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Abstract

While the impact of environmental regulations on exports is widely discussed in the MENA region, there has been little empirical analysis on how stringent environmental regulations might affect exports of key sectors in the future. The main objective of this work is to fill this gap by examining the impact of an appropriate resource conservation policy on output, export and population well being. We consider a real case involving a substantial water price increase and its impact on the export and production of some key irrigated products. Our results show that the impact of this price increase differs from one product to another.

ملخص

في حين تم مناقشة تأثير القواعد البيئية على المصدرات بشكل واسع في منطقة الشرق الأوسط وشمال أفريقيا إلا أن كان هناك تحليلا بسيطا تجريبيا على مدى صرامة القواعد البيئية والتأثير التي قد تسببه في التصدير لدى قطاعات هامة ورئيسية في المستقبل. لذلك، إن الهدف الرئيسي لهذا العمل هو ملء هذه الفجوة بدراسة تأثير سياسة محافظة لمصدر مناسب على النتيجة الإنتاجية، التصدير ورخاء المجتمع وسوف نتناول قضية حقيقية تتضمن الزيادة الملحوظة لسعر المياه وتأثير ذلك على تصدير وإنتاج بعض المنتجات الزراعية الأساسية وسوف توضح نتائجنا بأن تأثير هذه الزيادة في السعر على المنتجات يختلف من منتج إلى آخر.

Introduction

Environmental protection and foreign trade promotion are considered by Tunisia as two of the main pillars in its global strategy for a sustainable development. In this study, we focus our attention on a key aspect which is considered crucial for Tunisian decision makers: a sustainable design for managing a highly scarce and irregular resource, namely water, without seriously handicapping export competitiveness.

While the impact of environmental regulations on exports is widely discussed in the region, there has been little empirical analysis of how stringent environmental regulations might affect exports of key sectors in the future. We know that the introduction of environmental constraints will certainly reduce the countries' competitiveness. Indeed, a policy which promotes environment conservation and the adoption of new norms involves additional costs which may induce a reduction in both production and export levels.

This work will confirm this insight. Indeed, the increase of water prices and the adoption of new environmental norms will decrease the production as well as the exports of the concerned products. However, we must note that those effects are characterized by an important variability.

Our case study for Tunisia seeks to assess the impact of higher irrigation water costs on the production and exports of dates and citrus. The added values of these two products are very important at their respective regional level. Approximately 80 % of the southern area's agricultural production revolves around dates, and 33% of date production is exported. The conservation of these agricultural activities will have an important impact, not only on export levels but also on the societal welfare and income of inhabitant of those regions.

Production and more importantly exports of dates play an important role in the economic and social life of the population in the south. However, this activity requires a lot of water and thus makes an intense pressure on a scare resource in a desert area. Conservation of this invaluable resource constitutes a vital objective for the area. Effective and real water conservation needs an appropriate pricing design which necessarily involves a substantial price increase. However, this increase will raise the input costs which induce negative impacts on production and export levels. The quantification of these impacts and the evaluation of their effects, and especially the analysis of their repercussions on the economic and social equilibrium of the area, constitute the major objective of this work.

The estimation of the environmental regulations impacts on the production and exports of dates and citrus is accomplished in two stages:

- Specification of an empirical relation between the controlled input prices, the technological choice and the level of production under some environmental constraints. We present three kinds of models. A basic model evaluating the effect of a price increase on supply and export levels (Model 1), and then on water demand. The second model integrates some conservation tools in the production process. Model 2 considers the use of more efficient irrigation techniques and Model 3 integrates a price adjustment process through the regulation of supply and export levels. This price increase can spur the use of more efficient irrigation techniques despite their high expense.. (see Abler & Shortle (1997) and Easty & Geradin (1998)).
- Collection of reliable data on both the aggregate and the individual level is needed. The econometric estimation of our models requires a panel database. We have to analyze the farmer behavior and thus we need some individual data (survey data). However, if we restrict ourselves to only one survey we can't evaluate the effect of water price increase over time. The integration of time and spatial variations needs a panel database.

Unfortunately, this kind of data is not available for our Tunisian case. We have some time series on price, supply and export levels on one hand, and we have a survey incorporating the supply, water demand levels and other socioeconomic indicators evaluated at individual levels for a representative sample of farmers. To evade the problem of matching individual and aggregate data, we integrate some microeconomic hypothesis (see Larson, 2000 and Larson and al., 2002) on our farmer profit maximization problem. This manipulation will allow us to decompose the supply elasticity to water price as the product of three variables that can be estimated from our two different sets of data.

This work is organized as follows: we first present the Tunisian agricultural sector with a special focus on the exports of dates and citrus. Next, we introduce the models used in the empirical part. Finally, we discuss the results of our estimations and present the results of policy simulations and our recommendations for decision makers.

2. Exports of Irrigated Agriculture (is there any other kind???)

2.1 Economic Indicators

Tunisia considers exports a central axis in its strategy of sustainable economic growth. Agriculture, which has contributed to GDN by 11% to 15 % during the last decade, still occupies a strategic place in Tunisia's economic activity. The receipts of fruit exports reached 85.7 million US$ (29.3 % of total agricultural and food exports) in 2003, against 46.2 million US$ in 1985. However, dates and citrus represent more than 92 % of these fruit exports. Moreover, these two products play a major economic role in their respective areas:

- - Dates make 25% of agricultural exports; it is the second exported agricultural product after olive oil (which accounts for 50% of agricultural exports). Dates production plays a major economic and social role in the Tunisian South-West area, almost 80% to 90% of agricultural added value in the region relates to date products.
- - Citrus is one of the most traditional products of Tunisian export and represents one of the principal products for the agricultural activity of the Tunisian North-East area and more particularly the Cap- Bon area.

Nevertheless, the export quantities and value trends of these two products are very different. During the last ten years, citrus fruits exports recorded a fall in quantity followed by stagnation (Figure 1.a). However, exports of dates did not cease to increase - in particular during the last decade (Figure 2.a). Moreover, the market structures related to foreign demand of the two products are rather different.

2.2. Export Trends

2.2.1. Quantities and values of citrus fruits exports

The citrus fruits consist of Maltese oranges, a small tonnage of sweet oranges, limes and Valencia oranges off season. The average exported quantities have fallen during the last fifteen years, as seen in Graph 1. These exports reached their maximum in 1987 with 51 thousand tons and a value of 21.4 million US$, to reach 17.7 thousand tons valued at 11.2 million US$ in 2004. Yet, though exported quantities had regressed, export prices in US$ kept rising.

Inter country comparison shows that the share of exports of Tunisia (20.2 million tons (MT)) is very weak compared to Morocco (457.2 MT) or South Africa (331 MT) - (see Table A1 Appendix A). Tunis' share of citrus world demand is rather small. However, the country is an important exporter in winter when the "Maltese" variety is shipped to the foreign markets.

The volume of citrus exports is rapidly decreasing, but their corresponding value has decreased at slower rates, due to the increase in prices.

2.2.2 Quantities and values of date exports

In the last five years, the average annual production of dates was approximately 111 thousand tons. The "Deglat Ennour" variety represented more than half of this production. Date exports - composed of natural dates and conditioned dates - have increased in both volume and value in the last twenty five years. Indeed, exports surpassed 44.4 thousand tons, evaluated at 84.4 million US$, during the season 2003 / 2004, compared to 13.2 thousand tons evaluated at 31.6 million US$ in 1980/81. These exports place Tunisia in third place – in the list of date exporters - after Iran and Pakistan when quantities are considered, and in first place when the value of exports is considered (see Table A2, Appendix A). Let us also note that this sector experienced an extraordinary development; the exported share, which was about 9 % during the sixties, steadily increased to reach more than 33% of the production in 2004.

2.3 The Export Price and the Structure of Foreign Demand

The unit values of the exported dates and citrus fruits have followed two rather different tendencies during the last decade (see Graph 3). The unit values of citrus fruits have had an increasing tendency whereas those of dates have experienced a fall during the last decade.

2.3.1 The export prices of citrus fruits

Tunisia mostly exports citrus during the winter period (October - March). Table A2 shows that the average price of the Tunisian product is distinctively higher than the Moroccan product. Foreign consumers are ready to pay a higher price for Tunisian products, especially the “Maltese” variety. Moreover, these prices have been steadily increasing during the last decade. However, the foreign demand for Tunisian citrus is limited and thus any price modification won’t have a significant effect on this demand. As reported by the following foreign demand estimation results, the price doesn’t have a significant effect on citrus foreign demand;

$$\text{Log Qexp} = \underset{(5.4)}{3.76} - \underset{(0.7)}{0.214}\ \text{logprix\_US\\$} \qquad (1)$$

$R^2 = 0.02$

2.3.2 The export prices of dates

The price of the Tunisian dates exceeds world average prices by a fair margin. This is explained partially by the fact that the share of selected and well packed dates of the total Tunisian dates exported is higher than other exporters. However, in spite of this qualitative advantage the prices expressed in US Dollar have decreased - an observation that can be explained by the huge increase in exported quantity. This important fact must be explicitly integrated into our economic interpretations and can be illustrated by the analysis of date foreign demand curve (Graph 3b) and the following econometric estimation results. The foreign demand decreases when price increases and demand elasticity has a statistically significant negative sign.

$$\text{LogQexp} = \underset{(6.2)}{13.44} - \underset{(-4.8)}{3.05}\ \text{log price US\\$} \qquad (2)$$

$R^2 = 0.62$

2.3.3 The foreign demand market structures for citrus fruits and dates

Foreign demand for dates is strongly correlated to export prices and export market share of Tunisian dates, compared to world exports, is rather significant. Consequently, the level of exports of Tunisian dates could have a rather significant effect on their export prices. The consumer distinguishes between dates from different suppliers, (he purchases at different prices, see TableA2, Appendix A). We can consider the date market a monopolistic competitive market. This is closely related to the important share of Tunisian date exports in the world market. However, the foreign demand for citrus fruits follows a perfect competition market. Indeed the quantity of Tunisian citrus exports does not have a significant effect on the export price level of citrus fruits, although Tunisian citrus prices are high compared to the world level.

This statement is easily argued by seeing the foreign demand function of the two products. The foreign demand curve for dates is steadily decreasing but the curve for citrus demand doesn't have this shape (see Graph 3). This illustration is confirmed as we consider the econometric estimation of the respective foreign demand functions (equations (1) and (2)); dates demand elasticity is significantly negative, however the citrus demand elasticity isn't significant.

3. Models Incorporating Water Conservation Tools

3.1 Water Conservation and Water Tariffs

3.1.1 Implementation problems of water conservation tools

There are several ways to conserve water, which is becoming an increasingly scarce resource. Among all the feasible tools, the design of a suitable tariff remains the most effective one. However, we know that any price increase would translate into a rise in supply prices, which would consequently have a direct negative impact on the economic activity (production, export, etc.) and an indirect impact on the welfare of the concerned population.

These consequences would explain the resistance to, and sometimes even the refusal of, any form of tariff modification. To tackle the difficulties related to the implementation of this form of conservation, experts on the matter took mitigated positions.

- A decentralized solution, such as the water market, may be preferred by the farmers. However, the implementation of these decentralized mechanisms requires the modification of a rather complex institutional framework.
- The design of suitable tariffs preceded by a serious study of their impact on the various sectors concerned and followed by an information campaign to increase the users' awareness would be easier.

We focus our model, on this last orientation. Tunisia, which is one of the most concerned countries with the problem of water conservation, is a good example. Water authorities in Tunisia consider tariff modification as the main tool to promote reducing water waste. This policy is commonly called the "Water Conservation Schedule".

However, in spite of the timidity of the current water price increases in Tunisia, a real resistance of all concerned users exists. The implementation of a higher tariff policy is needed in order to incite users to preserve water. Failing that, the country would need to resort to non-conventional resources with exorbitant mobilization costs. However, a sharp resistance would rise against this policy[1].

[1] Indeed, the Ministry of Economic Development, the Ministry of Finance, the Ministry of Foreign Trade and various associations of farmers and industrials (UTAP, UTICA) would be opposed to raising prices of water based on the argument that water price increase will reduce the competitiveness of the economy as well as the income level of producers.

3.1.2. An econometric constraint

In order to help the water authority implement its unpopular water tariff policy, it is essential to estimate the impact of these environmental regulations on the supply and export levels. We will estimate the water prices supply and export elasticity, η_{yw} and η_{Ew} respectively. We will thus be able to evaluate the effects of changes of the supply and export levels in response to a possible water costs increase.

However, the types of data available do not allow a direct estimate, except if we limit ourselves to space elasticity which cannot be adapted to make simulations of the effects of water price increase over time. To circumvent this difficulty we will use certain micro-economic principles to break up this elasticity as a product of three terms which will be easier to estimate (see Larson et al... 2002).

The Basic Model

If we consider the farmer profit maximization problem

$$\pi(p,w,r) = Max_{x,k}\left[p.\, f(x,k) - wx - rk\right]$$

Where **x** is the quantity of water used and ***k*** the quantity of other inputs,
w is the water price and ***r*** the price of other inputs,
y = f(x, k) *is* quantity of output obtained, and
p is the supply price of the output.

his cost minimization problem,

C(w, r, y) = Min $_{x,k}$ (wx+rk) such as f(x, k)>y.

and using Hotteling's, Young's and Sheppard's Lemmas, we can see that our supply elasticity to water price can be written as (see Appendix C for more detail):

$$\eta_{Yw} = -\left[\frac{wX}{pY}\right].\eta_{Yp}.\eta^{c}_{XY} \quad (3)$$

This relation shows that the supply elasticity to the water price can be written as the product of three terms.

1) The proportion of the cost of the input compared to the total receipts $\frac{wX}{pY}$.
2) Elasticity of supply to its own price η_{Yp}.
3) The elasticity of the optimal water demand (which minimizes the total cost) to the output level η^{c}_{XY}.

Finally, we assume that the share of exports in the total production remains constant and thus the exports elasticity to the water price can be written:

$$\eta_{Ew} = \eta_{yw}\frac{1}{\left(E/Y\right)} \quad (4)$$

where E/Y represents the share of export in the aggregate output.

3.2. Water Conservation and Irrigation Techniques

Until now we were only interested in the direct effect of water price variation, i.e. the short term elasticity. Indeed, we can implicitly assume that a huge increase in water prices implies an improvement in water use efficiency by switching to more efficient irrigation techniques.

Farmers seek to reduce the effect of the huge water price increase by shifting to more efficient irrigation techniques.

The model

If we improve the efficiency of water use by a rate equal to **q,** the supply function of the farmer becomes:

y = f(qx, k) = f(z, k).

Consequently his profit function becomes:

$$\Pi\left(p,\frac{w}{q},r\right) = \underset{x,k}{Max}\left[p.\,f(qx,k) - wx - rk\right].$$

By applying Hotelling's Lemma we obtain:

$$x = x\left(p,\frac{w}{q},r,q\right) = \frac{z\left(p,\frac{w}{q},r\right)}{q} = -\frac{\partial\pi}{\partial w}$$

and

$$y = y\left(p,\frac{w}{q},r\right) = \frac{\partial\pi}{\partial p}$$

by posing m=w/q, we deduce:

$$\frac{\partial y}{\partial w} = \frac{\partial y}{\partial m}.\frac{\partial m}{\partial w} - \frac{\partial y}{\partial m}.\frac{\partial m}{\partial q}.\frac{\partial q}{\partial w} = \frac{\partial y}{\partial m}\left(\frac{1}{q} - \frac{w}{q^2}\frac{\partial q}{\partial w}\right)$$
$$= \frac{\partial y}{\partial m}\frac{1}{q}\left(1 - \frac{w}{q}.\frac{\partial q}{\partial w}\right).$$

We define $\eta_{qw} = \frac{\partial q}{\partial w}.\frac{w}{q}$ which postulates that a big water price increase will generate the use of a new technology of irrigation and

$$\frac{\partial y^{inefficient}}{\partial w} = \frac{\partial y^{efficient}}{\partial w}.\frac{1}{q} \text{ or } q\frac{\partial y^{inefficient}}{\partial w} = \frac{\partial y^{efficient}}{\partial w}$$

But since q>1, the supply level decrease, following the rise in water prices, will be less significant if we use a more efficient irrigation technique.

We obtain:

$$\frac{\partial y^{efficient}}{\partial w} = \frac{\partial y^{inefficient}}{\partial w}\left(1 - \eta_{qw}\right).$$

Or equivalently

$$\Psi_{yw} = \eta_{yw}\left(1 - \eta_{qw}\right) \qquad (5)$$

In this case the efficient supply elasticity to the water price Ψ_{yw} is expressed as a function of: η_{yw} the elasticity of ***y*** compared to ***w*** under the assumption of the irrigation technique invariance (qualified as an inefficient situation) and of: η_{qw} the elasticity of the water use efficiency rate ***q***, to an increase of the water price ***w.***

Let us note however that if $\frac{\partial q}{\partial w}$ = 0, (if the modification of the price of water does not have any effect on the irrigation techniques choices), then $\frac{\partial y^{efficient}}{\partial w} = \frac{\partial y^{inefficient}}{\partial w}$.

3.3 Water Conservation and Foreign Trade Regulation

The exported products can be differentiated according to country origin; the Tunisian date "Deglat Ennour" is an example. Since the Tunisian dates are regarded as higher quality dates, in comparison to varieties of other countries, they are thus sold at higher prices. Moreover, as the share of Tunisian exports has a significant proportion in the quantum of world exports, thus a modification of the national production and consequently of the exported quantities can affect the export prices of this product. We can think have dates foreign demand as a monopolistic competitive market one, we have shown that the foreign demand function of dates has a negative slope (see Figure 3b and equation 2).

Date exports can be analyzed using a model with an export price adjustment related to some export regulations.

The model

We define D=D(p) the foreign demand function and B=B(p) the domestic demand one. Supposing we have the following equilibrium condition:

D(p) = Y(p, w, r) – B(p),

thus the price that restores this equilibrium condition will be a function of the input prices w and r, therefore our export price function is,

p = p(w, r).

By calculating the total differential of the equilibrium condition we show that the impact of a water price increase under environmental regulation on the export price p is (see: Larson et al. (2002)):

$$\eta_{pw} = \left[\frac{\eta_{yw}}{\eta_{Bp}\frac{B}{Y} - \eta_{yp} + \eta_{Dp}\frac{E}{Y}} \right] \qquad (6)$$

where η_{Dp} is the elasticity of the external request compared to the price p,

B/Y is the share of domestic consumption compared to the production,

η_{Bp} is the elasticity of the domestic demand compared to the price, and

E/Y is the share of exports compared to the production.

The adjustment of export prices involves a modification of the equilibrium conditions, since the regulation of the water price will modify the export price p and will thus have a second effect (which we will describe as an indirect effect) on supply and export levels. Thus the supply function will be:

Y=Y(p(w, r), w, r).

And the export function will be:

E=Y(p(r, w), W, r) – B(p).

We will define a global supply and export elasticity to the water price, as it integrates a direct and an indirect effect, which will be written:

$$\Omega_{yw} = \eta_{yw} + \eta_{yp}\eta_{pw}$$

$$\Omega_{Ew} = \Omega_{yw}\frac{1}{\left(E/Y\right)} - \eta_{Bp}\eta_{pw}\frac{\left(B/Y\right)}{\left(E/Y\right)} \qquad (7)$$

4. Econometric Estimations and Economic Policy Simulations

After a short presentation of the data needed for the econometric estimates, we discuss the results of the estimation of the three previously identified models. The first result gives us the estimates of the direct effect of water price increases on the supply and export levels of the two products (date and citrus), assuming exogenous export prices and no irrigation technique modification. In the second, we will try to evaluate the indirect effects of a substantial water price increase on choosing more efficient irrigation techniques. This indirect effect will be combined with the direct one to define an efficient effect of a water price increase on supply and export levels. The third estimation result gives us an estimation of the global elasticity of supply and export to the water price that integrates the adjustment of export prices due to export regulations.

4.1. Data Base

The estimates of the supply elasticity to the water price for our three models, which we note η_{yw} , $\psi\ yw$ and $\Omega\ yw$ respectively, requires two kinds of data:

- The estimations of the supply elasticity to the export price require some aggregate time series on supply, export and price levels. We use time series for the period 1971 to 2004 collected by the FAO.
- The estimations of the water demand elasticity to the supply level and to water price respectively requires individual micro-economic data, representing the farmer's behavior.

The individual data are drawn from a national survey, ordered by the Agriculture Department (DGGR) and carried out in 1995 by the CNEA. This survey entitled "*Study of the management and the tariff of the irrigation water on the irrigated perimeters*" is composed by a representative sample of approximately 250 irrigated plantations. In our sample we have 16 plantations of dates and 30 plantations of citrus fruits. These sub-samples are representative of the dates and citrus agriculture activities in Tunisia. Some summary statistics related to survey data are reported in Appendix D.

4.2. Estimates of the Direct Impact: Model 1

4.2.1. Dates estimations

Using the time series on the supply and price levels between 1971 and 2004, we obtain statistically highly significant supply elasticity estimates:

$$\text{Log Y} = \underset{(6.5)}{0.83} + \underset{(8.1)}{0.33}.\ \text{Log p} \qquad (8)$$

$R^2 = 0.67$

where ,Y is the average annual supply and p is the export price of dates.

A 10 % price increase will raise the level of date supply by 3.3%.

The estimation of the water demand elasticity to the supply level is based on the CNEA survey data. We thus obtained the following estimates:

$$\text{Log } X = \underset{(5.5)}{3.35} + \underset{(2,4)}{0.46} \text{ Log } Y \qquad (9)$$

$R^2 = 0.29$

where X is the water demand and Y is the production per tree of "Deglat".

An increase of the supply level by 10% will increases the water demand by 4.6%.

Using the elasticity's estimation of the previous two equations we can compute the direct supply elasticity of dates compared to the water price. Using equation (3), we find that η_{Yw} = - 0,039. (3.9%).

This result could be interpreted as follows: a 100 % water price increase would lead to a fall of the production of "Deglat" by approximately 3.9%. But as 33% of "Deglat" production is exported, using equation (4) and assuming that the domestic consumption remains unchanged[2], the 100% price increase will decrease export levels by about 11.94% as η_{Ew}= -0.119.

This rate could appear rather weak, however it is alarming enough. We must note that the share of the water cost $\frac{wX}{pY}$ was steadily increased over time. The water price increases, necessary for environmental regulations, will be greater than the export price increases.

Yet what is even more alarming is that the water prices currently paid by agriculture are strongly subsidized. Hence if the producers pay the real water cost, the water price would be 0.416 Dinars by m^3 instead of 0.112 Dinars. In that pessimistic situation a 100 % water price increase will generate a fall of 15.6% (instead of 3.9 %) in the production level and a fall in exports level by more than 46% (instead of 11.9 %).

4.2.1. Citrus fruits estimations

The estimates of the citrus supply functions and the water demand function using the aggregate time series and the individual data base give us the following results:

(1) $\text{Log } Y = 1.60 + 0.28.\ \text{Log } p$ (10)

(12.5) (5.3) $R^2 = 0.47$

We can easily evaluate the following elasticities:

$\eta_{YP} = 0.28$, $\eta_{XY} = 0.24$ and $\eta_{Yw} = -0.005$.

Thus, a 100 % water price increase would induce a fall in citrus fruits supply by only 0.5%. The water price increase will not have the same effect on citrus supply and exports as on dates.

As the export share of citrus fruits production is 18 % on average, a 100 % increase in water prices would decrease orange export levels by 2.78 % (η_{Ew}= -.0278), instead of 11.9 % for dates.

[2] To simplify our presentation.

4.3. Estimate of the Indirect Impact of an Irrigation Technique Switch

Agricultural experts evaluate the following approximate rates of efficiency for the different irrigation techniques:

- Traditional irrigation efficiency level : 57 %
- Irrigation by sprinkling efficiency level : 85 %
- Drip irrigation efficiency level: 95 %.

We conclude that moving from the traditional technique to drip irrigation would improve efficiency by 67%. Thus, for the same quantity of water, the production will be multiplied by 1.67.

However, the change of irrigation techniques generates additional costs for the farmers; for example, the installation of a drip system would require an investment of 10 thousand Dinars per hectare. Thus, in our simulation we will assume that only a proportion of farmers will be able to change their irrigation technique. We will consider three scenarios:

1. A switch to a more efficient technique by 20% of farmers gives a dq/q = 13.4,
2. A switch to a more efficient technique by 40% of farmers gives a dq/q = 26.8,
3. A switch to a more efficient technique by 90% of farmers gives a dq/q = 60.3.

Our elasticity's estimation suggests that the long term decrease in production will be less if more farmers adopt more efficient irrigation techniques.

Supply decrease will move from 11.9% to 10.3% if only 20% of producer switch to drip irrigation, while this decrease will only be 4.7% if 90% of the farmers adopt the new technique.

4. 4. Estimates of the Total Impact Integrating Export Price Adjustments

The export price adjustment models express supply prices as a function of the input prices (***w***: the water price and ***r***: the other inputs price). However, this price endogeny will be effective if, and only if, the demand is sensitive to the export price variations. Thus exporters would indirectly define the export price levels by fixing the quantities offered at a desired level.

4.3.1. Estimates of the foreign and domestic demand functions

- Citrus fruits demand:

The foreign demand elasticity estimate for citrus wasn't significant, as reported by equation (1). However, the estimate of the domestic demand function was no better; it did not give any significant econometric relation. Thus we couldn't use the price adjustment model to analyze the citrus exports.

- Dates demand:

The foreign demand elasticity estimates for dates are significantly negative. The domestic one is also significant, but has a lower magnitude.

$$\log Q\text{domestic} = \underset{(5.9)}{8.19} - \underset{(-2.9)}{1.19} \log P\_\$ \qquad (11)$$

$R^2 = 0.37$

The econometric estimates allow us to say that the dates demand is characterized by a negative slope compared to export price variation. Moreover, as the Tunisian dates are differentiated enough, the exporters could influence the export price levels by fixing the adequate supplied quantities. Let us note that the rapid growth of exports had induced a significant increase in the quantities produced but involved a higher water demand. As this water is extracted from an exhaustible resource, the consequence would be an environmental degradation.

We notice that the export prices endogeny allows us to conclude that export decrease would be much less significant than that predicted by the basic model, if export authorities were to respect some export regulation which increase the export prices. Indeed this export fall would be only 5.6% instead of 11.9%. This correction also concerns the production level but with smaller proportions, namely a variation of 3.3% instead of 3.9%.

The adoption of low export prices, added to a water price increase, may lead some farmers to leave their agriculture activities and thus supply levels and exported quantities might be drastically reduced. An increase of export prices related to a foreign trade regulation will help to escape this pessimistic scenario.

5. Conclusion and Policy Implications

Our major task was to show that a detailed analysis of the impact of an increase in water prices on the supply level as well as on the export of irrigated products is more appropriate than a global economic analysis by sector. The estimation of the impact of a water price increase on the supply and export levels of dates and citrus will certainly help decision makers to design an appropriate and sustainable water management policy.

Our second ambition was to show how policy analysts in developing countries can use a fairly simple methodology to begin analyzing these topics quantitatively and in a timely fashion to feed the policy debate.

A major concern for policy makers is that any water price increase will hurt the competitiveness of key agricultural exports, resulting in lower exports and employment levels and an increase in imports. The evaluation of the relationship between those variables (water costs and key exports) will certainly help in the design of better policies.

Finally, we hope that the results of this work would contribute to the existing debate on trade and environment. Our work has allowed us to evaluate different effects for the selected products. A brief summary of those effects could be presented as follow:

- A 100 % price increase for date producers would cause a reduction of 11.9 % in date exports.
- A 100 % price increase for Cap Bon citrus producers would cause an export decrease of 2.8 %.
- Those direct effects don't explicitly integrate the producers' reaction - to improve production efficiency that is likely to result from such a price increase. We have showed that those indirect effects could be substantial.

Considering the two key products for Tunisian food exports, namely dates and citrus, we can highlight the two main results, which reveal that the negative impact of a 100 % water price increase is very substantial on dates-related economic activity but rather weak for citrus. We see that the decrease in the export level of dates is more than four times greater than the one associated with citrus.

Our study suggests that one should not apply the same undifferentiated water pricing policy in the citrus growing Cap Bon region and in the dates growing southern regions of Tunisia.

While a strong water pricing policy is appropriate in the Cap Bon, one would have to be more careful in the South.

A strong water pricing policy would overall generate a positive impact in the Cap Bon area. It would provide a much needed relief to the area's stressed water resources without significantly reducing the level of citrus production and exports, the traditional activity of the region. A substantial water price increase for citrus producers, if smoothly and progressively implemented, would be an appropriate policy for water conservation. This might not be so in the South as our results indicate that a substantial increase in water costs would provoke a dramatic decrease in the production of dates, the dominant irrigated product of the region.

The crucial problem would be to implement such a water conservation policy by enforcing stringent pricing measures.

We will begin with the citrus case, which seems to be rather simple. We have seen that a substantial water price increase has almost negligible effects. Despite this, the implementation of the water conservation policy could create some acute problems. Faced with increased prices, the producers would not want to sustain a reduction in their revenue. Among those irrigators, those characterized by low levels of productivity would be highly penalized by the new pricing scheme. It is possible that some of them would consider quitting the sector forever.

For those social reasons, it is urgent that the water authority find appropriate solutions to tackle the inescapable negative social consequences that may result from the increased prices.

We suggest the following preliminary steps for the implementation of the new water conservation policy:

Step 1: It would be wise to begin by an awareness campaign targeting the affected producers, to inform and explain the highly positive feedbacks that would accrue as a result of such a conservation policy.
Step 2: Design an implementation program for a progressive and smooth price increase.
Step 3: Make an inventory of the affected producers and device appropriate measures which would help generate an improvement in their productivity levels (e.g. adequate and targeted subsidies).

N.B.:The case of the South must be considered with extreme caution.

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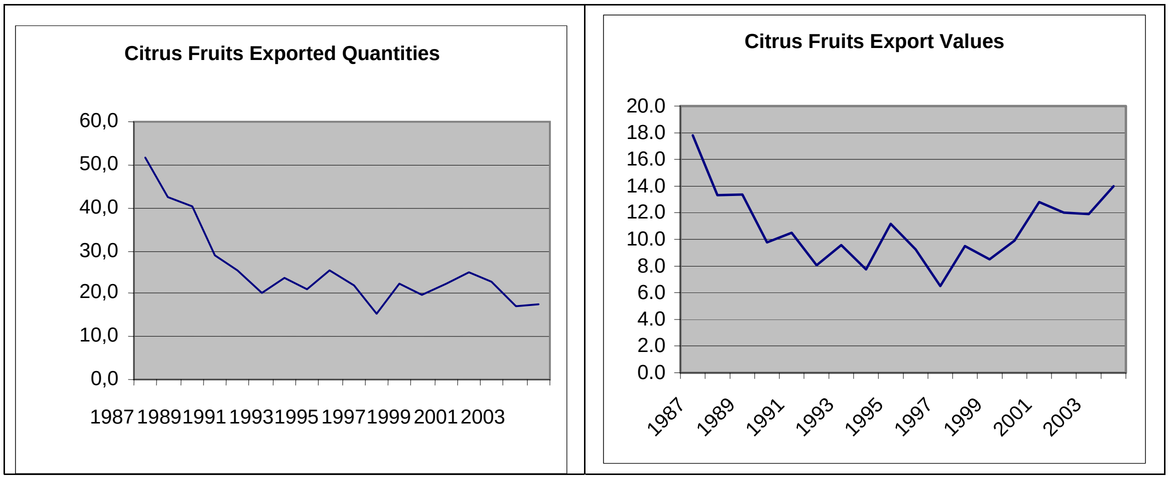
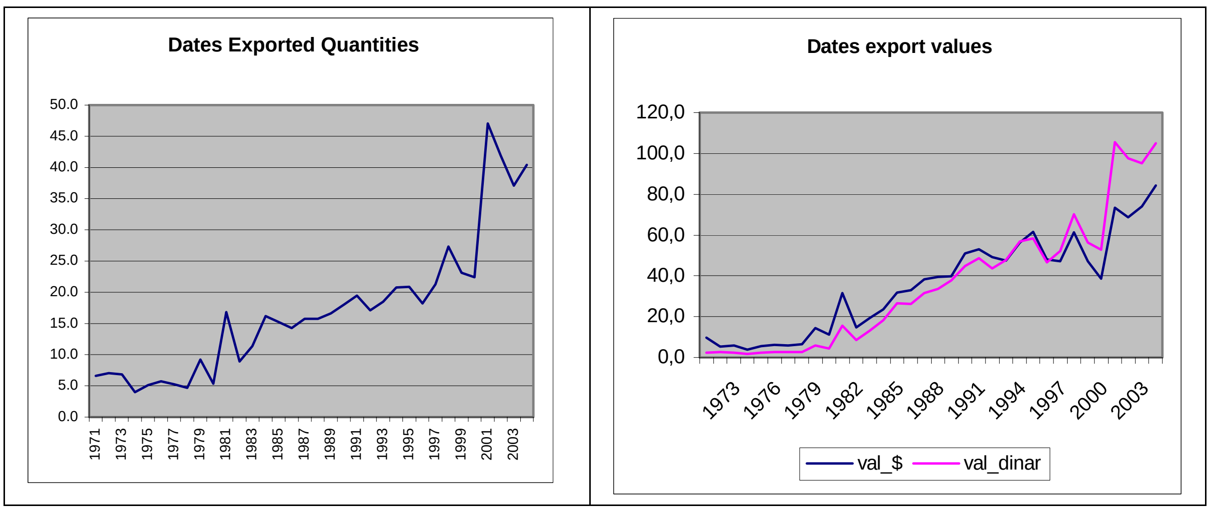
Graph 1: Export (in quantity and value) of citrus fruits



Graph 2: Export (in quantity and value) of dates



Graph 3: Foreign demand curves for citrus and dates (1990-2004)

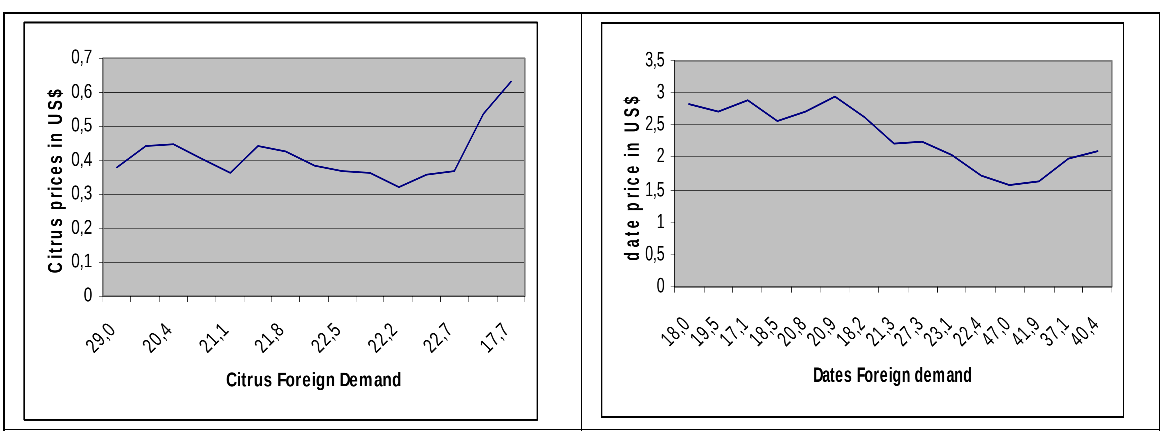


Table 1:Production and Export of Dates (*in thousands of tons)*:

	1981	1992	2004
Production	63	75.8	122
Exportation	13.7	19.3	40.4
Share of exports	21.4%	25.5%	33.1%

Source: INS

Table 2:Evolution of the Water Costs Shares Compared to the Dates Receipts $\frac{wX}{pY}$

	1984	1994	2002	2004
$\frac{wX}{pY}$ for dates	0 .12	0.16	0.39	0.43

Table 3: Estimation Results with Efficient Water Use:

		switching from traditional to drip irrigation		
		scenario 1	***scenario 2***	***scenario 3***
Share of producer using efficient technique		0,2	0,4	0,9
input efficiency parameter	q	1,67	1,67	1,67
efficiency of input use elasticity to his price	$\eta_{\omega\theta}$	0,134	0,268	0,603
Cross price elasticity with efficient use	$\Psi_{\omega\psi}$	-0,034	-0,029	-0,016
Percentage change in dates production	dY/Y	-3,41	-2,88	-1,56
Percentage change in date exports	dE/E	-10,34	-8,746	-4,74

Table 4: Results for the adjustment price model

	including export price adjustments	
Domestic share	B/Y	0,67
Domestic price elasticity	$\square_{Bp}$	-1,19
export price elasticity	$\square_{Dp}$	-3,05
export price elasticity	$\square_{pw}$	0,018
Final supply elasticity	$\square_{Yw}$	-0,033
Final export elasticity	$\square_{Ew}$	-0,056
final % change in output	dY/Y	-3,34
final % change in exports	dE/E	-5,64

Appendix A
Table A1: Citrus Fruit Exports by Country:

	1988	1992	1996	2000	2004
			Quantity (million tons)		
Tunisia	42	20	22	22	18
Morocco	413	345	428	312	223
South Africa	315	387	355	517	737
			Value (million $)		
Tunisia	15	9	9	7	11
Morocco	127	103	177	101	105
South Africa	384	140	124	134	271
			Unit value ($ by ton)		
Tunisia	355	447	425	323	633
Morocco	308	298	415	323	471
South Africa	384	363	350	259	367
			World Rank		
Tunisia	18th	19th	20th	> 20th	20th
Morocco	3d	5th	3d	4th	5th
South Africa	4th	3d	4th	3d	3d

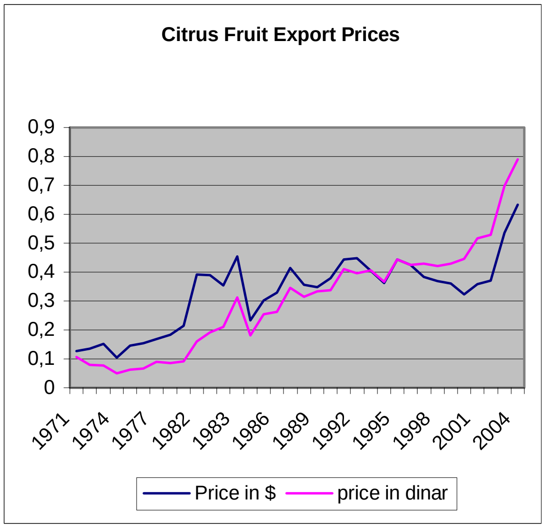
Source: FAO

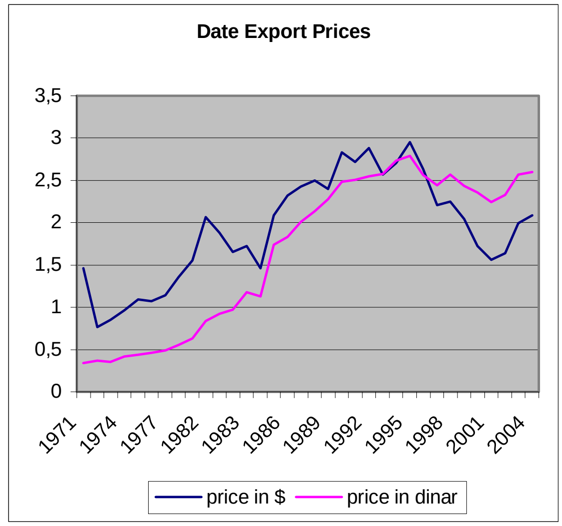
Table n°A2: Date Exports by Country:

	1988	1992	1996	2000	2004
			Quantity (thousand tons)		
Tunisia	15.8	17.1	18.2	22.4	40.4
Pakistan	35.5	41.5	34.5	78.7	65.4
U S A	4.1	7.2	5.1	3.2	4.2
			Value (million US$)		
Tunisia	39.4	49.6	47.9	38.6	84.4
Pakistan	15.8	17.4	16.2	29.7	22.5
U S A	7.6	16.9	15.4	11.5	13.4
			Unit value ($ by ton)		
Tunisia	2499	2884	2630	1722	2087
Pakistan	447	418	468	377	343
U S A	1861	2352	3036	3610	3179
			World Rank		
Tunisia	1st	2d	4th	2d	1st
Pakistan	3d	5th	7th	3d	5th
U S A	7th	6th	8th	8th	8th

Source: FAO

Appendix B
Graph B3: The Exports Prices of Dates and Citrus Fruits:





Appendix C

The Basic model

On the basis of a standard micro-economic problem, we suppose that the farmers maximize their profit:

$$\pi(p,w,r) = Max_{x,k}\left[p.\, f(x,k) - wx - rk\right] \qquad (1)$$

where $\quad$ ***x*** is the quantity of water used, ***k*** the quantity of other inputs,

w is the water price and ***r*** the price of other inputs,

y = f(x, k) *is* the quantity of output obtained, and

p the supply price of the output.

By applying Hotelling's Lemma we can define the supply functions ***y*** and water demand function ***x*** by:

$$Y = Y(p,w,r) = \frac{\partial\pi}{\partial p} \quad and \quad X = X(p,w,r) = -\frac{\partial\pi}{\partial w}. \qquad (2)$$

Moreover we can easily show (by applying Young's Lemma) that:

$$\frac{\partial Y}{\partial w} = \frac{\partial^2\pi}{\partial p\partial w} = \frac{\partial^2\pi}{\partial w\partial p} = -\frac{\partial X}{\partial p}\ . \qquad (3)$$

Thus the variation of the supply ***y*** following a rising of water price ***w*** is equal to the negative of a change of water demand ***x*** in response to a raising of output price ***p***.

On another hand we define the cost function C(w, r, y) by:

$C(w, r, y) = Min_{x,k}\ (wx+rk)$ $\qquad$ such as $\qquad$ $f(x, k)>y$. $\qquad$ (4)

By applying the Shephard's Lemma, we draw the water demand function which would make minimum the cost of the farmer:

$$X^c = X^c(w,r,y) = \frac{\partial C}{\partial w}, \qquad (5)$$

that we can rewrite as:

$X(p, w, r) = X^C (w, r, Y(p, w, r))$, $\qquad$ (6)

where ***Y*** corresponds to the level of production ***y*** which maximizes the profit level.

By deriving X(p, w, r) compared to p we can write:

$$\frac{\partial x}{\partial p} = \frac{\partial X^c}{\partial y}.\frac{\partial Y}{\partial p}. \qquad (7)$$

The effect of the output price increase on the water demand $\frac{\partial X}{\partial p}$ can be defined as the product of two terms. The first term $\frac{\partial X^c}{\partial y}$ measures the effect of the increase in the supply level on water demand. The second term $\frac{\partial Y}{\partial p}$ evaluates the variation of the production compared to its own price.

If we use the result of the equation (3), we can write:

$$\frac{\partial Y}{\partial w} = -\frac{\partial X}{\partial p} = -\frac{\partial X^c}{\partial y}.\frac{\partial Y}{\partial p},$$

thus we rewrite in the form:

$$\frac{\partial Y}{\partial w}.\frac{w}{Y} = -\frac{\partial X^c}{\partial y}.\frac{\partial Y}{\partial p}.\frac{w}{Y}.\frac{p}{p}.\frac{X}{X}.\frac{Y}{Y} = -\left[\frac{wX}{pY}\right].\left[\frac{\partial Y}{\partial p}.\frac{p}{Y}\right].\left[\frac{\partial X^c}{\partial w}.\frac{w}{X}\right]$$

or $\eta_{Yw} = -\left[\frac{wX}{pY}\right].\eta_{Yp}.\eta^c_{XY}$. (8)

Appendix D

Summary statistics

Dates

Let us note that we formed two spatial series using two normalization units: per hectare and per tree of Deglat (the measuring unit most used locally to evaluate the size of the exploitations). Thus, each plantation of our sample is made up of 55 trees of Deglat palm on average.

Table D1 Average supply and water consumption of the palm trees by hectare and by tree

	By Hectare	**By Tree**
Quantity of Date supply	3	0.26
Water consumption	14280	133
Share of water costs to receipts : ***wX/pY***	0.16	0.16

Source: CNEA Survey, 1995

Citrus Fruits

The majority of citrus plantations are located in the governorate of Nabeul. Indeed, 82% of the total production comes from this governorate. Whereas the productions of the governorates of Ben Arous, Ariana, Bizerte and Jendouba do not exceed 18%. Let us note however that the average output per hectare remains rather weak across the country.

Table D2: Individual and Aggregate Information on Citrus Fruits

	average	standard deviation
Exploitations number	30	
Average area (ha)	3	2.8
Production (t/ha)	14.1	5.3
Water used é (m3/ha)	5162	754
WX/pY	0.07	

Source : CNEA Survey, 1995