Centre interuniversitaire de recherche
en économie quantitative

CIREQ

Cahier 12-2014

Harvests' Lifespan and
North-South Market Share Rivalry

Hassan BENCHEKROUN and
Saad BENCHEKROUN

CIREQ

Le **Centre interuniversitaire de recherche en économie quantitative (CIREQ)** regroupe des chercheurs dans les domaines de l'économétrie, la théorie de la décision, la macroéconomie et les marchés financiers, la microéconomie appliquée ainsi que l'économie de l'environnement et des ressources naturelles. Ils proviennent principalement des universités de Montréal, McGill et Concordia. Le CIREQ offre un milieu dynamique de recherche en économie quantitative grâce au grand nombre d'activités qu'il organise (séminaires, ateliers, colloques) et de collaborateurs qu'il reçoit chaque année.

*The **Center for Interuniversity Research in Quantitative Economics (CIREQ)** regroups researchers in the fields of econometrics, decision theory, macroeconomics and financial markets, applied microeconomics as well as environmental and natural resources economics. They come mainly from the Université de Montréal, McGill University and Concordia University. CIREQ offers a dynamic environment of research in quantitative economics thanks to the large number of activities that it organizes (seminars, workshops, conferences) and to the visitors it receives every year.*

Cahier 12-2014

Harvests' Lifespan and North-South Market Share Rivalry

Hassan BENCHEKROUN and Saad BENCHEKROUN

Université de Montréal
Pavillon Lionel-Groulx, CIREQ
C.P. 6128, succursale Centre-ville
Montréal QC H3C 3J7
Téléphone : (514) 343-6557
Télécopieur : (514) 343-7221
cireq@umontreal.ca
http://www.cireqmontreal.com

Concordia UNIVERSITY McGill Université de Montréal

Dépôt légal - Bibliothèque nationale du Canada, 2014, ISSN 0821-4441
Dépôt légal - Bibliothèque et Archives nationales du Québec, 2014
ISBN-13 : 978-2-89382-672-1

Harvests' lifespan and North-South market share rivalry.

H. Benchekroun[a*] and S. Benchekroun[b]

(a) Department of Economics, CIREQ, McGill University

hassan.benchekroun@mcgill.ca

and

(b) Institut Agronomique et Vétérinaire Hassan II

s.benchekroun@iav.ac.ma

*Corresponding author: 855 Sherbrooke West, McGill University, Montreal, Quebec, Canada. Tel (1) 514 398 4400. Hassan Benchekroun acknowledges Le Fonds de Recherche du Québec- Société et culture (FQRSC) and the Canadian Social Sciences and Humanities Research Council (SSHRC) for financial support.

ABSTRACT

We consider a North-South duopolistic competition in the market of a perishable good. North's harvest can be sold over two periods whereas South's harvest can be sold in the first period only, because of the lack of storage technology. We examine the impact of the availability of a storage technology in South that would allow it to sell its harvest over two periods. We identify situations in which both North and South see their profits decrease and situations in which both North and South enjoy larger profits when the lifespan of South's harvest increases. Our findings can be useful to assess the support for policy interventions that aim at transferring better technologies to South. There are cases where North and South's industries will both push for (or both resist) the transfer of a technology to South that will lengthen the lifespan of its product.

Keywords: perishable goods, market share rivalry, dynamic oligopoly, storage.

JEL classiffication: Q16, Q13, O11, O30.

RÉSUMÉ

Nous considérons un duopole Nord-Sud sur le marché d'un bien périssable. La récolte du Nord peut être écoulée sur deux périodes alors que celle du Sud doit être écoulée en une période, à cause de l'absence de technologie de stockage. Nous examinons l'impact qu'il y a à rendre la technologie de stockage disponible au Sud lui permettant ainsi d'écouler sa récolte sur deux périodes. Nous identifions des situations où Nord et Sud voient leurs profits diminuer et des situations où les deux voient leurs profits augmenter. Nos résultats peuvent être utiles pour évaluer le soutien à des politiques qui visent un transfert technologique vers le Sud. Il existe des situations où les industries, du Nord et du Sud, vont toutes les deux encourager (ou toutes les deux résister à) un transfert vers le Sud qui augmenterait la durée de vie d'un produit.

1 Introduction

The objective of this paper is to analyze the incentive of a developing country to acquire a technology that can allow it to sell its harvest of perishable goods over a longer period of time. There are several ways to lengthen the lifespan of a given agricultural product; e.g., gaining access to industrial cooling facilities. For example in Egypt, farmers formed a marketing association called Horticulture Export Improvement Association (HEIA). The objective of HEIA is to facilitate better harvesting practices, postharvest handling, pre-cooling, packaging and cool transport. In 1993 HEIA established a Perishable Terminal, a cold store terminal at Cairo International Airport[1]. The store is used for the export of perishable goods[2].

Exports of fruits and vegetables are typically a source of important revenues for developing countries. For example, in 2012, the value of Morocco's exports was US$ 21.417 billion in[3]. Exports of fruits and vegetables represented US$ 1.627 billion, i.e., 7.6% of the country's exports[4]. By far, the European Union represents the major destination of these exports; close to half of these exports were to France and Spain alone[5]. Developing countries are important players in the total trade of fruits and vegetables. In 2001, the value of fruits and vegetables exports was US$ 8.18 billion for developing countries, that was close to a quarter of the total world exports estimated at US$ 34.6 billion (see Diop and Jaffee (2005)). Developing countries' export of citrus represents half the total exports of citrus and almost all exports of banana and tropical fruit are from developing countries (see Garcia (2006)). In 2012, Morocco's export of tomatoes to France represented approximately half of France's total imports of tomatoes[6].

It appears intuitive that, for a developing country exporting perishable goods, gaining access to a technology that allows a more flexible sale's schedule is good news. We show that this intuition may be misleading. We address our research question within a North-

[1] For more details see http://www.heia.org.eg/termin.htm

[2] We thank Dr. Lisa Kitinoja for suggesting this example.

[3] Source: United Nations Statistics Division - Commodity Trade Statistics Database (COMTRADE)

[4] In 2009, agricultural products' exports share of the value of total exports was 12.2% for Egypt and 23.4% for Morocco. See http://webservices.wto.org/resources/profiles/TP/ZZ/2009/MA_e.pdf and http://webservices.wto.org/resources/profiles/TP/ZZ/2009/EG_e.pdf

[5] Source: United Nations Statistics Division - Commodity Trade Statistics Database (COMTRADE)

[6] In 2012, Spain and Morocco accounted for close to 80% of France's imports of tomatoes. Source: United Nations Statistics Division - Commodity Trade Statistics Database (COMTRADE)

South framework. We consider a framework where both North and South produce a perishable good (e.g., a fruit or vegetable). We consider two scenarios: one, a la Brander and Spencer (1985), in which sales take place abroad and one in which sales take place in North. The harvest has a lifespan of one period if it is not stored in a cooling facility and two periods if it is. Sales are assumed to take place over two periods if the harvest is stored. North is assumed to have a technology that allows it to have a harvest that has a lifespan of two periods, whereas South has a harvest which lifespan is one period. Does South benefit from gaining access to a technology that allows it to have a product with a lifespan of two periods?

For simplicity we focus on the case where the total harvest over the two periods is fixed. Thus our framework can be related to a literature on exhaustible natural resources; more specifically natural resource oligopolies (Benchekroun et al. (2010), Chou and Long (2009), Fujiwara and Long (2012)), and storage of a natural resource (Gaudet et al. (2002)). Chou and Long (2009) and Fujiwara and Long (2012) formulate a dynamic game model of trade in an exhaustible resource between a cartel supplying the resource and an importing country. They consider different scenarios: simultaneous moves, leadership by the strategic importing country, and leadership by the exporting cartel. For example Fujiwara and Long (2012) examine welfare under different scenarios and show that the world welfare is highest under the importing country's leadership and lowest under the exporting country's leadership. In contrast with our paper the exhaustible resource can be sold at all periods of time and North is assumed not to own any resource. While this may true for some exhaustible resources, in many instances the importing country also has a group of domestic suppliers. In a recent and independent work Wan and Boyce (2014) analyze an exhaustible resource oligopoly within a two period framework similar to ours. Their aim is to fully characterize the equilibrium extraction sequences under Stackelberg competition and compare them to the equilibrium extraction sequences under Cournot competition. In Chou and Long (2009), Fujiwara and Long (2012) and Wan and Boyce (2014) the cost of extraction of each firm is the same in all periods. In our framework the possibility to sell over a longer lifespan comes at an additional cost. Therefore the cost of each firm is not constant over time. Gaudet et al. (2002) consider the possibility of storage of an exhaustible resource (e.g., oil stockpiling; land deforestation). They show that privatization of common property through storage may eliminate inefficiencies.

However storage may result in accelerated extraction from the common property and exacerbate inefficiencies. While their focus is on the impact of storage within a common property resource, in our model the harvest can be viewed as a private (but perishable) exhaustible resource. In their model, storage is used to 'privatize' the resource. None of these papers examine the question of the impact of the lifespan of the good extracted.

We show that South's access to a technology that allows it to sell its harvest over two periods instead of one can be detrimental to its profits. This can be rather surprising. The intuition of this result is that by not being able to sell its harvest in period 2, South gives up profits from sales in period 2 but gains a strategic advantage in period 1. This strategic advantage stems from the credibility of the sales of all its harvest in period 1[7]. Thus when South acquires the technology, it gains from increased profits in period 2 but loses its ability to commit to a more aggressive behavior in period 1. The impact of these two effects combined, on South's profits, is therefore ambiguous. The acquisition by South of the technology to sell in period 2 has also an ambiguous impact on North's profits. In particular, the possibility of selling the perishable good over two periods can result in a win-win or loss-loss for North and South. Furthermore we show that even a transfer of the best available technology from North to South results in an increase in South's profits and can result in an increase in North's profits as well, even if such a transfer is free. In terms of the impact on welfare, we show that it is possible that the mere access of South to the possibility of storage can reduce global welfare, i.e., the sum of South's profit, North's profits and consumers' surplus.

Section 2 gives a description of the model when South is not able to sell its harvest in period 2. It also provides the equilibrium outcome under that scenario. Section 3 covers the scenario where South has access to a technology that allows it to sell its harvest over two periods. The impact of the access to such technology on the equilibrium sales and profits is assessed. Section 4 includes a welfare analysis.

2 The model and preliminaries

For simplicity we will consider a three country world: South, North and the Rest of the World (RW). A perishable good can be produced both in North and South and we will

[7] This advantage is different from the first mover advantage in a Stackelberg game since South's firm in our game takes the strategy of North's firm as given (as in a Cournot game).

assume for simplicity that consumption takes place in the RW. This is a framework a la Brander and Spencer (1985); it is a standard framework to analyze strategic behavior of exporters. This approach is typically used to focus on profits and abstract from local consumption and welfare. In section 4 we will examine the case where North and RW are the same entity, i.e., North can produce and consumption takes place in North alone, South's market for the product is considered negligible and can be ignored.

We assume that there is one seller in each country (South and North) that compete in RW's market. A seller could be a firm, an association of farmers or a national board that coordinates the sales of the nation's producers in order to maximize profits[8]. Throughout the paper we use a firm to designate a seller. There are two periods: the perishable product is harvested in period 1 only. Let h_n and h_s respectively denote North's and South's harvests. North's firm is assumed to have a storage technology that allows it to sell its produce over period 1 and period 2. South's firm is assumed not to have access to a storage technology. In our model the role of storage is to allow profitable transfer of sales from one period to another[9]. We will later relax this assumption in the next sections to examine the impact of storage in the South.

In each period RW's market demand is assumed given by

$$P(Q) = a - Q$$

where Q denotes the quantity demanded of the perishable good.

The production cost consists of a harvesting cost, assumed to have constant marginal cost c_{hs} in South and c_{hn} in North and storage cost also assumed to have a constant marginal cost c_n in North. To emphasize the role played by the possibility of storage as the main difference between North and South we focus on the case where harvesting

[8]Krishna and Thursby (1992) consider an oligopolistic competition between export marketing boards. A board buys its input from competitive domestic producers and supplies its own domestic demand and sells it abroad. They allow for two types of marketing boards: one type that maximizes the board's profits and one type that maximizes the board's and the farmers' surplus. In our framework the two objectives coincide.

[9]Other marketing functions of storage include its use as insurance for future crop failures or consumption smoothing across periods. Handling these other functions of storage would require adding uncertainty, for example in the demand function. This would definitely be an interesting and relevant addition to the present model. The analysis of these alternate functions of storage is beyond the scope of the present paper.

costs are nil: we assume that $c_{hs} = c_{hn} = 0$. For this same reason we also consider that the fixed cost for South to acquire storage capacity is nil. The addition of fixed cost of the storage capacity will reduce the regions of parameters where South would gain from storage. However it would not alter the main message of the paper.

In the absence of storage technology South needs to decide how much of its harvest to sell in period 1 only. We assume that the market is large enough for South to want to sell all of its harvest (no harvest is destroyed, see more on that below).

North's firm maximizes the sum of its profits taking the supply of South as given and chooses how to allocate the harvest over the two periods

$$Max_{(q_{n1},q_{n2})} \left(P\left(q_{n1}+q_{s1}\right)q_{n1}+P\left(q_{n2}+q_{s2}\right)q_{n2}-c_nq_{n2}\right)$$

where q_{ij} denotes the sales of firm $i = n, s$ in period $j = 1, 2$.

In the scenario where South's firm can't store its produce the outcome is

$$q_{s1} = h_s$$

and therefore q_{n1} and $q_{n2} = h_n - q_{n1}$ maximize the profits of the firm in North

$$P\left(q_{n1}+h_s\right)q_{n1}+\left(P\left(h_n-q_{n1}\right)\left(h_n-q_{n1}\right)-c_n\left(h_n-q_{n1}\right)\right)$$

Consider the following three conditions

$$2h_n + 7h_s \leq 4 - c_n \tag{1}$$

$$2h_n + c_n > h_s \tag{2}$$

$$2h_n + h_s > c_n \tag{3}$$

It can be shown that when (1), (2) and (3) hold the equilibrium quantities produced by each firm are

$$q_{n1} = \frac{1}{4}\left(2h_n + c_n - h_s\right), q_{n2} = \frac{1}{4}\left(2h_n - c_n + h_s\right) \tag{4}$$

$$q_{s1} = h_s \text{ and } q_{s2} = 0$$

with

$$q_{n1} + q_{s1} = \frac{1}{4}\left(c_n + 2h_n + 3h_s\right).$$

The equilibrium profits in North are given by

$$\pi_n = \frac{1}{8}c_n^2 - \frac{1}{2}c_n h_n - \frac{1}{4}c_n h_s - \frac{1}{2}h_n^2 - \frac{1}{2}h_n h_s + h_n + \frac{1}{8}h_s^2 \tag{5}$$

and by

$$\pi_s = -h_s\left(\frac{1}{4}c_n + \frac{1}{2}h_n + \frac{3}{4}h_s - 1\right) = h_s - \frac{1}{4}h_s c_n - \frac{1}{2}h_s h_n - \frac{3}{4}h_s^2 \tag{6}$$

in South.

Assumption 1: Throughout the rest of the paper we will assume that the three conditions (1), (2) and (3) hold.

Condition (1) ensures that South sells all its harvest (no destruction of the harvest), conditions (2) and (3) ensure that q_{n1} and q_{n2} are positive. If these last two conditions fail to hold then, either North's firm sells all its harvest in period 1 (i.e., $q_{n2} = 0$) or its sell all its harvest in period 2 (i.e., $q_{n1} = 0$). The acquisition of storage capacity is always profitable for South (provided it has enough harvest to sell over two periods).

3 Access to Storage in South

3.1 The equilibrium

We now consider the case where South can store the perishable good and sell part of its harvest in period 2. The marginal cost of storage for South is c_s assumed constant and exogenous[10]. South may now choose to spread its harvest over both periods. In the second period both firms will sell their remaining harvest:

$$q_{n2} = h_n - q_{n1}$$
$$q_{s2} = h_s - q_{s1}.$$

We have two duopolists over the two periods.

The problem of North's firm

$$Max_{q_{n1},q_{n2}}\left(P\left(q_{n1}+q_{s1}\right)q_{n1} + \left(P\left(q_{n2}+q_{s2}\right)q_{n2} - c_n q_{n2}\right)\right)$$

and of South's firm

$$Max_{q_{s2},q_{s2}}\left(P\left(q_{n1}+q_{s1}\right)q_{s1} + \left(P\left(q_{n2}+q_{s2}\right)q_{s2} - c_s q_{s2}\right)\right)$$

[10] We discuss in Section 5 the case where it is endogenous, in particular when it is the result of a technology from North.

with

$$q_{i1} + q_{i2} = h_i \text{ with } i = s, n$$

It can be shown that the equilibrium quantities are given by

$$q_{n1} = \frac{1}{6}(3h_n + 2c_n - c_s); q_{s1} = \frac{1}{6}(3h_s - c_n + 2c_s) \tag{7}$$

$$q_{n2} = \frac{1}{6}(3h_n - 2c_n + c_s); q_{s2} = \frac{1}{6}(3h_s + c_n - 2c_s) \tag{8}$$

South's sales are positive in both periods iff $c_n - 2c_s < 3h_s$ and $-(c_n - 2c_s) < 3h_s$ that is

$$|c_n - 2c_s| < 3h_s \tag{9}$$

North's sales are positive iff

$$|c_s - 2c_n| < 3h_n \tag{10}$$

Assumption 2: We shall assume that (9) and (10) hold throughout the paper.

If for example $c_n - 2c_s > 3h_s$ then period 1's sales of South's firm are nil. The possibility of storage forces South's firm to sell all its harvest in period 2. The intuition behind this result is that South's harvest is not large enough, and therefore need not be spread over both periods, if the storage cost for South is small enough, compared to North's storage cost. Note that when $c_n = 0$ the condition $c_n - 2c_s < 3h_s$ is always met and period 1's sales of South's firm are always positive.

When $-(c_n - 2c_s) > 3h_s$ then period 2's sales of South's firm are nil. Despite the possibility of storage South's firm sells all its harvest in period 1. The intuition behind this result is that South's harvest is not large enough, and need not be spread over both periods if the storage cost for South is large enough, compared to North's storage cost. When $c_s = 0$ the condition $-(c_n - 2c_s) < 3h_s$ is always met and period 2's sales of South's firm are always positive.

The equilibrium profits of North's firm

$$\pi_n^{st} = (a - (q_{n1} + q_{s1}))\, q_{n1} + ((a - (h_s + h_n - (q_{n1} + q_{s1})))\, (h_n - q_{n1}) - c_n (h_n - q_{n1}))$$

and of South's firm

$$\pi_s^{st} = (a - (q_{n1} + q_{s1}))\, q_{s1} + ((a - (h_s + h_n - (q_{n1} + q_{s1})))\, (h_s - q_{s1}) - c_s (h_s - q_{s1}))$$

where $q_{n1}; q_{s1}; q_{n2}; q_{s2}$ are given by their equilibrium values in (7) and (8).

The equilibrium profits are given by

$$\pi_n^{st} = h_n + \frac{2}{9}c_n^2 + \frac{1}{18}c_s^2 - \frac{1}{2}h_n^2 - \frac{2}{9}c_n c_s - \frac{1}{2}c_n h_n - \frac{1}{2}h_n h_s \tag{11}$$

for North's firm and by

$$\pi_s^{st} = h_s + \frac{1}{18}c_n^2 + \frac{2}{9}c_s^2 - \frac{1}{2}h_s^2 - \frac{2}{9}c_n c_s - \frac{1}{2}c_s h_s - \frac{1}{2}h_n h_s \tag{12}$$

for South's firm.

3.2 Impact on profits

The impact of storage on South's firm's profits is given by

$$\Delta\pi_s = \pi_s^{st} - \pi_s$$

We have after substitution of π_s^{st} and π_s from (12) and (6) and simplification gives

$$\Delta\pi_s = \frac{1}{36}\left(2c_n - 4c_s + 3h_s\right)\left(c_n - 2c_s + 3h_s\right)$$

From $q_{s2} = \frac{1}{6}\left(3h_s + c_n - 2c_s\right) > 0$ we have that

$$\Delta\pi_s = \pi_s^{st} - \pi_s = \frac{1}{6}q_{s2}\left(2c_n - 4c_s + 3h_s\right) \tag{13}$$

and therefore

$$sign\left\{\Delta\pi_s\right\} = sign\left\{2c_n - 4c_s + 3h_s\right\}.$$

The impact on North's profits is given by

$$\Delta\pi_n = \pi_n^{st} - \pi_n$$

which after substitution of π_n^{st} and π_n from (11) and (5) and simplification gives

$$\Delta\pi_n = \frac{1}{12}q_{s2}\left(7c_n - 2c_s - 3h_s\right). \tag{14}$$

The impact of storage in South on total industry's profits is given by

$$\Delta\pi_n + \Delta\pi_s = \frac{1}{72}\left(c_n - 2c_s + 3h_s\right)\left(11c_n - 10c_s + 3h_s\right).$$

We argue in this paper that the availability of the option to store its produce can be detrimental to South's profits. The comparison of profits while taking into account the five conditions from Assumptions 1 and 2 is very tedious. We proceed by fixing h_n and c_s to specific values. This simplifies significantly the exposition and at the same time allows to deliver the main results of the paper.

From now on, unless otherwise stated, we set $h_n = \frac{1}{2}$ and $c_s = \frac{1}{2}$ and use the following assumptions instead of Assumptions 1 and 2:

Assumption 1': $h_s \leq \frac{5}{14}$

Assumption 2': $c_n > 1 - 3h_s$

Remark: it can be shown that for $h_n = \frac{1}{2}$ and $c_s = \frac{1}{2}$ Assumption 1' and Assumption 2' imply that Assumption 1 and Assumption 2 hold. The nature of the results derived below is to show that certain counter intuive outcomes can arise. The aim is not a comprehensive treatment of all the possible outcomes. We therefore proceed by giving priority to clarity of exposition at the price of more general statements, through the specification of some parameter values, i.e., $h_n = \frac{1}{2}$ and $c_s = \frac{1}{2}$. However the results derived in the paper hold for other parameter values[11] than the ones we fix[12].

Lemma 1 (South's profits)

The impact of storage on South's profits is ambiguous:

$$\Delta\pi_s < 0 \text{ iff } c_n < \bar{c}_s \equiv 1 - \frac{3}{2}h_s. \tag{15}$$

Proof:

From (13) $\Delta\pi_s < 0$ iff

$$3h_s < -2c_n + 4c_s \tag{16}$$

or

$$c_n < 1 - \frac{3}{2}h_s. \tag{17}$$

Therefore, assume that $h_s \leq \frac{5}{14}$ and $1 - 3h_s < c_n$ (i.e. Assumption 1' and 2' hold) then for any c_n such that $c_n < 1 - \frac{3}{2}h_s$we have $\Delta\pi_s < 0$.

It is interesting to note that Lemma 1 implies that the mere possibility to sell in the second period is detrimental to South. This is explained by the fact that action under storage is no longer a best response to (q_{n1}, q_{n2}), the equilibrium quantities from (4)

[11] a set of parameters of positive measure.

[12] The analysis of a technology transfer from North to South in Section 5 is carried out without setting $h_n = \frac{1}{2}$ and $c_s = \frac{1}{2}$.

chosen by North under no storage. South would have an incentive to reallocate some of its production from period 1 to period 2. The absence of storage served as a commitment device to sell the whole harvest in the first period. Once this commitment is no longer credible, in equilibrium South's firm will end-up selling in both periods with a positive marginal cost in the second period and therefore its equilibrium profits could end-up smaller than its equilibrium profits under no storage. The intuition behind this result is that when South's firm has no storage capacity, the Northern transfers a significant share of its harvest to period 2's sales. This allows South's firm to enjoy a high price and larger profits. When South's firm has a storage capacity, then North's firm transfers a smaller share of its harvest to period 2, thereby resulting in smaller profits in period 1. According to Lemma 1, this happens when the cost of storage in North is below a certain threshold, or alternatively when the South's harvest is below a certain threshold. When South's harvest is large enough then South unambiguously benefits from the capacity to store its harvest. Despite the tougher competition from North in period 1, South's profits rise because a substantial amount of harvest can now be sold in period 2.

Lemma 2 (North's profits)

The impact of South's access to storage on North's profits is ambiguous:

$$\Delta\pi_n > 0 \text{ iff } c_n > \bar{c}_n \equiv \frac{1+3h_s}{7}.$$

Proof: immediate from

$$\Delta\pi_n = \frac{1}{12} q_{s2} \left(7c_n - 1 - 3h_s\right). \tag{18}$$

We can compare $\bar{c}_n$ to the threshold $\bar{c}_s$: for $h_s > \frac{4}{9} = 0.444\,44$ we have $\bar{c}_n > \bar{c}_s$.

We can now combine, for $h_s > \frac{4}{9}$, Lemmas 1 and 2 to obtain the impact of the availability of storage on both firms simultaneously.

Proposition 1

Suppose $h_s > \frac{4}{9}$. When North's cost of storage is below (above) a certain threshold then both firms' profits fall (increase) when South acquires the possibility of storage. For intermediate values of North's cost of storage South's firm's profits rise while North's firm's profits diminish when South acquires the possibility of storage. More precisely:

for $1 - 3h_s < c_n < \bar{c}_s < \bar{c}_n$ we have $\Delta\pi_s < 0$ and $\Delta\pi_n < 0$

for $1 - 3h_s < \bar{c}_s < c_n < \bar{c}_n$ we have $\Delta\pi_s > 0$ and $\Delta\pi_n < 0$

for $1 - 3h_s < \bar{c}_s < \bar{c}_n < c_n$ we have $\Delta\pi_s > 0$ and $\Delta\pi_n > 0$.

Proof: Immediate from Lemmas 1 and 2 and the fact that for $h_s > \frac{4}{9}$ we have $\bar{c}_n > \bar{c}_s$.

When $h_s < \frac{4}{9}$ we need to compare the thresholds $\bar{c}_n$ and $1 - 3h_s$. For $h_s > \frac{1}{4}$ we have $\frac{1+3h_s}{7} > 1 - 3h_s$. Combining again, for $\frac{1}{4} < h_s < \frac{4}{9}$, Lemmas 1 and 2 gives the impact of the availability of storage on both firms simultaneously.

Proposition 2

Suppose $\frac{1}{4} < h_s < \frac{4}{9}$. When North's cost of storage is below (above) a certain threshold then both firms' profits fall (increase) when South acquires the possibility of storage. For intermediate values of North's cost of storage South's firm's profits fall while North's firm's profits rise when South acquires the possibility of storage. More precisely:

for $1 - 3h_s < c_n < \bar{c}_n < \bar{c}_s$ we have $\Delta\pi_s < 0$ and $\Delta\pi_n < 0$

for $1 - 3h_s < \bar{c}_n < c_n < \bar{c}_s$ we have $\Delta\pi_s < 0$ and $\Delta\pi_n > 0$

for $1 - 3h_s < \bar{c}_n < \bar{c}_s < c_n$ we have $\Delta\pi_s > 0$ and $\Delta\pi_n > 0$.

Proof: Immediate from Lemmas and 2 and the fact that for $h_s > \frac{1}{4}$ we have $\frac{1+3h_s}{7} > 1 - 3h_s$.

For $h_s < \frac{1}{4}$ we have $\bar{c}_n < 1 - 3h_s$, and from Lemmas 1 and 2 we deduce the impact of the availability of storage on both firms simultaneously.

Proposition 3

Suppose $h_s < \frac{1}{4}$. When North's cost of storage is below (above) a certain threshold then both firms' profits fall (increase) when South acquires the possibility of storage. More precisely:

for $\bar{c}_n < 1 - 3h_s < c_n < \bar{c}_s$ we have $\Delta\pi_s < 0$ and $\Delta\pi_n > 0$

for $\bar{c}_n < 1 - 3h_s < \bar{c}_s < c_n$ we have $\Delta\pi_s > 0$ and $\Delta\pi_n > 0$.

Proof: Immediate from Lemmas and 2 and the fact that for $h_s < \frac{1}{4}$ we have $\frac{1+3h_s}{7} < 1 - 3h_s$.

Therefore we could have $\Delta\pi_s < 0$ and $\Delta\pi_n < 0$ simultaneously hold: a loss-loss outcome. We could also have $\Delta\pi_s > 0$ and $\Delta\pi_n > 0$ simultaneously: a win-win outcome.

It is interesting to note that, for all admissible levels of South's harvest, when North's cost of storage is large enough then both firms would gain from South's acquiring storage. The intuition behind this result is that when North's cost of storage is large enough then North has little flexibility over the allocation of its harvest between the two periods. In the limit case, it sells all its harvest in period 1 only. Clearly in this case the acquisition of storage for South comes as a relief for both firms, since it allows shifting some of the sales from period 1 to period 2 and an increase in period 1's prices.

The impact on the total industry's profits

$$\Delta\pi_n + \Delta\pi_s = \frac{1}{72}\left(c_n - 1 + 3h_s\right)\left(11c_n - 5 + 3h_s\right)$$

Given Assumption 1' and Assumption 2' we have $\Delta\pi_n + \Delta\pi_s < 0$ iff

$$h_s > \frac{1}{5} \text{ and } 1 - 3h_s < c_n < \frac{5 - 3h_s}{11}$$

otherwise $\Delta\pi_n + \Delta\pi_s \geq 0$. Thus the industry's profits may fall if South's firm can lengthen the lifespan of its produce.

3.3 The impact on RW consumers' surplus

In period 1 the quantity sold decreases when South's firm has access to storage. So RW consumers' surplus decreases in period 1 and increases in period 2. What is the net impact on consumers' surplus?

Let CS_i^{st} (CS_i) denote RW consumers' surplus under (without) storage in period $i = 1, 2$, it can be shown that

$$CS_i^{st} = \frac{\left(Q_i^{st}\right)^2}{2} \text{ and } CS_i = \frac{\left(Q_i\right)^2}{2}$$

where

$$Q_1 = \frac{1}{4}\left(1 + c_n + 3h_s\right)$$

and

$$Q_2 = \frac{1}{4}\left(1 + h_s - c_n\right)$$

and where

$$Q_1^{st} = \frac{1}{6}\left(2 + 3h_s + c_n\right)$$

and

$$Q_2^{st} = \frac{1}{6}\left(1 + 3h_s - c_n\right).$$

The change in consumers' surplus in period 1 is given by

$$\begin{aligned}\Delta CS_1 &= CS_1^{st} - CS_1 \\ &= \frac{1}{2}\left(Q_1^{st} - Q_1\right)\left(Q_1^{st} + Q_1\right)\end{aligned}$$

with

$$
\begin{aligned}
Q_1^{st} - Q_1 &= \frac{1}{12}\left(1 - c_n - 3h_s\right) \\
&= -\frac{1}{2} q_{s2} < 0.
\end{aligned}
$$

In period 2 we have

$$
\Delta CS_2 = \frac{1}{2}\left(Q_2^{st} - Q_2\right)\left(Q_2^{st} + Q_2\right) > 0
$$

with

$$
Q_2^{st} - Q_2 = -\left(Q_1^{st} - Q_1\right) > 0.
$$

We can now determine the impact of storage on RW consumers' surplus over both periods:

$$
\begin{aligned}
\Delta CS_1 + \Delta CS_2 &= -\frac{1}{24} q_{s2}\left(\frac{5}{12}c_n + \frac{1}{12} + \frac{1}{2} + \frac{5}{4}h_s\right) + \frac{1}{24} q_{s2}\left(\frac{1}{2} - \frac{1}{12} - \frac{5}{12}c_n + \frac{3}{4}h_s\right) \\
&= -\frac{1}{144} q_{s2}\left(1 + 5c_n + 3h_s\right) < 0
\end{aligned}
$$

RW consumers' surplus decreases when South has access to storage. By allowing the reallocation of consumption from period 1 to period 2, the price in period 1 increases and the welfare loss for RW's consumers from this price increase is not compensated by the gain in consumption in period 2.

4 The impact on welfare

Let W^{st} (W) denote global welfare, i.e. the sum of North's, South's and RW's welfare, under (without) storage:

$$
W \equiv CS_1 + CS_2 + \pi_n + \pi_s \text{ and } W^{st} \equiv CS_1^{st} + CS_2^{st} + \pi_n^{st} + \pi_s^{st}.
$$

After substitution of $CS_1^{st}, CS_2^{st}, \pi_s^{st}$ and π_n^{st} and algebraic simplifications we have

$$
\begin{aligned}
\Delta W &\equiv W^{st} - W \\
&= \frac{1}{72} q_{s2}\left(31c_n - 13 - 21h_s\right)
\end{aligned}
$$

and therefore

$$
\Delta W < 0 \quad \text{iff} \quad c_n < \frac{13 + 21h_s}{31}. \tag{19}
$$

It is possible that the mere access of South to the possibility of storage can reduce the sum of RW's, South's and North's welfare.

Note that $\frac{13+21h_s}{31} > 1-3h_s$ iff $h_s > \frac{3}{19}$. Therefore when $h_s < \frac{3}{19}$ then from Assumption 2' we have $\frac{13+21h_s}{31} < c_n$ and therefore $\Delta W > 0$.Moreover, when $h_s < \frac{4}{15}$ we have $\frac{13+21h_s}{31} < \bar{c}_s$. Thus, for $h_s < \frac{3}{19}$ we have $\Delta W > 0$ and from Proposition 3, when $\frac{13+21h_s}{31} < c_n < \bar{c}_s$ we have $\Delta\pi_s < 0$ *and* $\Delta\pi_n > 0$.North's profit gains from the availability of storage to South can compensate for South's profit losses as well as RW loss in consumers' surplus. When $h_s < \frac{3}{19}$ and $\frac{13+21h_s}{31} < \bar{c}_s < c_n$ we have $\Delta\pi_s > 0$, $\Delta\pi_n > 0$ *and* $\Delta W > 0$. The increase in both firms' profits following South's access to storage compensates the loss in consumers' surplus.

It can be interesting to investigate an alternate scenario where RW and North are the same entity: consumption takes place in North and North only, South's market is negligible[13]. The analysis we have conducted readily contains the main ingredients to examine such a scenario. Indeed since South's and North's firms are profit maximizers, their equilibrium quantities sold in each period do not depend on whether the good is being sold in North's market or in a third market[14].

Let W_n^{st} (W_n) denote North's welfare under (without) storage. We have

$$W_n \equiv CS_n + \pi_n \text{ and } W_n^{st} \equiv (CS_1^{st} + CS_2^{st}) + \pi_n^{st}$$

After substitution of CS_1^{st}, CS_2^{st} and π_n^{st} and algebraic simplifications we have

$$W_n^{st} = \frac{1}{4}c_n^2 - \frac{1}{3}c_n + \frac{1}{4}h_s^2 + \frac{11}{24}$$

In the absence of storage we have after simplification

$$W_n = \frac{3}{16}c_n^2 - \frac{1}{4}c_n - \frac{1}{8}c_n h_s + \frac{7}{16} + \frac{7}{16}h_s^2$$

We now determine the impact of storage on North's welfare

$$\begin{aligned}\Delta W_n &\equiv W_n^{st} - W_n \\ &= \frac{1}{48}\left(c_n - 1 + 3h_s\right)\left(3c_n - 1 - 3h_s\right)\end{aligned}$$

[13]This could be viewed as a (highly) stylized representation of, for example, the European Union and the market of an agricultural product produced by some EU members as well as other countries south of the Mediterranean sea.

[14]This is because we assume away active strategic trade policies, such as export subsidies. In the presence of such subsidies the market equilibrium under this scenario and the scenario where both firms sell in a third market would differ.

or

$$\Delta W_n = \frac{1}{8} q_{s2} \left(3c_n - 1 - 3h_s\right).$$

Therefore we have

$$\Delta W_n < 0 \quad \text{iff} \quad c_n < \frac{1+3h_s}{3}.$$

The impact of South's access to storage on North's welfare is therefore ambiguous. Indeed the sign of $3c_n - 1 - 3h_s$ can be positive or negative on the set of admissible (c_n, h_s) under Assumption 1' and Assumption 2'. More precisely, it is straightforward to show that given Assumption 1' and Assumption 2' we have

$$\Delta W_n < 0 \text{ iff } h_s < \frac{1}{6} \text{ and } 1 - 3h_s < c_n < \frac{1+3h_s}{3}. \tag{20}$$

The sum of North's and South's welfare is given by

$$\Delta W_n + \Delta \pi_s = \frac{1}{72} q_{s2} \left(31c_n - 13 - 21h_s\right)$$

and therefore

$$\Delta W_n + \Delta \pi_s < 0 \text{ iff } \quad \frac{13 + 21h_s}{31} > c_n. \tag{21}$$

It is possible that the mere access of South to the possibility of storage can reduce the sum of South's and North's welfare.

Using (21) and (20) we can notice that when $\frac{13+21h_s}{31} < c_n$, i.e., $\Delta W_n + \Delta \pi_s > 0$ we necessarily have $\Delta W_n > 0$. Therefore if global welfare increases following South's access to storage then, even if $\Delta \pi_s < 0$, the gains in North's welfare can more than compensate South's losses. If there is any monetary transfer to make both North and South better off under the possibility storage, the transfer must be from North to South. However if $h_s > \frac{1}{6}$ and $\frac{13+21h_s}{31} > c_n$ we have $\Delta W_n > 0$ and $\Delta W_n + \Delta \pi_s < 0$: South's loss of profits cannot be compensated by North's welfare gain.

5 Technology Transfer

Throughout the analysis above we have considered that the cost of storage in South is exogenous. This cost could be the result of an investment stage that precedes the two period competition game analyzed above. Alternatively the storage technology can be transferred from North. For that last scenario the analysis above contains the main ingredients for the determination of the impact of storage. In this section we no longer set

$c_s = \frac{1}{2}$ and $h_n = \frac{1}{2}$. We examine the impact of storage in the case where storage technology is transferred from North with $c_s = c_n$. In principle North could transfer a technology that is inferior to the one available in North[15], i.e., which would yield $c_s > c_n$. The case $c_s = c_n$ corresponds to the case where North transfers its best available technology. We consider the fixed cost of the transfer to be nil to focus on the strategic motive of the transfer. We then have $q_{s2} = \frac{1}{6}(3h_s - 2c_n) > 0$ and from (13)

$$\Delta\pi_s = \pi_s^{st} - \pi_s = \frac{1}{6} q_{s2} (-2c_n + 3h_s) > 0 \tag{22}$$

South always gains from access to storage.

Using (14), we have that the impact on North's profits is given by

$$\Delta\pi_n = \frac{1}{12} q_{s2} (5c_n - 3h_s). \tag{23}$$

When $c_n < \frac{3}{5}h_s$ we have $\Delta\pi_n < 0$. The transfer of technology results in a win-win for North and South, i.e., $\Delta\pi_n > 0$ and $\Delta\pi_s > 0$, when $\frac{3}{2}h_s > c_n > \frac{3}{5}h_s$. A transfer of the best available technology can result in an increase in North's profits, even if such a transfer is free. South's firm would gain from access to storage when its harvest is large enough. South's firm would then prefer to split its sales over the two periods to generate higher revenues. Without North's technology it cannot do so. As for North's firm, it gains from South's access to storage only when its storage cost is large enough, i.e., $c_n > \frac{3}{5}h_s$. Because of substantial storage costs, North's firm sells a large share of its harvest in period 1, therefore, in the absence of storage in South competition in period 1 is reminiscent of the outcome of a price competition, since both parties have little or no flexibility over the sales' schedule. South's access to storage allows South's firm to shift some of its sales to period 2, and alleviate the strong competition that prevails in period 1.

6 Concluding remarks

We have shown that South's access to a technology that allows it to sell its harvest over two periods instead of one can result in a decrease of its firm's profits. This is explained by the fact that gaining access to a new technology results in South losing a strategic advantage that stems from the credibility of selling all its harvest in period 1. Our findings can be useful for policy interventions that aim at transferring better technologies

[15] See e.g., Mukherjee and Sinha (2014).

to South. In particular this analysis shows that there may be cases where both North and South's industries will resist (or advocate) the transfer of a technology to South that will lengthen the lifespan of its products. We have shown that a transfer of the best available technology from North to South can result in an increase in North's profits, even if such a transfer is free. It would be interesting to examine our research question under alternative scenarios such as Stackelberg leadership of North or the case where domestic markets and international markets are not segmented and where sellers may have other objectives than maximization of their profits as in Krishna and Thursby (1992). Throughout our analysis, we have fixed the overall sales capacity over the two periods, i.e., the harvest of each country is supposed fixed and we ignored the fixed cost of acquiring storage capacity. This was to emphasize the strategic role of the presence of storage. Our results suggest that revisiting the problem of capacity choice (see, e.g., Nakamura (2014)) in the case of perishable goods would be a fruitful exercise. If the fixed cost of acquiring storage capacity were considered, we would expect the region of parameters under which storage is profitable for South's firm to diminish. We have examined the case where the possibility to sell over two periods is due to a storage technology, alternatively it would be interesting to consider the case where the life span is due to genetic modification (see e.g., Choi (2010)). In that scenario two imperfect substitutes compete in the market: a genetically modified (GM) product and a traditional product.

Another relevant case to investigate is where both producing countries are also consuming countries, i.e. the case where both North and South consume the harvest. While a full analysis of this case is left for future research, we can however expect that the outcome of the acquisition of storage capacity will depend on the relative size of the North's and South's markets. When South's domestic market is small enough relative to North's market we expect our qualitative results to hold.

Our results suggest that the extension of the analysis of industrial policies and strategic trade policies to the case of perishable goods is not trivial and is likely deliver new insights. This exercise would be particularly relevant since the agricultural sector is one of the very few sectors that still benefits from substantial subsidies and protectionist policies and where the World Trade Organization has failed to make progress towards free trade. This is left for future research.

References

[1] Benchekroun, H., A. Halsema and Withagen, C. (2010), "When additional resource stocks reduce welfare." *Journal of Environmental Economics and Management*, 59(1):109–114.

[2] Brander, J.A. and Spencer, B.J. (1985), "Export subsidies and international market share rivalry." *Journal of International Economics,* 18 (1-2): 83-100.

[3] Chou, S. and N.V. Long (2009), "Optimal tariffs on exhaustible resources in the presence of cartel behavior." *Asia-Pacific Journal of Accounting and Economics* 16(3): 239–254.

[4] Choi, K., "International trade in genetically modified products." *International Review of Economics and Finance*, 19 p: 383-391.

[5] Diop, N., Jaffee, S.M. (2005), "Fruits and Vegetables: Global Trade and Competition in Fresh and Processed Product Markets," in (eds), Aksoy, M.A, Beghin, J.C., *Global Agricultural Trade and Developing Countries*, World Bank: 237-257.

[6] Fujiwara, K. and N.V. Long, (2012), "Optimal Tariffs on Exhaustible Resources: The Case of a Quantity Setting Cartel," CESifo Working Paper Series 3721, CESifo Group Munich.

[7] Garcia, Z. (2006), "Agriculture, trade negotiations and gender." Food and Agriculture Organization (FAO).

[8] Gaudet, G., M. Moreaux and Salant, S.W. (2002), "Private Storage of Common Property," *Journal of Environmental Economics and Management*, 43 (2): 280-302.

[9] Krishna, K. and M. Thursby, (1992), "Optimal policies and marketing board objectives," *Journal of Development Economics,* 38: 1-15.

[10] Mukherjee, A. and U. B., Sinha, (2014), "Can cost asymmetry be a rationale for privatisation?," *International Review of Economics and Finance*, 29(C), pages 497-503.

[11] Nakamura, Y., (2014), "Capacity Choice in a Duopoly with a Consumer-friendly Firm and an Absolute Profit-maximizing Firm." forthcoming, *International Review of Economics and Finance,* doi: 10.1016/j.iref.2014.07.004.

[12] Wan, R. and Boyce, J.R. (2014), "Non-Renewable Resource Stackelberg Games," forthcoming, *Resource and Energy Economics*, doi: 10.1016/j.reseneeco.2013.11.012

Récents cahiers de recherche du CIREQ
Recent Working Papers of CIREQ

Si vous désirez obtenir des exemplaires des cahiers, vous pouvez les télécharger à partir de notre site Web http://www.cireqmontreal.com/cahiers-de-recherche

If you wish to obtain copies of the working papers, you can download them directly from our website, http://www.cireqmontreal.com/cahiers-de-recherche

16-2013 Benchekroun, H., G. Gaudet, "On the Effects of Mergers on Equilibrium Outcomes in a Common Property Renewable Asset Oligopoly", octobre 2013, 33 pages

17-2013 Andersson, T., L. Ehlers, "An Algorithm for Identifying Agent-k-Linked Allocations in Economies with Indivisibilities", novembre 2013, 7 pages

01-2014 Alvarez-Cuadrado,F., N.V. Long et M. Poschke, "Capital-Labor Substitution, Structural Change and the Labor Income Share", janvier 2014, 55 pages

02-2014 Long, N.V., "The Green Paradox under Imperfect Substitutability between Clean and Dirty Fuels", février 2014, 23 pages

03-2014 Doko Tchatoka, F., J.-M. Dufour, "Identification-Robust Inference for Endogeneity Parameters in Linear Structural Models", janvier 2014, 29 pages

04-2014 Amarante, M., "What Is Ambiguity?", mars 2014, 51 pages

05-2014 Ehlers, L., "Strategy-Proofness and Essentially Single-Valued Cores Revisited", avril 2014, 22 pages

06-2014 Laussel, D., N.V. Long, J. Resende, "Network Effects, Aftermarkets and the Coase Conjecture : A Dynamic Markovian Approach", mai 2014, 65 pages

07-2014 Bossert, W., K. Suzumura, "Expected Utility without Full Transitivity", mai 2014, 12 pages

08-2014 Gaudet, G., S.W. Salant, "The Hotelling Model with Multiple Demands", octobre 2013, 22 pages

09-2014 Andersson, T., L. Ehlers, L.-G. Svensson, "Transferring Ownership of Public Housing to Existing Tenants : A Mechanism Design Approach", août 2014, 30 pages

10-2014 Negri, M., Y. Sprumont, "Size Invariant Measures of Association : Characterization and Difficulties", août 2014, 26 pages

05R-2011 Castro, R., N. Koumtingué, "On the Individual Optimality of Economic Integration", août 2014, 54 pages

11-2014 Castro, R., D. Coen-Pirani, "Explaining the Evolution of Educational Attainment in the U.S.", juillet 2014, 64 pages (2014-08)

15R-2010 Castro, R., G.L. Clementi, Y. Lee, "Cross-Sectoral Variation in the Volatility of Plant-Level Idiosyncratic Shocks", juin 2013, 33 pages