Competition in the gum arabic market: a game theoretic modelling approach

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Abstract

Gum arabic is mainly produced from two Acacias that are found in the gum belt of Sub-Saharan Africa. These are *Acacia senegal* that produces high quality gum and *Acacia seyal* that produces low quality gum. In recent years the gum market structure has changed and Sudan lost its near monopoly position as Chad and Nigeria became important gum suppliers. In order to understand the competition between Sudan, Chad and Nigeria in the export of high and low quality gum arabic we develop a von Stackelberg model with interdependent markets. Whereas Sudan (the leader) has an absolute cost advantage in the export of high quality gum, Chad and Nigeria (the followers) have a cost advantage in the export of low quality gum. We determine the market equilibrium outcomes and study the impact of development assistance scenarios to promote either the high or low quality gum. Our results suggest that the leader is better off promoting the quality for which it has cost advantage, i.e. the high quality gum. This also leads to a lower reduction in the competitors' profit than promoting low quality gum. Similarly, when followers promote the quality for which they have cost advantage, i.e. the low quality gum, this results in a lower reduction in the leader's profit than when they promote high quality gum. The best strategy of the followers is, however, sensitive with respect to the elasticities of demand.

Keywords: Sub-Sahara, gum arabic, oligopoly, interdependent markets, Stackelberg equilibrium
JEL: D43, L11, Q13, Q17

1. Introduction

Gum arabic or gum Acacia trade is a market of vital importance to Sub-Saharan African countries' economy and environment. Gum exports represent a source of foreign exchange and gum harvest is an additional income source for the poor farming

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population in the Sub-Saharan area. Gum arabic is mainly produced from two Acacias that are found to a varying intensity in the gum belt of Sub-Saharan Africa. These are: *Acacia senegal* that produces hard gum and *Acacia seyal* that produces friable gum, the latter is considered to have a relatively low quality and is only used for a price advantage or when supplies of hard gum are low (MACRAE and MERLIN, 2002). Trade in friable gum is relatively new and more recently increasing whereas trade in hard gum dates back to the Pharaoh's civilization and was used by the ancient Egyptians for the preparation of ink, water colours and dyes.

Acacia trees are cultivated by farmers as part of an agroforestry system. Under this system the tree serves a variety of ecological functions in addition to gum production. These are soil erosion and run off reductions, water retention and nitrogen fixation. Over large areas of the Sahel zone the presence of the tree acts as a buffer against desertification – a major environmental problem in the region. Profitable gum arabic production is crucial to ensure that farmers have appropriate incentives to cultivate and expand gum production, and thereby maintain the ecological functions of the tree.

The aim of this article is to understand the functioning of the gum arabic market because of its vital importance for the agro-forestry systems in the gum belt of Sub-Sahara Africa. We provide a model capturing the market structure of the gum arabic market and we describe two scenarios to study impacts of subsidies to the local gum producing industry.

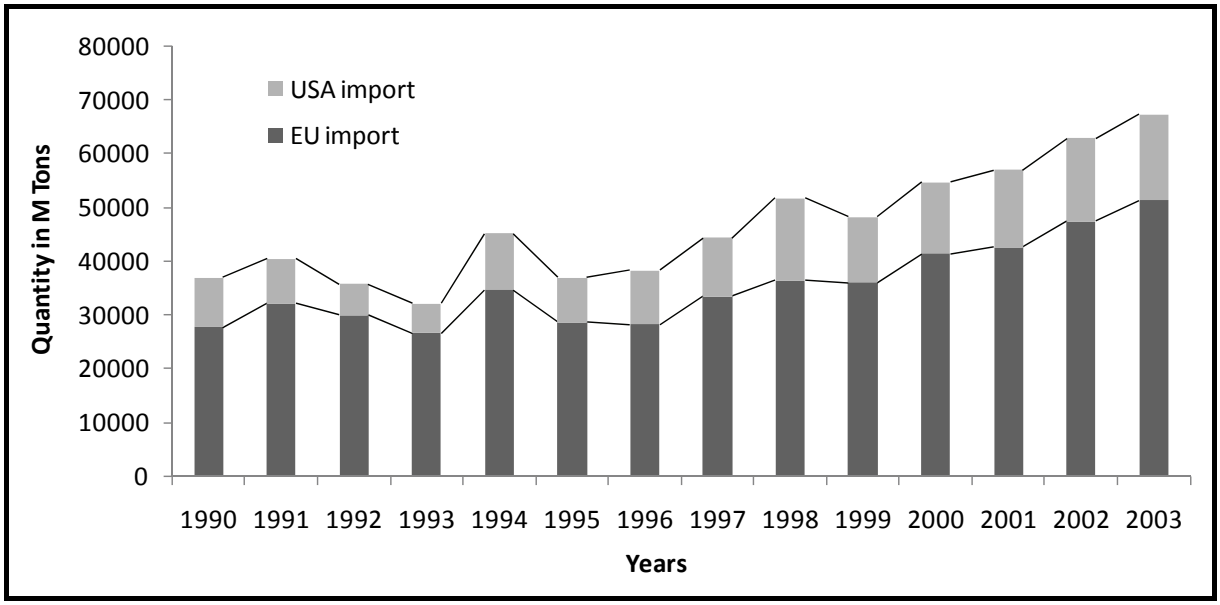
Gum arabic generally has no or few uses in the producing countries but is demanded on the international market mainly by the pharmaceutical and food industries. The main uses of gum arabic are based upon its properties of emulsification, adhesiveness, thickening, binding and stabilization. The precise molecular structure of gum arabic, its functional properties, the uses to which gum arabic can be put, and its commercial value differ according to the botanical origin of the gum, i.e. *Acacia senegal* or *Acacia seyal* (FAO, 1995).[1] Friable gum has inferior emulsifying properties and sometimes forms dark solutions in water due to the presence of tannins and others impurities (ibid). Nevertheless, recently a technique was developed to decolourize the naturally dark friable gum without damaging its attractive natural properties (ISC undated). This development is likely to open new markets for friable gum in food and pharmaceutical applications which require colourless solutions.

The market for gum arabic is dominated by few countries in terms of exports, re-exports and imports. The European Union is the biggest importer of gum arabic (over

[1] The two gum qualities can be distinguished from each other by molecular characteristics such as: optical rotation, the relative proportion of nitrogen content, viscosity, and sugar and uronic acid composition (WILLIAMS and PHILLIPS, 2000).

70%) and within the EU, France, UK and Germany are the major re-exporters of processed gum. The United States is the second major importer. Figure 1 shows gum imports by the EU and USA over the period 1990-2003. An upward trend in imports can be observed and the market is projected to grow at an annual rate of 5% reaching a level of 90,000 metric tons by the year 2010 (MACRAE and MERLIN, 2002).

Figure 1. Imports of gum arabic (EU and USA 1990-2003)



Source: COPPEN (1999) and COMTRADE (2005)

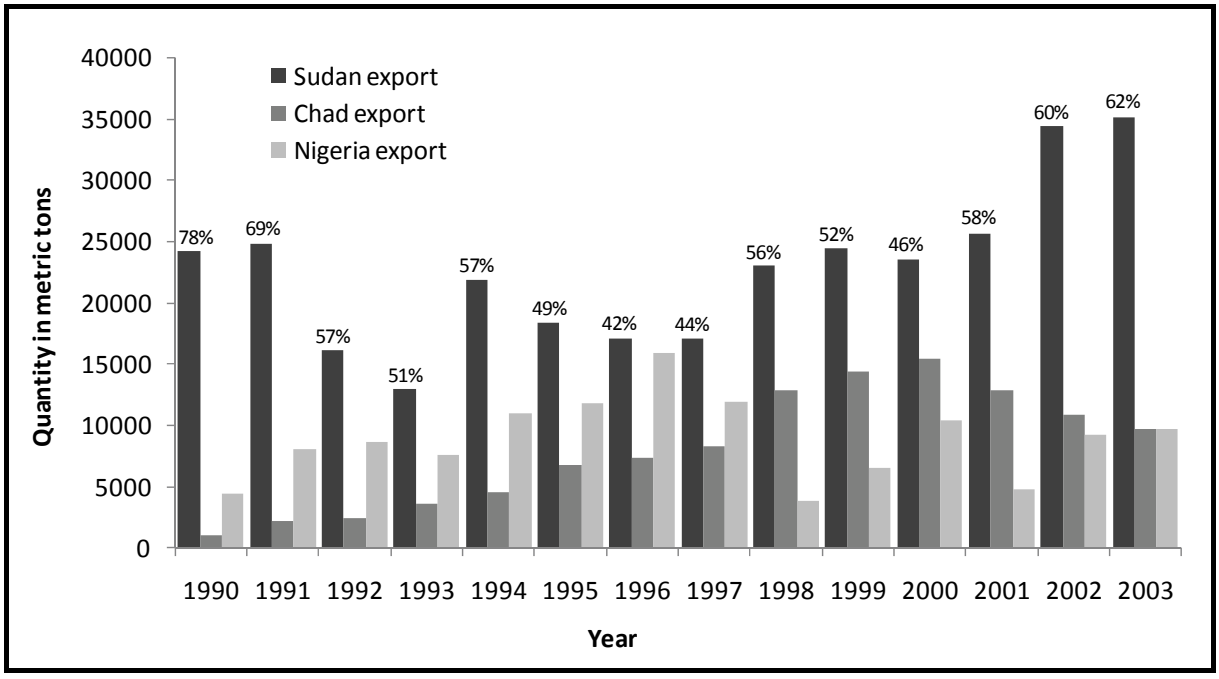
Exports of gum arabic are almost exclusively of African origin and mainly produced in the Nile River basin (Sudan, Ethiopia), the Lake Chad region (Chad, Nigeria, Cameroon, Niger, Central African Republic) and the Senegal River basin (Senegal, Mali, Mauritania).[2] Though the exact balance between the two qualities in the market is difficult to identify and volatile, *Acacia senegal* dominates the gum arabic commerce and on average has a market share of 70%. For Sudan 80% of gum export is from *Acacia senegal* and 20% is from *Acacia seyal* (ABDULLAHI, 2004). Historically Sudan has dominated world production and trade of gum arabic. During the period 1925-85 exports from Sudan accounted for around 80% of world exports (CHIKAMAI et al., 1996; MACRAE and MERLIN, 2002). This domination, however, has become less marked in recent years. Years of the Sahel drought (1970s-1980s) have led to erratic and low supplies of gum from Sudan and a huge rise in price that have choked off the demand for gum arabic. This has triggered an effort to develop manufactured

[2] Few of these countries appear in trade statistics as gum exporter, nevertheless, the non exporting ones have the potential to export gum because of the presence of Acacia trees.

substitutes and to diversify the gum supply sources so as to spread the risks involved in purchasing gum from a part of the world which is liable to climatic and socioeconomic unrest. The technical properties of a sample of gum arabic from other African countries was assessed and the quality of gum arabic from Chad and Nigeria is found to be good and some importing companies started to be active in supporting the promotion of gum development in these countries (COPPEN, 1999).

Market studies on gum arabic suggest that the demand for friable gum has increased in recent years and is expected to increase further following the recent specification of gum arabic by the joint FAO/WHO Expert Committee on Food Additives (JECFA) which consolidates the position of gum from *Acacia seyal* as a food additive (JECFA 1999).[3] The increased demand for friable gum further opened the way for other African exporters that are specialized mostly in the export of friable (low quality) gum and Sudan currently faces a growing competition from Chad and Nigeria. Figure 2 shows gum export from Sudan, Chad and Nigeria during the period 1990-2003 and the percentage share of Sudan on the world export market for gum. It can be seen that Chad's exports have increased since 1993 and started to decline again since 2001.

Figure 2. Export of gum arabic (Sudan, Chad and Nigeria, 1990-2003)



Source: COPPEN (1999) and COMTRADE (2005)

[3] The term "gum arabic" was previously defined as "the gummy exudation of *Acacia senegal* (L) Willdenow or closely related species". The new definition adopted by JECFA was contested by Sudan since restricting the definition of gum arabic to the product of *Acacia senegal* will allow Sudan to maintain its control over the gum market (MACRAE and MERLIN, 2002)

Current international interest in gum arabic can be gauged from the fact that the world market for gum arabic was the subject of several recent commercial reviews (PARKER, 2005). In light of the increased demand for gum arabic and the instability in the gum arabic supply which is caused by natural calamities along with political unrest in the producing countries[4] a number of governments, entrepreneurs and international gum stakeholders are embarking on supporting the promotion of gum production in Sub-Saharan Africa. The main objective is to diversify the supply base and to stabilize prices of gum arabic. Other complimentary objectives – stated by donors – to promote gum production in the Sahel include among others desertification control, local employment and increased income for farmers as well as increased foreign exchange earning for the producing countries. Acacia trees are important for the livelihoods of many rural populations and its incorporation into farming systems will diversify agriculture, enhance income generation and contribute to land improvement, replenish soil fertility and mitigate desertification (ACACIAGUM, 2005).

In addition reducing dependence on Sudanese gum is also on the agenda of some donor organizations not only because of the natural calamities and the political upheavals that adversely affects gum production in Sudan but also because of Sudan's political link to terror. MACRAE and MERLIN (2002: 11) report:

"As a result of the bombing of the World Trade Centre in September 2001, the United States have put into action a program designed to reduce their dependence on the Sudan, considered to be too close to terrorism for comfort. As regard gum arabic, Nigeria has been singled out as a possible replacement for the Sudan and currently the USAID is in the process of mounting an important program of assistance to the gum arabic sector in this country".

It is apparent from the preceding that strategic and political interest in reducing the volatility of the gum arabic supply and prices along with the positive economic and environmental externalities associated with gum production have triggered proposals to support gum production in Sub-Saharan Africa. In the light of the recent changes in gum market structure and the proposed policies we aim to understand the best strategy for the key players. In particular we assess the impact of two alternative development assistance projects for promoting gum in the Sahel on gum arabic output, prices and welfare in the respective countries. The analysis is based on a von Stackelberg model to represent the gum market structure with Sudan as leader and Chad and Nigeria as the followers and investigating the effect of two competing development assistance projects on market equilibrium. In this approach each country is represented by one

[4] This is particularly true in the case of Sudan as the current war in Darfur a major producing region of gum arabic in west Sudan have adversely impacted the collection and exportation of gum arabic (PURCELL, 2005).

firm. This is a natural assumption because for Sudan the gum arabic trade is controlled by the Gum Arabic Company (GAC). While in the case of Chad and Nigeria, though there are few companies involved in the gum arabic business, the industry is coordinated by central bodies (Société Commerciale du Chari et du Logone (SCCL) in Chad and the Nigerian Gum Arabic Association in Nigeria.

Our paper makes a novel contribution to the literature by introducing interdependent markets of vertically differentiated gum qualities (high and low quality gum) in a Stackelberg framework. Moreover, we extend the existing literature by allowing for differences in production cost. Although the leadership of Sudan in the gum market is quite evident, our paper is the first to apply the Stackelberg model to this market. We start with the base case in which Sudan is assumed to have an absolute cost advantage over the followers in the production and export of the high quality gum and vice versa. We then compare the market equilibrium outcomes under two development assistance projects to promote gum production as currently on the agenda of international stakeholders in the gum arabic business. Sudan (the leader) is the recipient of the first development assistance project. The project fund could either be devoted to promote the production and export of high quality or low quality gum. Chad and Nigeria (the followers) receive the second development assistance project and allocate the project fund to promote either high quality or low quality gum. In both cases we assume that the development assistance project fund will lead to 10% reduction in the marginal cost of production and export of the gum quality for which the project fund is allocated. The political decision to provide the development assistance is exogenous to our model. Our aim is not to explain geo-political behaviour of donors but rather to assess the impact of subsidies channelled toward the gum arabic producers.

The remainder of the paper is structured as follows. The next section further motivates the choice of a Stackelberg model to represent the gum market structure and understand the relevant policy options. Section 3 describes the model we use for analysis followed by section 4 that presents the data and the parameter calibration. Section 5 presents the different development assistance scenarios and section 6 discusses and compares the scenario results. Section 7 offers conclusions.

2. Theoretical background

The international gum export market can be characterized as an oligopoly market where three major producing countries (Sudan, Chad and Nigeria) represent over 95% of the world gum primary export market (ITC, 2000) while other minor producing countries serve different niche markets. Amongst the three major players Sudan is a dominant exporter. In oligopoly models, one side of the market typically consists of either price or quantity setters, with price takers on the other side. With a homogenous

product the Cournot model is most often chosen to describe market interaction, and with differentiated products, the Bertrand model is usually applied. For each of these static simultaneous decision models of oligopoly there is a sequential decision counterpart. These sequential decision models are the progeny of VON STACKELBERG's (1934) strategic analysis of quantity setting. Stackelberg models rely on leadership by one of the rivals and extend the Cournot model to include leadership behaviour. The Stackelberg leader's output choice influences the output choices of its rival and the leader chooses output in full recognition of its follower's reactions. Von Stackelberg's insight has also been adapted to the Bertrand pricing model. In this case the leader would choose a price that its followers would respond to (HIGGINS, 1996).

In Stackelberg models, the decisions of followers and the choice of output or price by the leader are made sequentially in two stages (SHAPIRO, 1989). In stage 1 the leader chooses to maximize profit anticipating how his choice affects his rivals' choices. In stage 2 the followers independently maximize their profit functions taking the decisions of the leader as given. In this regard, the choice between price-setting (Bertrand) and quantity-setting (Cournot) models usually depends on the relative heterogeneity of the products for sale in the market to be analyzed. The original Stackelberg model consists of two firms, a leader and a follower. Subsequently, researchers have generalized the model to include more than two firms (ANDERSON and ENGERS, 1992; CHURCH and WARE, 1996). Most existing work that extends the Stackelberg model to include more than two firms always assumes identical cost functions for all firms (PAL and SARKAR, 2001). This assumption, however, is rather restrictive, since the firms' costs may actually differ. Here we introduce a cost advantage for the leader (Sudan) for high quality gum, but a cost advantage for the followers (Chad and Nigeria) for low quality gum.

Our model mimics the international market for gum arabic using von Stackelberg's model of non-cooperative oligopolistic behaviour where Sudan is a leader while Chad and Nigeria are followers. This seems a natural representation of the gum arabic export market since Sudan is not only a dominant exporter for gum but also its quality and classification for the hard gum is used as yardstick on the world market. The countries' decision variables are output levels for the two gum qualities and the output decisions are made sequentially: the dominant firm (Sudan) has the first mover advantage while the other firms (Chad and Nigeria) take the decision of the leader as given (CARLTON and PERLOFF, 2000). Due to government control of the gum arabic exports in the respective countries we can treat each country as a single firm. We assume, however, that there is no market power on the demand side. The importing industrialised countries (EU and USA) have competitive markets in food processing and chemical industries.

We use our model to examine the impact of market interventions like international development assistance projects proposed by the USAID, EU and other international donors to promote gum arabic production in Sub-Saharan Africa.

3. The model

The gum arabic market in our Stackelberg model is divided into two segments: the high quality gum and the low quality gum hereafter indicated by q $(q = 1,2)$, respectively. We assume that the utility from the consumption of the two gum qualities is quadratic and strictly concave: $U(X_1, X_2) = \alpha_1 X_1 + \alpha_2 X_2 - 1/2(\beta_1 X_1^2 + \beta_2 X_2^2 + 2\gamma X_1 X_2)$.

Following the analysis of SINGH and VIVES (1984) this utility function generates a linear system of inverse demand functions

(1a) $P_1 = \alpha_1 - \beta_1 X_1 - \gamma X_2$

(1b) $P_2 = \alpha_2 - \beta_2 X_2 - \gamma X_1$

where P_1, P_2 are the prices of high and low quality gum, respectively. Parameters $\alpha_1, \alpha_2, \beta_1$ and β_2 are positive constants and X_1, X_2 are the total world demands for high and low quality gum, respectively. The parameter γ measures the level of substitutability (i.e. the degree of product differentiation) between the two gum qualities and we assume that $\gamma > 0$.[5] Furthermore, $X_q = x_q^S + x_q^C + x_q^N$ where x_q^S is the output of Sudan (the leader) and x_q^C, x_q^N are the outputs of Chad and Nigeria, respectively, of gum of quality $q = 1, 2$.

We assume that in each country i the high and low quality gum are produced under constant marginal costs of production equal to c_1^i and c_2^i, respectively. The marginal cost of producing the high quality gum is greater than the marginal cost of producing the low quality gum ($c_1^i \geq c_2^i$) because the high quality gum is usually exported after cleaning, sorting and grading while the low quality gum only undergoes a cleaning process. In addition the production of the high quality gum is stimulated by "tapping" the *Acacia senegal* tree whereas the low quality producing gum tree (*Acacia seyal*) does not require tapping and exudes its gum naturally. Furthermore, for simplification, we assume identical marginal costs for Chad and Nigeria equal to c_q^f where $f = C, N$ refers to the fringe.

[5] If $\gamma = 0$, then the two products are independent and can be modeled as separate markets.

For historical and institutional reasons we consider Sudan to be the incumbent with first mover advantage, so the countries choose their quantities as follows: Sudan chooses its high and low quality gum quantity setting strategy (x_1^S, x_2^S) incorporating the reaction functions of Chad and Nigeria which specify their profit maximizing quantities as a function of Sudan's output choice.[6] Chad and Nigeria observe x_q^S, for $q = 1, 2$ and simultaneously choose x_q^C and x_q^N respectively, for $q = 1, 2$.

Given that Sudan chooses x_q^S and Chad chooses x_q^C, then Nigeria will choose x_q^N to maximize:

$$\Pi^N(X_1, X_2) = P_1 x_1^N + P_2 x_2^N - c_1^f x_1^N - c_2^f x_2^N .$$

Substituting the inverse demand functions in (1a) and (1b) into the profit function of Nigeria gives

$$\begin{aligned}\Pi^N(X_1, X_2) = &\left[\alpha_1 - \beta_1\left(x_1^S + x_1^C + x_1^N\right) - \gamma\left(x_2^S + x_2^C + x_2^N\right)\right] x_1^N \\ &+ \left[\alpha_2 - \beta_2\left(x_2^S + x_2^C + x_2^N\right) - \gamma\left(x_1^S + x_1^C + x_1^N\right)\right] x_2^N - c_1^f x_1^N - c_2^f x_2 .\end{aligned}$$

Nigeria will maximize its profit with respect to its output choice of the high quality and low quality gum by setting marginal revenues equal to marginal costs that is

(2a) $$\alpha_1 - \beta_1 x_1^S - \beta_1 x_1^C - 2\beta_1 x_1^N - \gamma\left(x_2^S + x_2^C + 2x_2^N\right) = c_1^f .$$

(2b) $$\alpha_2 - \beta_2 x_2^S - \beta_2 x_2^C - 2\beta_2 x_2^N - \gamma\left(x_1^S + x_1^C + 2x_1^N\right) = c_2^f .$$

Solving equation (2a) and (2b) to derive Nigeria's output response function we get

(3a) $$x_1^N = \frac{\beta_2\left(\alpha_1 - c_1^f\right) - \gamma\left(\alpha_2 - c_2^f\right) - \left(\beta_1\beta_2 - \gamma^2\right)\left(x_1^S + x_1^C\right)}{2\left(\beta_1\beta_2 - \gamma^2\right)} .$$

(3b) $$x_2^N = \frac{\beta_1\left(\alpha_2 - c_2^f\right) - \gamma\left(\alpha_1 - c_1^f\right) - \left(\beta_1\beta_2 - \gamma^2\right)\left(x_2^S + x_2^C\right)}{2\left(\beta_1\beta_2 - \gamma^2\right)} .$$

Likewise, by symmetry, the output maximizing quantity for Chad with respect to each gum quality is also given by (3a) and (3b) when superscripts *N* and *C* are exchanged.

[6] Although Sudan is not dominant in the low quality gum market we model Sudan as leader in the market for the two gum qualities in order to simplify the analysis.

Substituting the output maximizing quantities for Nigeria in (3a) and (3b) for the high and low quality gum respectively into the expression for Chad maximizing output quantities and rearranging gives the reaction functions of Chad as a function of Sudan output choice which is by symmetry equal to the reaction functions of Nigeria.

(4a) $$x_1^{C*} = x_1^{N*} = \frac{1}{3}\left[\frac{\beta_2\left(\alpha_1 - c_1^f\right) - \gamma\left(\alpha_2 - c_2^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} - x_1^S\right].$$

(4b) $$x_2^{C*} = x_2^{N*} = \frac{1}{3}\left[\frac{\beta_1\left(\alpha_2 - c_2^f\right) - \gamma\left(\alpha_1 - c_1^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} - x_2^S\right].$$

Sudan will maximize its profit with respect to output choice incorporating the reaction functions of Chad and Nigeria shown in equation 4a and 4b.

$$\Pi^S\left(X_1, X_2\right) = \left[\alpha_1 - \beta_1\left(x_1^S + x_1^{C*} + x_1^{N*}\right) - \gamma\left(x_2^S + x_2^{C*} + x_2^{N*}\right)\right]\cdot x_1^S + \left[\alpha_2 - \beta_2\left(x_2^S + x_2^{C*} + x_2^{N*}\right) - \gamma\left(x_1^S + x_1^{C*} + x_1^{N*}\right)\right]\cdot x_2^S - c_1^S x_1^S - c_2^S x_2^S.$$

From the first order conditions we get Sudan's profit maximizing quantities for the high and low quality gum

(5a) $$x_1^S = \frac{3}{2\beta_1}\left(\alpha_1 - c_1^S\right) + \left(\frac{\gamma^2}{\beta_1} - \beta_2\right)\frac{\left(\alpha_1 - c_1^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} - \frac{\gamma}{\beta_1}x_2^S.$$

(5b) $$x_2^S = \frac{3}{2\beta_2}\left(\alpha_2 - c_2^S\right) + \left(\frac{\gamma^2}{\beta_2} - \beta_1\right)\frac{\left(\alpha_2 - c_2^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} - \frac{\gamma}{\beta_2}x_1^S.$$

Substituting x_2^S from (5b) into (5a) and vice versa and simplifying we get

(6a) $$x_1^S = \frac{1}{\left(\beta_1\beta_2 - \gamma^2\right)}\left[\begin{array}{l}\frac{3}{2}\beta_2\left(\alpha_1 - c_1^S\right) + \frac{\left(\gamma^2\beta_2 - \beta_1\beta_2^2\right)\left(\alpha_1 - c_1^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} \\ -\frac{3\gamma}{2}\left(\alpha_2 - c_2^S\right) - \frac{\left(\gamma^3 - \gamma\beta_1\beta_2\right)\left(\alpha_2 - c_2^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)}\end{array}\right].$$

(6b) $$x_2^S = \frac{1}{\left(\beta_1\beta_2 - \gamma^2\right)}\left[\begin{array}{l}\frac{3}{2}\beta_1\left(\alpha_2 - c_2^S\right) + \frac{\left(\gamma^2\beta_1 - \beta_2\beta_1^2\right)\left(\alpha_2 - c_2^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)} \\ -\frac{3\gamma}{2}\left(\alpha_1 - c_1^S\right) - \frac{\left(\gamma^3 - \gamma\beta_1\beta_2\right)\left(\alpha_1 - c_1^f\right)}{\left(\beta_1\beta_2 - \gamma^2\right)}\end{array}\right].$$

In order to get Chad's and Nigeria's output of high and low gum quality we substitute the profit maximizing quantity for Sudan in equation (6a) and (6b) into the reaction functions of Chad and Nigeria (4a) and (4b).

4. Data and parameters

Generally the scarcity and unreliability of time series data for gum arabic production and export pose special difficulties for empirical analysis and to our best knowledge no empirical study has been carried out on the differentiated gum market. This is probably caused by the fact that custom statistics do not distinguish between the two varieties (hard and friable gums) and both are recorded under the same Harmonized System-code, exception being Sudan as the annual reports published by the Gum Arabic Company distinguish Sudan's gum export by variety.[7] Since the three countries represent over 95% of world export, the world demand is taken to be equivalent to the supply from these countries. In addition since the production is almost entirely exported and local use of gum arabic is insignificant in relation to the amount exported (SEIF EL DIN and ZARROUG, 1996; MACRAE and MERLIN, 2002), the export figures are a good proxy for the level of production in the different countries.

Given the lack of time series data on the export by variety for Chad and Nigeria we could not estimate the demand equations given in (1a) and (1b). For the purpose of our comparative static analysis we, therefore, made a rough estimate on the relative share of each variety on the total gum export of Chad and Nigeria. We used information mentioned in the literature (COPPEN, 1999, and MACREA and MERLIN, 2002) on the relative breakdown of Chad's and Nigeria's exports into the two qualities and data for the years 2001-03 on gum export value and export quantity for Chad and Nigeria obtained from ITC and COMTRADE data bases. We used the three years average total export of each variety (X_1, X_2) and the corresponding weighted average price (P_1, P_2) in the equations for own price elasticities and cross price elasticity.[8] In order to under

[7] In order to obtain information on Chad's and Nigeria's exports by variety and the export price we have contacted several gum stakeholders (organizations and individuals) including among others – FAO database on NTFP, International Trade Center (ITC), CNI (largest importer of gum arabic at http://www.cniworld.com), Nigerian Gum Association and Association Française des Volontaires de Progrés-Tchad-Ndjaména. Unfortunately, it appears that obtaining the needed statistics is difficult as these organizations either don't have the required information or are reluctant to give it.

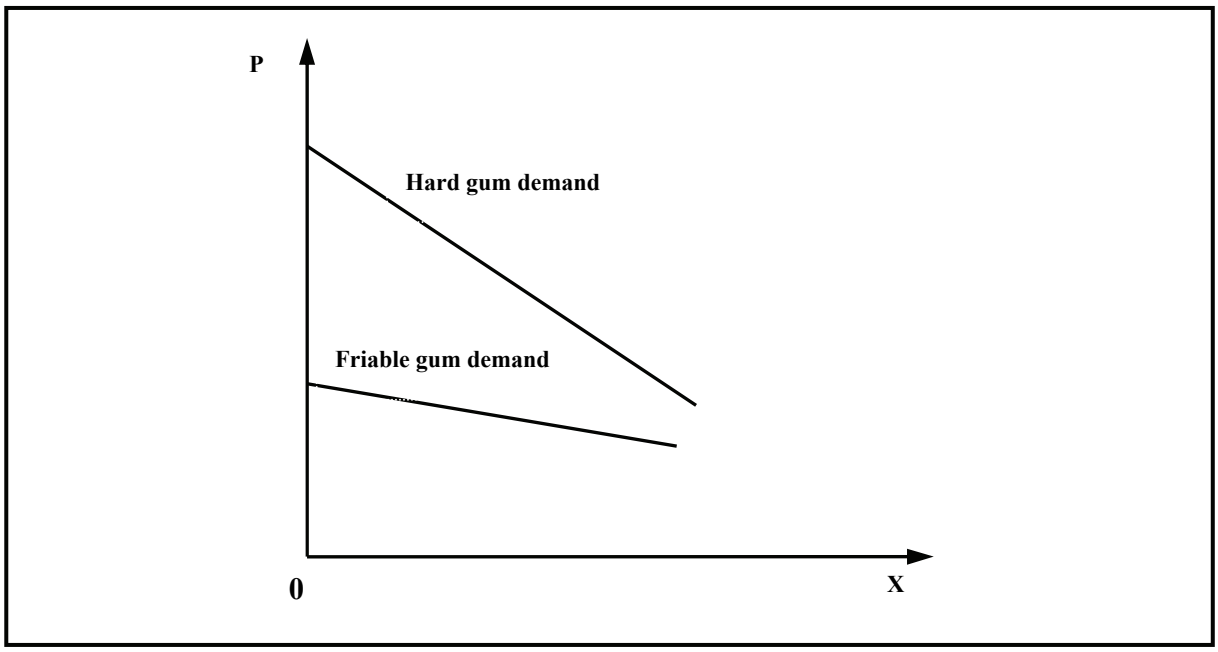
[8] Appendix A.1 gives the data set we used in the analysis and shows the export quantity for high and low quality gum from Sudan, Chad and Nigeria and their respective export price for the years 2001-03. Appendix A.2 shows Sudan export quantity and prices for the two qualities over the period 1990-2003. As mentioned earlier there is lack of long time series data on the export by variety from Chad and Nigeria. Whereas appendix A.3 shows the base case simulation data which can be compared to the data we used for the analysis in appendix A.1.

take the analysis we made the following assumptions for own and cross price elasticties, production and export cost and firm's output:

Own price elasticities

Few empirical studies have estimated gum arabic price elasticity of demand. ABDELGALIL (2004) reports an elasticity of demand for gum arabic of -1.78. Because of a lack of better information and as a starting point for our analysis we consider this elasticity to be the average price elasticity for both qualities. Based on our understanding of the gum arabic market we start by assuming that the demand for hard gum is more inelastic as compared to the friable gum since it has been mentioned in the literature that the price of hard gum depends on a much tighter market (ITC, 2000). Therefore, in our base case we start with elasticties of demand for high and low quality gum of -1.2 and -2.2, respectively. Given the uncertainties about these values we perform a sensitivity analysis. The stylized demand functions of the two gum varieties are shown in figure 3.

Figure 3. Stylized demand system for hard gum and friable gum demand



Cross price elasticity

We assume that a change in a variety's price impacts more its own quantity demanded than the quantity of the other variety. We also expect a strong substitution effect between the demand for high quality with respect to a low quality price change as end-

users can opt for the lower grades from the hard gum (such as the siftings, dust and red gum (see appendix A.4) in case the price of the low quality increases. Using the three years average export of each quality and the corresponding weighted average price we calibrated the model to reflect as close as possible the export quantity and export value tuning the cross price elasticity of the high quality gum with respect to the low quality gum price at 0.6 ($\varepsilon_{12} = 0.6$), which reflects a fair but not excessive level of substitutability.

We then derive the parameters $\alpha_1, \alpha_2, \beta_1, \beta_2$ and γ for the base case of our analysis from the inverse demand equations given in (1a) and (1b) and the following equations for the elasticities:

$$\varepsilon_1 = \frac{-\beta_2}{\beta_1\beta_2 - \gamma^2}\frac{P_1}{X_1},\ \varepsilon_2 = \frac{-\beta_1}{\beta_1\beta_2 - \gamma^2}\frac{P_2}{X_2},\ \varepsilon_{12} = \frac{\gamma}{\beta_1\beta_2 - \gamma^2}\frac{P_2}{X_1} \text{ and } \varepsilon_{21} = \frac{\gamma}{\beta_1\beta_2 - \gamma^2}\frac{P_1}{X_2}$$

where ε_1 is the price elasticity for the high quality gum, ε_2 is the price elasticity for the low quality gum , ε_{12} is the cross price elasticity of the high quality gum with respect to the low quality gum price and ε_{21} is the cross price elasticity of the low quality gum with respect to the high quality gum price.

Production and export cost

Before reaching the importer or end-users, most gum arabic from the producer countries will have gone through some sort of cleaning, sorting and grading. Gum quality is certainly an important factor in determining the price which the exporters can obtain. There are two aspects to quality: (i) natural quality, which is outside the control of the producer and is determined by the botanical source of the tree (affecting in turn its functional properties) as mentioned earlier and (ii) quality aspects determined by the treatment and post-harvest handling subsequent to exudation from the tree. With regard to the latter it has been stated that the quality of hard gum from Chad and Nigeria is compromised by collecting and mixing gums from different botanical sources reflecting the less rigorous and efficient methods of harvesting and post-harvest treatment practiced in Chad and Nigeria compared to Sudan (FAO, 1995).

In our base case, we, therefore, consider Sudan to have an absolute cost advantage over the followers in the production and export of high quality gum i.e. $c_1^S < c_1^f$. Two main reasons, besides its long history and experience in the trade, are behind Sudan's absolute cost advantage in high quality gum harvest and post-harvest handling: first, the distribution of *Acacia senegal* in Sudan is uniform and the species is found in pure stand, whereas in other African producing countries *Acacia senegal* is found mixed with other species (MACRAE and MERLIN, 2002). Therefore, separation of mixtures of

hard gum from different botanical sources during the harvest and post-harvest cycle requires less labour input. Second, since 1991 the last operation of post-harvest handling (re-cleaning, sorting and grading) for the hard gum in Sudan has been mechanized using a system of conveyor belt in combination with shaking and sieving machines. In addition Sudan has developed a standardized grading system for hard gum while other countries export their hard gum only as cleaned grade.[9]

On the other hand, all the three countries export their friable gum only in standard and cleaned form. Nevertheless, the quality of friable gum from Chad and Nigeria is thought to be better than the product from Sudan, which gives a darker solution in water (COPPEN, 1999). In addition the friable gum export of Chad and Nigeria is rarely mixed with other types of gum (ibid); accordingly we assume that the followers have an absolute cost advantage over the leader in the production and export of low quality gum i.e. $c_2^f < c_2^S$.

We have data for Sudan's cost structure obtained from the Gum Arabic Company, however, for Nigeria and Chad the cost structure is not well documented and despite all our attempts it was not possible to obtain the needed information for these countries. Based on the information we obtained from Sudan we start by assuming that the cost of production and export of each variety is 65% of its weighted average market price for the years 2001-03 and the followers' marginal cost for the low quality gum is less than the leader's marginal cost by 15% and vice versa for the high quality gum.

Firm's output

We assume that in equilibrium each firm will produce a positive output quantity of both varieties This assumption together with the above assumption on own and cross price elasticities implies: $\alpha_1 > \alpha_2 > c_q^i$ and $\beta_1 > \beta_2 > \gamma$.[10]

Table 1 reports the base case values of the parameters that we derived. All the parameters used for the base case are in accordance with the constraints and assumptions described above.

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[9] Appendix A.3 gives a description of the different grades of Sudanese hard gum ranked according to the purity and desirability of the grade.

[10] When $\alpha_1 = \alpha_2$ and $\beta_1 = \beta_2 = \gamma$, the goods are perfect substitutes (SINGH and VIVES, 1984). In addition $\beta_1 > \beta_2 > \gamma$ implies that $\beta_1\beta_2 - \gamma^2 > 0$ which is the sufficient condition for the strict concavity of the utility function.

Table 1. Derived parameters values for the base case ($\varepsilon_1 = -1.2, \varepsilon_2 = -2.2, \varepsilon_{12} = 0.6$)

Parameter	Value
α_1	3682.45
α_2	2071.13
β_1	0.0644
β_2	0.0293
γ	0.0258

Parameter	Value
c_1^S	772.28
c_2^S	517.35
c_1^f	908.57
c_2^f	439.75

Source: own calculations, GUM ARABIC COMPANY, annual reports (2001-2003)

5. Scenario analysis

Scenario 1: Development assistance to the leader

Under this scenario Sudan receives a development assistance project and is considering whether to become more competitive in production and export of hard gum or use the development project fund to develop and promote production and export of its friable gum as the demand for the latter has increased recently and friable gum is now accepted as a certified food additive. For the purpose of comparison we will assume that once the decision is made on which quality to target, the project fund will lead to 10% reduction in the marginal cost of production of the targeted quality. Scenarios 1a and 1b indicate that the project fund is allocated for the high quality and low quality gum, respectively. Cost reduction can be achieved by adopting mechanical systems of cleaning, sorting and grading for all the stages of post-harvest handling. The amount of development assistance fund needed to achieve 10% reduction in the marginal cost of either quality is equal to cost difference from the base case times the export quantity increase under the development assistance scenario. We expect, however, promotion of the high quality gum to be more profitable for Sudan as compared to promoting low quality gum because Sudan already has competence and cost advantage in the production and export of high quality gum.

Scenario 2: Development assistance to the followers

Under scenario 2 the followers receive a development assistance project and are deciding which gum quality to promote and develop further. They try to catch up with Sudan's cost advantage in the production and export of high quality gum, for instance by undertaking extension services to disseminate advice to the farmers and traders involved in the gum industry in order to improve their cleaning and quality control procedures. Alternatively the followers can use the project fund to become more

competitive in the low quality market and take advantage of the surge in the demand for friable gum. The development assistance fund is supposed to lead to 10% reduction in marginal cost for production of either quality. We refer to these scenarios as scenario 2a and 2b, respectively, to indicate that the project fund is used for the high or low quality gum sector.

6. Scenario results and discussion

Table 2 shows the percentage change in market parameters under the different scenarios. We fix the cross price elasticity ε_{12} at 0.6 and calculate the market parameters for two plausible values on own price elasticity for the high and low quality gum, respectively ($\varepsilon_1 = -1.2, \varepsilon_2 = -2.2$) or ($\varepsilon_1 = -1.5, \varepsilon_2 = -1.8$).

A comparison of the proportionate change in the gum price level and total gum export when the development assistance is granted to Sudan (scenario 1) or the followers (scenario 2) is shown in table 2. We can see that the reduction in the price of high and low quality gum is higher under scenario 1 than under scenario 2 and similarly the percentage change in total gum export is relatively higher under scenario 1 as compared to scenario 2. This is expected considering the dominant role Sudan plays in the gum arabic market and its high market share.

Results in table 2 suggest a proportionately larger increase in Sudan's profit when the project fund is used to promote high quality gum under scenario 1a instead of promoting the low quality gum under scenario 1b (14.5% and 16.8% increase in profit compared to 2.1% and 1.8% increase). It is not surprising that Sudan will benefit more from using the project fund to increase its competitiveness in high quality gum since Sudan already has an absolute cost advantage in the export of this gum variety. Total gum export from Sudan increases by 9.2% and 5.9% under scenario 1b and only by 1.3% and 3.6% under scenario 1a. The proportionately higher increase in Sudan's total gum export under scenario 1b as compared to scenario 1a arises from the larger increase in Sudan's export of low quality gum (123.1% and 122.6%) when the project fund is used to promote low quality gum.

On the other hand whether the followers obtain a proportionately higher or lower profit when they use the project fund to promote the high or low quality gum depends on the assumptions for the own price elasticities. A proportionately higher profit is obtained when the project fund is used for the promotion of low quality gum (14.2% under scenario 2b compared to 12.1% under scenario 2a) when assuming own price elasticities $\varepsilon_1 = -1.2$ and $\varepsilon_2 = -2.2$. The followers profit is relatively higher when the project fund is used for the promotion of high quality gum (14.3% under scenario 2a compared to 13.8% under scenario 2b) when we assume the own price elasticities to

be -1.5 and -1.8 for the high and low quality gum, respectively. The intuitive interpretation for this specific result is that when the demand for the high quality gum becomes more elastic (ε_1 decreases from -1.2 to -1.5) then the followers can compete more aggressively with Sudan and increase their sale of high quality gum (the difference in the proportionate increase in followers sale of high quality gum when ε_1 is equal to -1.2 and -1.5 is about 11%).

Table 2. Changes in market equilibrium under the different scenarios (in percent) Cross price elasticity $\varepsilon_{12} = 0.6$

	Scenario 1: Development assistance to the leader				**Scenario 2: Development assistance to the followers**			
	Scenario 1a: 10% reduction in c_1^S		Scenario 1b: 10% reduction in c_2^S		Scenario 2a: 10% reduction in c_1^f		Scenario 2b: 10% reduction in c_2^f	
	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8
x_1^S	11.9	13.3	-7.0	-6.3	-9.3	-10.4	4.0	3.5
x_2^S	-73.5	-89.4	123.1	122.6	57.6	70.1	-69.8	-69.5
Sudan total export	1.3	3.6	9.2	5.9	-1.0	-2.8	-5.2	-3.4
$x_1^{C(N)}$	-31.8	-38.7	18.7	18.2	49.9	60.7	-21.2	-20.6
$x_2^{C(N)}$	10.1	11.4	-16.9	-15.6	-15.8	-17.9	19.1	17.7
Followers total export	-1.0	-3.4	-7.5	-5.6	1.6	5.3	8.4	6.4
X_1	3.2	3.6	-1.9	-1.7	2.5	2.8	-1.1	-1.0
X_2	-4.2	-4.8	7.0	6.6	-3.3	-3.8	4.0	3.7
Total gum export	0.2	0.7	1.7	1.2	0.2	0.5	1.0	0.7
P_1	-3.0	-3.1	0.0	0.0	-2.3	-2.4	0.0	0.0
P_2	0.0	0.0	-3.4	-3.4	0.0	0.0	-2.0	-1.9
Π^S	14.5	16.8	2.1	1.8	-10.2	-11.7	-0.5	-0.4
$\Pi^{C(N)}$	-5.2	-5.6	-10.5	-10.3	12.1	14.3	14.2	13.8

Source: own calculations

Interestingly, our results show that if the followers use the project to promote their high quality gum export, then it will lead to a proportionately higher reduction in Sudan's profit than when the project fund is used for the promotion of low quality gum (Sudan's profit decreases by 10.2% and 11.7% under scenario 2a but only by 0.5% and 0.4% under scenario 2b). Results also show that under scenario 1 the followers' profit

reduction is higher for scenario 1b as compared to scenario 1a (10.5% and 10.3% compared to 5.2% and 5.6%), suggesting that when Sudan uses the project fund to promote low quality gum, then a proportionately higher reduction in the profit for the followers will occur.

The result that Sudan receives a larger profit and that the followers suffer from smaller reduction in profits when Sudan use the project fund to promote high quality gum suggests that it will not only benefit Sudan in case it directs its effort to the export of high quality gum, but it is also better for Chad and Nigeria. In a similar way Sudan will also benefit in case Chad and Nigeria focus on promoting low quality instead of high quality gum. However, in case the demand for high quality gum is more elastic, the followers prefer to promote the high quality gum. This causes substantial losses for Sudan. In light of these results coordination of export by the three major players might be useful.

Table 3. Changes in market equilibrium under the different scenarios (in percent) Cross price elasticity $\varepsilon_{12} = 0.3$

	Scenario 1: Development assistance to the leader				**Scenario 2: Development assistance to the followers**			
	Scenario 1a: 10% reduction in c_1^S		Scenario 1b: 10% reduction in c_2^S		Scenario 2a: 10% reduction in c_1^f		Scenario 2b: 10% reduction in c_2^f	
	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8	ε_1=-1.2 ε_2=-2.2	ε_1=-1.5 ε_2=-1.8
x_1^S	11.5	13.0	-3.4	-3.1	-9.0	-10.2	1.9	1.7
x_2^S	-15.2	-16.4	50.8	44.8	11.9	12.8	-28.8	-25.4
Sudan total export	4.8	6.6	10.2	7.4	-3.8	-5.2	-5.8	-4.2
$x_1^{C(N)}$	-23.5	-28.8	6.9	6.8	36.8	45.1	-7.8	-7.7
$x_2^{C(N)}$	5.0	5.6	-16.6	-15.3	-7.8	-8.8	18.8	17.4
Followers total export	-4.3	-6.7	-9.0	-7.5	6.7	10.4	10.2	8.5
X_1	2.9	3.3	-0.9	-0.8	2.3	2.6	-0.5	-0.4
X_2	-1.7	-1.8	5.6	5.1	-1.3	-1.5	3.2	2.9
Total gum export	0.9	1.3	1.9	1.5	0.7	1.0	1.1	0.8
P_1	-3.3	-3.4	0.0	0.0	-2.6	-2.7	0.0	0.0
P_2	0.0	0.0	-4.0	-3.9	0.0	0.0	-2.3	-2.2
Π^S	18.8	21.2	5.0	4.5	-13.3	-14.8	-1.9	-1.8
$\Pi^{C(N)}$	-9.9	-10.9	-14.4	-14.2	20.9	24.4	19.5	18.9

Source: own calculations

Sensitivity analysis

There are three major assumptions in our analysis: the level of the own price elasticity for the high and low quality gum ($\varepsilon_1, \varepsilon_2$) and the cross price elasticity of the high quality gum with respect to the low quality gum price (ε_{12}). The latter affects the value of the parameter γ which measures the extent of product differentiation between the high and low quality gum.

Above (in table 2) we presented results for two plausible values on own price elasticity for the high and low quality gum ($\varepsilon_1 = -1.2, \varepsilon_2 = -2.2$) and ($\varepsilon_1 = -1.5, \varepsilon_2 = -1.8$). In order to check the robustness of our results with respect to the assumption on cross price elasticity we also calculate the market parameters for a cross price elasticity level ε_{12} of 0.3 and the two plausible values on own price elasticity for the high and low quality gum as before ($\varepsilon_1 = -1.2$ and $\varepsilon_2 = -2.2$ then $\varepsilon_1 = -1.5$ and $\varepsilon_2 = -1.8$). Results are shown in table 3 and confirm the pattern shown on table 2 for a cross price elasticity level of 0.6. That Sudan is better off promoting the high quality gum and the proportionate increase in the followers' profit in case they promote high or low gum quality is also sensitive to the assumption on cross price elasticity. Also promotion of low quality gum by Sudan leads to a proportionately larger reduction in followers' profit and promotion of high quality gum by Chad and Nigeria leads to a proportionately larger reduction in Sudan's profit.

7. Conclusion

Gum arabic is mainly produced from two Acacias that are found in the gum belt of Sub-Saharan Africa. These are: *Acacia senegal* that produces hard gum and *Acacia seyal* that produces friable gum. The demand for gum arabic, and particularly for friable gum, has increased in recent years. At present the world market is divided more or less equally between hard and friable gum. Nonetheless, friable gum is considered to have a relatively low quality and is only used for a price advantage or when supplies of hard gum are low. Historically, Sudan was known to monopolize the gum trade, exporting mainly the high quality hard gum. Following the drought that affected the Sahel in the 1970s and 1980s the gum arabic market structure has changed. Not only because the position of friable gum is consolidated as a credible food additive but also because the shares of Chad and Nigeria in gum arabic export generally and for friable gum specifically have increased substantially in recent years. Sudan that is known for its expertise in exporting high quality gum is now facing a growing competition from Chad and Nigeria who are specialized in the export of friable gum.

In order to understand the best strategy for three major players to pursue in light of the recent changes in the gum market and the proposed donor policies, we model the international market for gum arabic using a Stackelberg model of oligopolistic supply, where Sudan is a leader and Chad and Nigeria are followers. We start with the base case in which Sudan is assumed to have an absolute cost advantage over the followers in the production and export of the high quality gum and vice versa. We then compare the market equilibrium outcomes under two competing development assistance projects: Under the first scenario we introduce a development assistance project to the leader which will be either used to promote the production and export of high quality or low quality gum. Under the second scenario the followers receive the development assistance fund which is allocated to promote either high quality or low quality gum.

Our results show that the proportionate increase in Sudan's profit is higher when Sudan uses the project fund to promote high quality gum than when it uses the project fund to promote the low quality gum. We, therefore, recommend that in the short and medium term Sudan should direct its efforts basically to the export of high quality gum. For Chad and Nigeria, however, the decision on which quality to promote appears to be sensitive to the levels of own and cross price elasticities.

The main finding of this paper is that, when the leader promotes the quality for which it has a cost advantage, the high quality gum, this leads to a lower reduction in the competitors' profits. Similarly when followers promote the quality for which They have a cost advantage, the low quality gum, this results in a lower reduction in the leader's profit than when they promote high quality gum. Therefore, our results suggest that coordination of exports by the three countries will result in additional gains for the exporting countries. Such cooperation, however, essentially implies a monopolistic gains and, hence, will induce welfare losses on the demand side.

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Appendix A.1. Export data for high and low quality gum from Sudan, Chad and Nigeria (2001-2003): volume (tons) and export price (USD/ton)

Year	Sudan	Chad	Nigeria	Total
High quality gum export per country in tons				
2001	18,953	3,478	623	23,054
2002	22,878	5,975	742	29,595
2003	25,499	4,557	898	30,954
Three years average				27,867.67
High quality gum export price USD/ton				Weighted average price
2001	1,590	1,290	1,200	1,534.2
2002	1,580	1,100	950	1,467.29
2003	1,210	1,150	890	1,191.88
Average				1,397.8
Low quality gum export per country in tons				
2001	1,379	9,403	4,172	14,954
2002	7,584	6,293	8,534	22,411
2003	4,786	5,975	8,901	19,662
Three years average				19,009
Low quality gum export price USD/ton				Weighted average price
2001	780	880	830	856.83
2002	700	890	720	760.97
2003	750	920	680	769.97
Average				795.9
Total gum export for each country				
2001	20,332	12,881	4,795	
2002	30,462	12,268	9,276	
2003	30,285	10,532	9,799	

Source: Sudan export quantity and export price (FOB) for each gum quality is obtained from the Gum Arabic Company.
Computation of Chad and Nigeria export quantity and export price are based on data obtained from ITC TradeMap http://www.trademap.net/pmaps/world_trade.htm which gives export quantity and the value of export in USD and unit value (USD/ton) using these data we made a rough estimate on the relative share of each variety on the total export of Chad and Nigeria.

Appendix A.2

Appendix A.2.1. Export quantity and price for high and low quality gum from Sudan (1990-2003) in tons and USD/ton

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total gum export	26,912	24,978	14,068	15,730	22,735	16,847	13,722	22,548	20,989	19,928	24,179	20,332	30,462	30,285
High quality gum export	22,960	21,543	8,198	9,925	18,339	11,564	8,377	15,576	16,107	15,019	21,358	18,953	22,878	25,499
Low quality gum export	3,852	3,435	5,870	5,805	4,396	5,283	5,345	6,972	4,882	4,909	2,821	1,379	7,584	4,786
High quality gum export price	2,260	2,260	2,460	3,630	3,950	4,050	2,580	1,480	1,110	1,800	1,500	1,590	1,580	1,210
Low quality gum export price	730	640	570	690	850	600	510	450	510	660	450	780	700	750

Source: GUM ARABIC COMPANY, annual reports

Appendix A.2.2. Summary statistics for Sudan gum export data (1990-2003)

	Minimum	Maximum	Mean	Standard deviation
Total gum export	13,722	30,462	21,694	5,427
High quality gum export	8,198	25,499	16,878	5,721
Low quality gum export	1,379	7,584	4,816	1,606
High quality gum export price	1,110	4,050	2,247	993
Low quality gum export price	450	850	635	125
Price correlation for high and low quality	0.297			

Source: own estimates based on GUM ARABIC COMPANY annual reports, see Appendix A.2.1.

Appendix A.3. Base case simulation values for export quantity (tons), equilibrium export price (USD/tons) and profits in USD (ε_1=1.2, ε_2=2.2 and ε_{12}=0.6)

Variable	Values
Sudan export of high quality gum	23,381
Fringe export of high quality gum	2,902.9
High quality gum equilibrium price	1,302.74
Sudan export of low quality gum	3,311.3
Fringe export of low quality gum	8,044.45
Low quality gum equilibrium price	750.4
Sudan profit from gum export	13,174,600
Fringe profit from gum export	3,643,650

Source: own calculations

Appendix A.4. Grades of Sudanese hard gum

Grade	Description
Hand-picked selected	Large nodules which have been carefully selected. Cleanest and lightest in colour.
Cleaned (standard)	The material that remains after hand-picked selected and siftings are removed. Comprises whole or broken nodules varying in colour from pale to dark.
Siftings	Fine particles remaining following sorting of the standard grade. Contains some sand, bark and dirt.
Dust	Very fine particles collected after the cleaning process. Contains sand and dirt.
Red	Dark gum removed by hand from the other nodules.

Source: GUM ARABIC COMPANY annual reports