to consult with the country that denied the export licence before proceeding with a sale, which otherwise would undercut the original denial. The outcome of this consultation mechanism can be either that the state which has issued the denial notification revokes it, and thus allows the export to proceed, or that both countries agree on the soundness of the denial and, consequently, refuse the licence. (SIPRI Yearbook 1998).

The no undercut policy is a tool that recognizes the role played by competition between different exporter firms in the implementation of export controls. As seen in the previous section, designing credible mechanisms by which governments make explicit their decision not to take competitive advantage from other countries restrictions is especially important in export industries where competition is fierce and exporting firms have no captive markets. It is not by chance then, that the need for an undercut policy was intensively discussed between the members of the WA. However, the members of the WA have not yet agreed to refuse a licence for a transfer of the same product to the same destination where another member has denied it.

Most of the export control agreements also have regulations that prohibit unauthorized re-transfers. These regulations become especially important in the case of dual use products. A country might decide to export a dual use product to a country which does not care about security as long as it is sure that it is not going to be used for a military application. But, this country could re-transfer the product to a country which would use it for military purposes as it does not care about security. The prohibition of transfers attempts to avoid this event.

Altogether, we have seen that multilateral export controls have some features which make them different from other international institutions. The need for coordination can arise in a static game environment. The reason for this is the irreversibility of the decision over exporting some of the most dangerous technologies. A decrease in CO_2 emissions can always ameliorate the pollution problems and eliminating barriers to trade can improve welfare but, once a (potentially) massive destruction technology has been transferred to an aggressive country, the exporter countries will have to bear the security costs in perpetuity.

6. SUMMARY AND CONCLUSIONS

This paper has analyzed military related export control regimes using a game theoretic analysis of the interaction between countries setting export controls under different market structures. We have explained that the military related exports firms are involved in oligopolistic competition but, they still have strong links with their governments, a fact which encourages the existence of captive markets. Also, high $R\&D$ investments have quickly increased the quality level which make these products more dangerous and the definition of dual use more difficult. In this context, exporter countries face a trade-off between security and profits. After discussion of different methods of aggregating the effects of exports on producer countries, we have concluded that exported quality provides a good index of the exporters' perception of security.

In a discrete choice environment, the *exports control game* was shown to be a coordination game in which whether or not the Pareto superior both countries restricting equilibrium is obtained cannot be predicted with certainty. The existence of captive markets increases the chances of coordination but, an increase in the number of players or the existence of uncertainty over the degree of security concern of the other country decreases these chances seriously. This emphasizes the important role played by the interaction between competing exporter firms in the prediction of the viability of multilateral exports control. We have also identified the properties of the perception of security and exporter firms' profits that result in the export control game becoming a coordination game in a continuous choice environment. Finally, we have studied the effect that high-tech exporters restrictions can have on low-tech producers using results from the vertical differentiation literature. The analysis was then supported with different examples of actual international agreements. Throughout the paper we have focused on multilateral export controls in which all countries have a concern for security. However,

there are other situations in which a security concerned country can enter into a bargaining process with a security *unconcerned* country in order to persuade it through some compensation not to export a specific security sensitive technology (Jehiel et al. (1996) and Rotillon et al. (1996)) or try to implement a penalty system (Smith and Udis (1998)).

FOOTNOTES

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[1] For an exhaustive analysis of these changes, especially in Europe, see Mollas-Gallart and Robinson (1998).

[2] See e.g. García-Alonso (1998b) and Levine and Smith (1997) for an analysis of the strategic interactions between domestic procurement and arms exports decisions.

[3] For a full explanation of the CES production function see Varian (1992).

[4] For instance, we could consider $S_i = -\alpha_{\max} q_{\max} - \sum_{j \neq \max} \alpha_j q_j$,(where α are some quality adjusted weights).

[5] HPC are those of speeds above 2000 theoretical operations per second (MTOPS). The most recent regulations on the exports of HPC have been implemented in February of 1998 (Federal Register, Vol. 63, No. 22. Tuesday, February 3, 1998. Rules and Regulations).

[6] If only one of the two countries cares about security the game would clearly have a unique Nash equilibrium in pure strategies in which none of the governments restricts. However, countries could still engage in a bargaining process which could lead them to a Pareto superior equilibrium. Such possibility has been analyzed in Jehiel et al. (1996) and Rotillon et al. (1996) for the nuclear technology exports and global warming, respectively.

[7] The issue of multiplicity of equilibria and coordination failures has also been analyzed in the macroeconomics literature. See Cooper and John (1988) as an example. For an application to the analysis of arms races see Brito and Intriligator (1999).

[8] This comes from the sufficient conditions required for the existence of a Nash equilibrium:

$$\lim_{q \longrightarrow 0} \left. \frac{\partial \pi_1 (q_1, q_2)}{\partial q_1} \right|_q + \theta_1 \left. \frac{\partial S_1 (q_1, q_2)}{\partial q_1} \right|_q > 0,$$

$$\lim_{q \longrightarrow \infty} \left. \frac{\partial \pi_1 (q_1, q_2)}{\partial q_1} \right|_q + \theta_1 \left. \frac{\partial S_1 (q_1, q_2)}{\partial q_1} \right|_q < 0.$$

[9] With positive externalities the implication would be the opposite: see Cooper and Andrew (1988).

[10] The information we analyzed here is based on SIPRI Yearbook 1997 and 1998 and the web pages they refer to.

[11] See US Arms Control and Disarmament Agency, "Australia Group" (28 Oct. 1997), URL <http://www.acda.gov/factshee/wmd/cw/aus496.htm>.

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