National-security export-quality restrictions in segmented and non-segmented markets

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Abstract

This paper examines the effect of international price arbitrage on the willingness to set unilateral export controls. The restriction on the quality of exports of security-sensitive products limits the outside option of domestic customers: if the product available on the international market is of low quality, the firm can charge a high price to domestic customers for its latest technology. This effect leads the government to be less willing to introduce export controls on security-sensitive products. © 2003 Elsevier Science B.V. All rights reserved.

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1. Introduction

The development of dual-use technologies has made it difficult to give a clear answer to which products are ‘security-sensitive’, i.e., which products have potential military applications. It is particularly interesting to observe how the evolution of information technologies and computer capacity has provoked a change in the perception of national security among the most developed countries. This change in perception is especially evident in the U.S. The increasing dependency that the U.S. has on information networks makes it the most vulnerable objective in the world to eventual attacks with “viruses” or “logic bombs” from a foreign enemy. The U.S. Presidential Commission for the Protection of Essential Infrastructures (DARPA) was created to design defensive mech-
anisms in the event of “Information Warfare”. In addition, the Bureau of Export Administration (BXA) implements several means of export controls in order to avoid state-of-the-art technologies becoming a threat to US national security when exported to other countries. The National Defense Authorization Act on High Performance Computers\(^1\) controls and restricts the exports of powerful computers to Tier 3 countries. This is a group of 50 countries. Some of these countries are also producers of high tech computers, though U.S. computers generally have a higher quality. Export controls also apply to computer-related products such as software and cryptographic equipment. European countries have recently introduced security-related export controls on dual-use items and technology.\(^2\)

There is a debate over the use of export controls as a method to preserve national security (Becker, 1998). Defence producers have been long known to lobby governments (see, e.g. Lichtenberg, 1989). The extension of export controls to dual-use goods has further stimulated the involvement of different interest groups that attempt to influence governments in their policy making. Firms lobby governments to obtain export licences, defence authorities want to see national security preserved, and export controls on dual-use products may also affect domestic consumers.

The purpose of this paper is to examine the effect of quality restrictions on the profits of domestic and foreign producers and on the welfare of a country that sets export controls with and without international price arbitrage.

This research is related to a literature on strategic trade policy, which shows how governments use various trade instruments (e.g. tariffs, quotas or subsidies) in an attempt to capture rents from foreign firms.\(^3\) Strategic trade policy as proposed in this literature has little empirical foundation. This paper shows, however, how aspects of the framework apply to goods for which there are national-security concerns. The present paper introduces two main innovations. Firstly, because of the security concern of the governments, I focus on a new policy tool namely, restrictions on the quality of exported goods.\(^4\) Secondly, in order to reflect the “free-flowing” nature of the international markets, I consider the effect of international price arbitrage on the quality restriction. The security concern of exporters of weapons has been analyzed in the Arms Trade literature.\(^5\)

Few papers analyze trade policies in the presence of price arbitrage. Donnenfeld (1998) examined the effect of commercial policy on the composition and quality of imports supplied by a multiproduct foreign monopolist that sells goods of variable quality to a population of buyers who differ in their willingness to pay for quality. Donnenfeld

\(^1\) High Performance Computers (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).


\(^3\) See e.g. Brander and Spencer (1983). For a review of this literature see Brander (1995).

\(^4\) There has been investigations, however, of the effect of trade policies on quality choice of exporters. See for example Vandenbussche and Wauthy (2001).

describes a foreign monopolist using product differentiation to discriminate among domestic consumers whose preferences differ. He examines the consequences for trade policy of this type of discrimination and shows that restricting the quantity of imports improves the welfare of consumers.

Markusen and Venables (1988) compared trade and industrial policies in segmented and non-segmented markets. They use a model in which firms located in two different countries compete in quantities with transport costs between the two countries. With segmented markets, firms decide domestic and foreign quantities, taking as given the quantity that the foreign competitor sells in the domestic and foreign markets. With non-segmented markets, firms decide the aggregate quantity, taking as given the aggregate quantity that the competitor sells in both markets. The authors conclude that the effect of policy is greater when markets are segmented than when they are not segmented. This is related to my model because I am also interested in comparing government policies and national security policies, in my case, with and without market segmentation.

Trade globalization and the internet should contribute to integrate markets and reduce cross-country price differences. Computer-related goods are the single largest category of retail goods sold on-line (see Goolsbee, 2001). This study also suggests that on-line (remote) and off-line sales of computer-related products are unlikely to be truly separate markets. Although Goolsbee focuses on the U.S. market, his study is a good indicator of why globalization is more intense in the computer industry. Lower transport costs and an increase in the flow of information through on-line buying accelerate such international market integration.

I shall analyze the effect of price arbitrage on the decision of governments to impose quality restrictions on exports of security-sensitive products. A model depicts two firms located in different countries and producing a good with an exogenously given quality. One of the firms is restricted by the domestic government to sell a lower quality in the foreign market. I compare the effect of a restriction on the quality exported in the case in which the non-restricted firm can set different prices in the home and foreign market (i.e. no price arbitrage) with the case in which it sells its product at the same price in both markets (i.e. perfect price arbitrage).

It is shown that, under perfect price arbitrage, a looser restriction on the quality of the security-sensitive good exported has a negative effect on the domestic profits of the restricted firm and a positive effect on consumer welfare. I also show that the introduction of restrictions on quality becomes more difficult with perfect price arbitrage.

Section 2 presents the model and compares the results with and without perfect price arbitrage between the two countries. Section 3 presents the main conclusions of the paper.

2. The model

I consider two firms located in different countries, A and B. Firms produce a good with quality $q_A$ and $q_B$ respectively. Both firms sell their product in the home and the foreign market.

Consumers buy either one or zero units of the good. Their willingness to pay is increasing in the quality of the product, but they perceive the goods produced by the two
firms as imperfect substitutes. This is modeled by assuming that consumers are ‘located’ at different distances from the firms. This, together with the acknowledgment of transportation costs, different for each consumer, allows a firm with a lower quality product to have a positive share in the market. More precisely, consumers in both countries are uniformly distributed along the (0–1) line according to their preference for the two firms’ products (firm and consumers in country A will be usually referred to as domestic firm and consumers). Firms A and B are located at 0 and 1 on the line respectively. The utility function of a domestic consumer $i$ that buys from firm $j$ has the following form:

$$U_{ij}[q_j, P_j] = R + q_j - \lambda d_{ij} - P_j,$$

where $U_{ij}$ is the utility of consumer $i$ from buying good $j$, $j=A,B$; $d_{ij}$ is the distance between consumer $i$ and firm $j$. $\lambda$ is a positive parameter and $q_j$ and $P_j$ are the quality and price, respectively, that firm $j$ offers. $R$ is a positive constant, which we assume to be high enough for the participation constraint of consumers to be fulfilled. Foreign consumers have the same utility function. This framework provides a simple way of modelling vertical differentiation together with horizontal differentiation, and was first used by Economides (1989). Also, as in Economides (1989), quality is normalized so that an increase of one unit of quality increases utility from the product by one unit. For example, quality could be the speed of a computer.

The government in country A restricts the quality that the domestic firm, firm A, can export; it allows the firm to export a proportion $c$ of the quality available in the domestic market. The domestic firm offers a quality $q_A$ in its domestic market and a quality $q_A^*$ in its foreign market such that:

$$q_A^* = c q_A, \quad c \in [0, 1].$$

The government in country B does not restrict quality. Hence, the foreign firm, B sells the same quality at home and abroad, since willingness to pay for consumption is increasing in quality. I denote this quality as $q_B$.

I will only consider cases when the restricted quality, $\gamma q_A$, is equal or larger than the other firm’s quality, $q_B$. This reflects the idea that governments in countries that set export controls do not want the state-of-the-art technology to be transferred to other countries.

The domestic firm sets a price $P_A$ in its domestic market and a price $P_A^*$ in its foreign market. The foreign firm sets prices $P_B^*$ and $P_B$ its home and foreign markets, respectively.

In equilibrium, it must be the case that domestic consumers in country A are not better off by buying the lower quality good that the home firm sells in the foreign market. It must therefore be that $U_{iA}[q_A, P_A] \geq U_{iA}[q_A^*, P_A^*]$. For this to be the case, the following arbitrage condition must hold:

$$q_A(1 - \gamma) \geq P_A - P_A^*.$$

There is a distance from firm A, denoted $y$, at which a consumer in country A is indifferent between buying from the domestic or the foreign firm. Correspondingly, the
consumer from country B, which is at a distance $x$ from firm A is indifferent between buying from either of the two firms. Therefore, a proportion $y$ of consumers in country A buy from the domestic firm, A, and proportion $(1 - y)$ of the consumers of country A import from firm B. Also, a proportion $x$ of consumers of country B import from firm A and a proportion $(1 - x)$ of country B’s consumers buy from their domestic firm, B (see Fig. 1).

Note that we assume that there is a unilateral concern about security so that only government A sets a restriction on the exported quality. This reflects the different levels of concern about security across countries. Security, $S[\gamma]$, is expressed as a decreasing function of the proportion of quality exported, $S'[\gamma] < 0$. Note also that

$$(1 - \gamma) = \frac{q_A - \gamma q_A}{q_A}$$

can be interpreted as the rate of restriction on the exported quality. As in García-Alonso (2000), security is not a function of quantity but of quality, which corresponds with the characteristics of the export control rules on high-tech dual-use products (see García-Alonso and Hartley, 2000 and Becker, 1998 for a discussion). However, here I also assume that security depends on the domestic restriction on export quality. This captures the fact that those countries most concerned about the security consequences of exporting high-tech dual-use goods, specially information technology, are also more technologically advanced, and therefore, we would expect the quality produced by security-unconcerned countries to be lower.

The model is presented as a two-stage game. In the first stage, government A commits to a quality restriction. In the second stage, firms compete in prices. The game is solved backwards for both the no price arbitrage and price arbitrage cases.

2.1. No price arbitrage

I begin by assuming that firm B can discriminate between home and foreign consumers, and therefore set different domestic and export prices. I will use this as a benchmark for comparison with the case when there is perfect price arbitrage between the two countries.

\[\begin{align*}
\text{FIRM A} & \quad 0 \quad \cdots \quad y \quad \cdots \quad 1 \\
\text{FIRM B} & \quad 0 \quad \cdots \quad x \quad \cdots \quad 1
\end{align*}\]

Fig. 1. The security sensitive market.
2.1.1. The firms’ problem

In order to solve the maximization problem of the firms, we first derive the domestic and foreign demand of each of the two firms. These are given by the locations of the indifferent domestic and foreign consumers: \( y \) and \( x \). Using Eq. (1), we obtain the following firm A’s export demand:

\[
x = \frac{q_A - q_B + P_B^* - P_A^*}{2\lambda} + \frac{1}{2}.
\]  

(4)

Similarly, we obtain firm A’s domestic demand:

\[
y = \frac{q_A - q_B + P_B - P_A}{2\lambda} + \frac{1}{2}.
\]  

(5)

Since firm A sells goods with different qualities in the domestic and foreign market, there are two decision variables in the maximization problem, domestic and exports price. For simplicity, I assume zero production costs:

\[
\text{Max } \pi_A + \pi_A^* = \alpha P_A + x P_A^*,
\]  

(6)

where, \( \pi_A \) are the profits that firm A obtains in the domestic market, \( \pi_A^* \) are the profits it obtains in the export market, and \( \alpha \) is the relative size of the market in country A compared to the market in country B. We can think of \( \alpha \) as the density of consumers along the line in country A.

Substituting \( x \) and \( y \) from Eqs. (4) and (5) into the profit function of firm A (Eq. (6)) gives the first order conditions for the maximization problem of firm A:

\[
P_A = \frac{q_A - q_B + P_B}{2} + \frac{\lambda}{2},
\]  

(7)

\[
P_A^* = \frac{q_A - q_B + P_B^*}{2} + \frac{\lambda}{2}.
\]  

(8)

These are the reaction functions of the domestic and export price of firm A with respect to the export and domestic price of firm B. They are both upward sloping.

In the absence of price arbitrage, firm B can also discriminate between the home and the foreign market, even though it sells the good with the same quality in both markets. The maximization problem of firm B is:

\[
\text{Max } \pi_B + \pi_B^* = P_B(1 - x) + P_B\alpha(1 - y),
\]  

where, \( \pi_B \) are the profits that firm B obtains in the domestic market and \( \pi_B^* \) are the profits it obtains in the export market.

Substituting the \( x \) and \( y \) into the profit function of firm B gives the following first order conditions:

\[
P_B = \frac{1}{2}(\lambda - q_A + q_B + P_A),
\]  

(9)
Substituting Eqs. (7) and (8) into the above expressions gives the equilibrium domestic and export price of firm B in the absence of price arbitrage:

\[ P_{Bna}^* = \frac{\gamma q_A - q_B}{3} \]  
(11)

\[ P_{Bna} = \frac{\gamma q_A - q_B}{3} \]  
(12)

Substituting Eq. (12) into Eq. (7) gives the domestic price of firm A as:

\[ P_{Ana} = \frac{\gamma q_A - q_B}{3} \]  
(13)

and substituting Eq. (11) into Eq. (8) gives the export price of firm A as:

\[ P_{Ana}^* = \frac{\gamma q_A - q_B}{3} \]  
(14)

Finally, we derive the foreign and domestic demand for firm A:

\[ x_{na} = \frac{\gamma q_A - q_B + P_{Bna}^* - P_{Ana}^*}{2\lambda} + \frac{1}{2} = \frac{\gamma q_A - q_B}{6\lambda} + \frac{1}{2} \]  
(15)

\[ y_{na} = \frac{q_A - q_B + P_{Bna} - P_{Ana}}{2\lambda} + \frac{1}{2} = \frac{q_A - q_B}{6\lambda} + \frac{1}{2} \]  
(16)

The following remark summarizes the main properties of prices and demand.

**Remark 1.** In the absence of price arbitrage between countries, an increase in the proportion of quality exported, \( \gamma \), has a positive effect on the home firm’s export price, \( P_{Ana}^* \), and the exports demand for the domestic firm, \( x_{na} \), and a negative effect on the competitor’s domestic price, \( P_{Bna}^* \).

A variation in the proportion of quality exported does not however affect the domestic price, \( P_{Ana} \), or domestic demand of the restricted firm. Neither does it affect the export price of the non-restricted firm, \( P_{Bna} \). The relative size of the markets does not influence the equilibrium prices and market shares.

2.1.2. Country A’s problem

The government of country A sets the upper limit to the quality that the domestic firm is allowed to export to maximize domestic welfare. Welfare in country A is a function of the domestic firm’s profits, domestic consumer surplus, CS, and security, \( S[\gamma] \), \( S'[\gamma] < 0 \), \( S''[\gamma] < 0 \):  

\[ W = \pi_A + \pi_A^* + xCS + S[\gamma]. \]  
(17)
Consumer surplus in country A is:

\[
CS = \int_0^y U_{iA} \, \partial d_{iA} + \int_0^{1-y} U_{iB} \, \partial d_{iB}. \tag{18}
\]

The first element in the RHS of the above expression is the consumer surplus of consumers who buy from the home firm and the second element is the consumer surplus of the consumers who buy from firm B.

The first order condition of the maximization problem of the government is:

\[
\frac{\partial W}{\partial \gamma} = \frac{\partial \pi_A}{\partial \gamma} + \frac{\partial \pi_A^*}{\partial \gamma} + \frac{\partial CS}{\partial \gamma} + S'[\gamma] = 0. \tag{19}
\]

Using the equilibrium prices and quantities derived previously, we can analyze the effect of a variation in \( \gamma \) on the different elements of the welfare function separately. In the absence of price arbitrage, the profits that the domestic firm obtains in the domestic market do not depend on the upper limit to quality exported, since neither the domestic demand nor the domestic price depend on this. Also, consumer surplus is not affected by a variation in \( \gamma \) because the prices at which domestic consumers buy from the domestic or the foreign firm are not affected by it.

An increase in the upper limit to quality exported has however a positive effect on the export profits of the domestic firm:

\[
\frac{\partial \pi_A^*}{\partial \gamma} = \frac{\partial x_{na} P_{A^*}}{\partial \gamma} + \frac{dP_{A^*}}{dy} x_{na} = \frac{q_A}{3\lambda} \left( \frac{\lambda + \gamma q_A - q_B}{3} \right). \tag{20}
\]

Using Eq. (19) and the fact that security is the only term in the welfare function negatively affected by an increase in the upper limit to quality exported, we can see that the government of the security-concerned country restricts the quality exported by the domestic firm, only if the concern about security is sufficiently high.

2.2. Price arbitrage

I now analyze the consequences of perfect price arbitrage between the two countries. Since firm B sells the same quality in the domestic and foreign market, it must charge the same price in both markets. If the export price was lower than the domestic price, consumers in country B could always buy the good with the same quality and a lower price in the international market and vice versa.

2.2.1. The firms’ problem

Using Eq. (1) and taking into account that the price of firm B under perfect price arbitrage coincides in both markets, i.e., \( P_B^* = P_B \) (we use \( P_B \) in what follows) we obtain the following export demand for firm A:

\[
x = \frac{\gamma q_A - q_B + P_B - P_A^*}{2\lambda} + \frac{1}{2}. \tag{21}
\]
Similarly, firm A’s domestic demand is:

\[ y = \frac{q_A - q_B + P_B - P_A}{2\lambda} + \frac{1}{2}. \]  

(22)

Notice that the non-arbitrage condition (Eq. (3)) on \( P_A \) and \( P_A^* \) is fulfilled if \( y > x \). I will proceed under the assumption that the arbitrage constraint is not binding for firm A. The intuition for this is that, since the home firm is not restricted in the domestic market, competition there is more intense; therefore the consumer will always obtain a ‘better deal’ there. We will check if the assumption is indeed satisfied in equilibrium.

Substituting \( x \) and \( y \) from Eqs. (21) and (22) in the profit maximization problem of firm A (Eq. (6)), we derive the first order conditions:

\[ P_A = \frac{q_A - q_B}{2} + \frac{P_B}{2} + \frac{\lambda}{2}. \]  

(23)

\[ P_A^* = \frac{\gamma q_A - q_B}{2} + \frac{P_B}{2} + \frac{\lambda}{2}. \]  

(24)

Using Eqs. (23) and (24), it can be seen that the arbitrage condition is fulfilled.

Firm B must now set the same price in the export and domestic market due to the existence of perfect price arbitrage between the two countries:

\[ \max_{\{P_B\}} \pi_B^* + x \pi_B = P_B (1 - x + x(1 - y)). \]  

(25)

Substituting \( x \) and \( y \) into Eq. (25) gives the first order condition for firm B:

\[ P_B = \frac{\lambda}{2} + \frac{q_B}{2} - \frac{q_A (\gamma + x)}{2(1 + x)} + \frac{P_A^* + xP_A}{2(1 + x)}. \]  

(26)

Eqs. (23), (24) and (26) are the reaction functions of firms A and B. Note that they are upward sloping with respect to competitors’ price.

We now have a three equation system in \( P_A, P_A^* \) and \( P_B \). In order to derive the equilibrium prices, we substitute Eqs. (23) and (24) into Eq. (26) and solve for \( P_B \) in order to obtain its equilibrium value:

\[ P_B = \frac{\lambda}{3} + \frac{q_B}{3} - \frac{q_A (\gamma + x)}{3(1 + x)}. \]  

(27)

It is interesting to compare the no arbitrage prices with the prices obtained with perfect price arbitrage between the two countries. The export price that firm B sets if there is no arbitrage is smaller than the price it sets when there is arbitrage. Its domestic price without arbitrage is however higher than the price firm B sets when there is perfect price arbitrage. The reason is that since firm B cannot discriminate between foreign and domestic consumers, it must set a unique price for its good in-between the two prices it sets when there is not perfect price arbitrage.
The properties of firm B’s equilibrium price are also affected by the inability of firm B, due to the existence of perfect price arbitrage, to discriminate between domestic and foreign consumers. The price of firm B is decreasing in the upper limit to quality exported by the competitor. If firm B could set different prices in markets A and B, a variation in the quality restriction for firm A would only affect the domestic price of firm B. With price arbitrage, however, a variation in the quality gap with firm A in the domestic market affects the price of firm B in both markets.

Also, notice that the price of firm B is decreasing in the relative size of the market of country A (i.e., \( \alpha \)) as long as there is a restriction on the quality that firm A can export (i.e., if \( \gamma < 1 \)). Since firm B must face the highest quality from the competitor in country A, if firm B could set different prices, it would set a lower price in market A than in market B. Since it cannot discriminate between the foreign and home markets, it sets a price that is in-between the two prices it would set if it could discriminate. However, if the importance of market A increases (i.e., if \( \alpha \) increases), firm B will set its price closer to the optimal price it would set in market A if it could discriminate.

Now, substituting Eq. (27) into Eqs. (24) and (26) we obtain the equilibrium domestic price of firm A:

\[
P_A = \frac{1}{C_0} \left( \frac{k}{3} + \frac{q_B}{2} \left( 1 - \frac{\gamma + \alpha}{3(1 + \alpha)} \right) \right).
\]

The price that firm A sets in its home market is decreasing in the upper limit to quality exported. The intuition is that an increase in the upper limit to quality that firm A can export decreases the price of the competitor. This leads firm A to decrease its domestic price as well. Hence, even though the variation in quality exported does not directly influence the domestic price of firm A (since it does not affect the quality of its domestic product), there is an induced effect due to the perfect price arbitrage between the two countries.

We can also see that when \( \gamma < 1 \), firm A’s domestic price is decreasing in the size of the home market due to the indirect negative effect that this has on firm B’s price. As we know, when there is a restriction (\( \gamma < 1 \)), the higher the relative size of market A, the smaller the price of firm B, and this induces a lower domestic price of the restricted firm, A.

Finally, we derive the equilibrium export price of firm A:

\[
P_A^* = \frac{1}{C_0} \left( \frac{k}{3} + \frac{q_A}{2} \left( \frac{\gamma + \alpha}{3(1 + \alpha)} \right) \right).
\]

Firm A’s export price is increasing in the upper limit to quality exported. An increase in this upper limit allows the firm to set a higher price for any given \( P_B \). Even though firm B reacts to the increase in A’s quality by decreasing its price, the net effect on \( P_A^* \) is clearly positive. Also, for the same reason as before, the export price is decreasing in the size of the home market.

We can now compare the equilibrium prices of firm A with those that would prevail in the absence of price arbitrage. Firm A’s domestic price is higher when there is arbitrage than when there is not. Meanwhile, firm A’s export price is smaller when there is perfect.
price arbitrage than when there is not. The intuition is based on the competitor setting an export price smaller than the unique price it could set with perfect price arbitrage. Since the competitor’s export price is now smaller, firm A’s domestic price becomes smaller too.

Substituting the equilibrium prices in Eqs. (21) and (22), we derive the foreign and domestic demand for firm A:

\[
 x = \frac{1}{2\lambda} \left( \frac{q_A}{2} \left( \frac{1}{3(1 + \alpha)} \right) - \frac{q_B}{3} \right) + \frac{1}{2}, \tag{30}
\]

\[
 y = \frac{1}{2\lambda} \left( \frac{q_A}{2} \left( \frac{1}{3(1 + \alpha)} \right) - \frac{q_B}{3} \right) + \frac{1}{2}. \tag{31}
\]

Both the domestic and foreign demands of firm A are decreasing in the relative size of market A. An increase relative size of market A has a negative effect on firm B’s price and this effect outweighs the decrease in the prices of the domestic firm and therefore reduces its domestic and export demand. An increase in the upper limit to quality allowed to be exported has a positive effect on the foreign demand of firm A and a negative effect on the domestic demand of firm A. Let us recall that firm B must sell at the same price in both markets. The increase in the quality exported by firm A makes firm B reduce the price of its good. This makes firm B’s product more attractive for the consumers in country A.

Comparing the above expressions with Eqs. (15) and (16), we see that the foreign demand of firm A is smaller with perfect price arbitrage between the two countries; however its domestic demand is higher. In Fig. 1, x and y are closer in the absence of price arbitrage.

In summary:

**Proposition 1.** When there is perfect price arbitrage between countries, an increase in the upper limit to quality exported has a negative effect on the price of the nonrestricted firm and the domestic price of the restricted firm and a positive effect on the export price of the restricted firm. Also, an increase in the upper limit to exported quality has a positive effect on the export demand of the restricted firm and a negative effect on its domestic demand. An increase in the importance of the home market of the security-concerned country has a negative effect on all prices as well as on the domestic and foreign demand of the restricted firm.

I now analyze the optimal security policy of the security-concerned government that sets the upper limit of quality that the domestic firm is permitted to export.

### 2.2.2. Country A’s problem

By using Eq. (19) and the equilibrium prices and quantities previously derived, we can establish the effect of a variation in the upper limit to quality exported on the different elements of the welfare function.

I first consider the effect of a decrease in the restriction on the consumer surplus in country A.
Proposition 2. Under perfect price arbitrage, an increase (decrease) in the proportion of quality exported has a positive (negative) effect on domestic consumer surplus.

Proof

\[
\frac{\partial \text{CS}}{\partial \gamma} = (R + q_A - P_A - \lambda y) \frac{\partial y}{\partial \gamma} - y \frac{\partial P_A}{\partial \gamma} - (R + q_B - P_B - \lambda (1 - y)) \frac{\partial y}{\partial \gamma} - (1 - y) \frac{\partial P_B}{\partial \gamma}.
\]

Substituting \((\partial y/\partial \gamma)\) above we have:

\[
\frac{\partial \text{CS}}{\partial \gamma} = -(1 - y) \frac{\partial P_B}{\partial \gamma} - y \frac{\partial P_A}{\partial \gamma} = \frac{q_A}{3(1 + x)} \left(1 - \frac{y}{2}\right) > 0.
\]

The intuition is that an increase in \(\gamma\) has a negative effect on the prices that domestic consumers pay for buying the good from either the domestic or the foreign firm.

I now derive the effect of an increase in the upper limit to quality exported on profits. An increase in the proportion of quality allowed to be exported has a positive effect on the profits that firm A obtains from selling in the foreign market, and a negative effect on the profit it obtains in the home market. That is,

\[
\frac{\partial \pi_A^*}{\partial \gamma} = \frac{\partial x}{\partial \gamma} P_A^* + \frac{\partial P_A^*}{\partial \gamma} x = \frac{q_A}{3} \left(2 + 3x\right) x > 0,
\]

\[
\frac{\partial \pi_A}{\partial \gamma} = \frac{\partial y}{\partial \gamma} P_A + \frac{\partial P_A}{\partial \gamma} y = -\frac{q_A}{3(1 + x)} y < 0.
\]

The negative effect of an increase in the quality allowed to be exported on firm A’s domestic profits is due to firm B selling its good at the same price in both markets. As a consequence of the increase in the upper limit to quality exported, firm A faces a lower price from firm B. This reduces the profits of firm A in its home market.

We can now compare the incentives to introduce a quality restriction with perfect price arbitrage and without price arbitrage.

Proposition 3. The introduction of restrictions on the quality of security-sensitive goods exports is less likely in the presence of price arbitrage.

Proof. We first calculate the effect of a variation in the upper limit to quality exported on the domestic firm’s profits evaluated at \(\gamma = 1\). Note that, when \(\gamma = 1\), \(x = y\), therefore, from Eqs. (30) and (31), we have:

\[
\left. \frac{\partial (\alpha \pi_A + \pi_A^*)}{\partial \gamma} \right|_{\gamma=1} = \frac{q_A}{3} \left(\lambda + \frac{q_A - q_B}{3}\right).
\]

Note that this coincides with the effect of a variation in the upper limit to quality exported on the domestic firm’s profits evaluated at \(\gamma = 1\) when there is no price arbitrage, as in Eq.
(20). As has been noted, in the absence of perfect price arbitrage, a variation in the upper limit to quality exported does not affect consumer surplus. Finally, from the previous proposition, under perfect price arbitrage, a reduction in the upper limit to quality exported has a negative effect on consumer surplus.

We can now discuss what would happen if the government assigned a different weight on the welfare function to consumers’ and producers’ interests. In the case of no price arbitrage, a different weight on consumers would not affect the decision to introduce export controls. We saw that with no price arbitrage, export controls do not affect domestic consumer surplus. Therefore, the crucial factor influencing the decision regarding export controls without price arbitrage remains the relative weight on security with respect to profits in the welfare function.

The introduction of perfect price arbitrage does not change much. As seen in the last proposition, restrictions on exported quality have a negative impact on both producer profits and domestic consumer surplus. Therefore, the higher the weight on producers’ or consumers’ interests, the less likely is the introduction of an export control. This however looks at the consumer interest in terms of consumption, as formulated in the social welfare function. Consumers are also affected by the security concerns reflected in the government’s policy regarding export quality.

3. Concluding remarks

Because of the interface between military and civil technology, restrictions on the quality of exports for national-security reasons affect a wide range of civil products. The most important cases are information technology and computers. This paper has analyzed the effect of unilateral export controls on the domestic and foreign producers’ profits and the welfare in the country that sets the export controls, with and without perfect price arbitrage. I have shown that when there is perfect price arbitrage between countries, a looser restriction on the quality of exports of a security-sensitive product decreases the price of a foreign competitor and the domestic price of restricted firm, while the export price of the restricted firm increases. By contrast, in the absence of price arbitrage between countries, a looser restriction only affects the market in which goods with restricted quality are sold. The home firm’s export price increases, as does the export demand for the domestic firm. The competitor’s domestic price decreases.

The effect on welfare of quality controls has also been analyzed. In the absence of perfect price arbitrage, a looser restriction has a positive effect on the export profits of the restricted firm. Due to the negative effect that a restriction has on domestic consumer surplus, the introduction of such a restriction is less likely in the presence of price arbitrage. In other words, under the existence of price arbitrage, the perceived negative security consequences of exporting state-of-the-art dual-use goods must be higher for restrictions to be introduced.

The weight given in the welfare function to national security relative to consumer surplus and domestic firm’s profits is a crucial factor in the decision of whether or not to impose an export control. Such weight is likely to be influenced by lobbying activities of producers and consumers of dual-use products, and also positions taken by national defence authorities.
I have assumed that non-restricted qualities are exogenous. Relaxing this assumption would require a further set of assumptions on the timing of decisions and firms’ cost structures. Depending on the commitment power of the government, the export control stage could be before or after the stage where firms compete in qualities. Also, asymmetry on cost structures would have to be included to reflect the technological superiority of the country imposing the export quality restrictions. An initial analysis of the effects of export controls on quality can be found in García-Alonso (2000).

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