Green Electricity and Access Charges

Chema Abderrazak M'Sallem and Adel Ben Youssef
Adis- Univ. Paris Sud

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Abstract

Draft: The object of this article is to analyze theoretically the behavior of a network monopoly when two firms compete in the electricity market. One firm offers the green electricity product whereas the other proposes the conventional electricity one. Each firm pays an access charge to the natural monopoly in order to access to the transportation network. Through a vertical differentiation model, we try to analyze the link between the access charges payed by the two firms and the qualities offered. We also attempt to understand why the green electricity product is not chosen by the consumer. Finally, we suggest some ideas that lead the consumers to choose the green electricity product instead of the conventional electricity one. The main results that we have obtained are the following. In deciding on quality, the firms face three basic considerations. The first is the profitability of the location in quality space based on revenues and the cost of investment in quality for a given distance from the rival's quality. The second is the effect of a change in the difference between the two qualities proposed. Indeed, a reduction in the gap between qualities increases the associated price competition and therefore limits the gain of the two firms. Conventional electricity firm will not be incited to increase its quality level. The third consideration is the level of the access charges payed by the two firms to the network monopoly in order to access to the transportation network. The choice of the access charges level by the natural monopoly is crucial (four cases). If he diminishes the access charge of the green electricity producer and increases the access charge of the conventional electricity one, then the difference in prices will fall. The green electricity firm will be incited to increase its quality level and the conventional electricity one will be incited to decrease its quality level in order to alleviate the price competition. We must notice here, that the green electricity producer can't increase its quality level a lot because of the fixed costs that are very high. So despite the efforts of the two firms to alleviate the price competition, the price difference will always remain very low. This case will induce confusion of the consumers which will think that the two firms offer the same product and that there is not green electricity product . If the network monopoly increases the access charge of the green electricity producer and diminishes the access charge of the conventional electricity one, then the difference in prices will go up. In this case none of the two firms is incited to increase its quality level. Facing a high price difference, the consumers will not be ready to buy the green product. If the network monopoly increases the two respective access charges, then the price difference will fall. The green electricity firm will not be incited to increase its quality level because its marginal revenue is increasing in this case. Finally, if the natural monopoly diminishes the two access charges, then the price difference will be very high. Consumers could not buy the green electricity product because its price is very high. The choice of the access charge level by the network monopoly induces two kind of problems: (1)- Confusion and the lack of confidence of the green electricity product,and (2)- The high price difference between green electricity and conventional electricity

1. Introduction

Electricity market was at the heart of two major changes last two decades. From the one hand, many countries experienced liberalisation and deregulation (Glachant, J.M. (2002) and Joskow, P. (1996)). The liberalization of this market has increased competition between producers. Hence, consumers can choose between several companies this service. From the other hand the climate change has impact the consideration of the environment. Consumers are more aware about the needs of less harmful sources of electricity. Many experiences have shown that some consumers are willing to pay more for renewable energy. In that way, green electricity i.e. generated by green energy sources is modifying the border of the electricity market.

There exist at least five renewable energy sources (inputs): wind energy, solar, biomass, geothermic, hydroelectric. Each technology has its own harmful effects. If we observe the production technology using the combustion of fossil energy (fuel, coal, natural gas); the basic environmental externalities are the throwing of greenhouse gas, which causes the climate change. The generation of electricity using nuclear energy resolves the problem of greenhouse emissions of $CO2$ and $SO2$ but poses the problem of ionizing radiations. The generation of electricity using hydroelectric power doesn't have emissions of $CO2$ and $SO2$ or ionizing radiations but may cause important changes on the ecosystem. Indeed, the construction of barrages modifies considerably the water cycle. It may lead to spices extinction or the proliferation of noxious vegetable species.

Electricity market can be divided into three networks: the generation network which is competitive network since the liberalization of this market, the transmission or transportation network, and the distribution network toward consumers which can be natural monopoly or competitive segment. In the generation network, different competitors select their electricity type (environmental, conventional,...) , invest and compete. The transportation network permits the transportation of the different types of electricity produced. This network is a natural monopoly since its duplication is expensive and not socially desirable. In order to transmit their electricity to consumers, the producers need to access to the transportation network. They have to pay an access charge to the owner of the transportation network i.e to the natural monopoly. This access charge is proportional to their use of the network [1].

The debate in order to promote green electricity can be divided into two main aspects. From the one hand, what kind of the regulatory instruments are needed in order to promote green electricity. For example, European commission has imposed by its directives [2] that 10% of the total production of electricity must be generated by green sources. From the other hand, how to promote green electricity in a competitive market where consumers play an important role. Labelling green electricity was recommended as an appropriate policy since then different countries set up a official green electricity label. Little attention was given to the link between the promotion of green electricity and the deregulation of the market. Our purpose is to analyze how a change in the policy towards access charges can promote the green electricity. We know that in practice this case is prohibited in order to have a fair competition. However, if environmental goals are as important as competition goals one must ask the foundation of these policies. The aim of this article is to discuss this issue.

[1] The reader can refer to the article of Laffont and Tirole (1994) and (1997) to better understand the structure of a network industry.

[2] The label "petite fleur" has been created by the european commission in 1992;

Our model considers two firms. One firm offers the green electricity product whereas the other proposes the conventional electricity one. Each firm pays an access charge to the natural monopoly in order to access to the transportation network. Through a vertical differentiation model, we try to analyze the link between the access charges payed by the two firms and the environmental qualities offered. We also attempt to give some arguments about the empirical fact consisting of a very small rate of adoption of green electricity in a deregulated markets. Finaly, we suggest some policy recommendations in terms of competition law in order to promote green electricity.

This paper is structured like the followings. Second section reviews the literature. Section three sets out the model and the main hypothesis. Section four investigates price competition and studies the link between equilibrium prices and access charges. Section five analyzes the equilibrium in environmental quality and we study the link between access charges and environmental qualities. In the last part, we give some policy recommendations in term of State interventions in order to promote the green electricity demand.

2. Review of the literature

There are several authors who has studied the transmission prices in the electricity market. An ideal transmission pricing mechanism should satisfy a number of criteria. A more in-depth discussion of these criteria is provided in Armstrong and Doyle (1995) and Green (1997). Here, we present a short survey. Prices are the instrument used by market participants in the economy to communicate with each other. Ideally, the price is a measure of the relative scarcity or of the relative cost of the good or service. However, this signalling function will work properly only if the price reflects the marginal cost, i.e. the cost of the last unit produced. Applied to the transmission market, economic efficiency implies that the transmission prices should provide the electricity customers and suppliers with the correct economic incentives in at least six ways. First access prices must encourage an efficient use of the existing network (Economic Dispatch). Basically, the job of the network operator is to continuously balance electricity generation and demand at the lowest possible cost. If generation and demand is geographically spread, then the network operator must also take into account the marginal costs of transmission. These marginal costs are due to transmission losses and to transmission constraints (congestion). In the process of electricity transmission, some power is lost in the form of heat. Thus, more power is generated than is ultimately consumed, and somebody must pay for the difference. This is the marginal cost of transmission losses. Furthermore, the wires connecting the different nodes in the transmission grid only have a limited transmission capacity. This might imply that it is not always feasible to dispatch the cheapest available generator because of a lack of transmission capacity for the power generated. This cheap generator must then be replaced with a more expensive one. The cost difference between those two generators is the opportunity cost of the transmission constraint. These are the major components of the marginal cost of transmission. Ideally, both should be taken into account in the pricing mechanism, which would result in differentiated prices per node. Secondly, transmission prices must encourage an efficient location of new generation capacity and new customers Economic dispatch is a matter of short-run efficiency, which can be steered by the grid operator through changes in the scheduling decision. But at the basis of potential congestion problems is the location of generators and customers, which is by far the most important contributor to the marginal transmission cost. If one would be able to guide the generators and customers in their location decision, then this could improve the efficiency of the grid use. This is done through the transmission price, if this price correctly reflects the cost of transmission. The third criteria for an ideal transmission price is that it must encourage efficient investment in network expansion and maintenance. Finaly the last three criteria are prices should be non-discriminating. This means that identical customers, buying a good at the same place and at the same time, also pay the same price or in general should receive the same treatment. Prices should also be transparent. this means that it is desirable that the pricing mechanism that is used is transparent in the sense that all users know how the prices are calculated and can take them into account in their consumption. Finaly transmission prices must allow suppliers to cover their costs.

The green electricity litterature is especially empirical (econometrical). The whole works can be divided in three parts. A first group has studied conditions of environmental labelization of electricity market. Bernhard Truffer, Jochen Markard, et Rolf Wüstenhagen (2001) have analized the electricity market labelization. They have compared the different approaches that have been developped in Europe and USA recently. They have concluded that in the case of green electricty some labels are limited to renewable energy while others on CO2 emissions,... Consumers understand easily the ecolabels; but in an environmental point of view these ecolabels have a low impact. Indeed, in order to be accepted and understanded, a label must answer to the subjective perception of green electricity by consumers. The introduction of an eco-label will then have a low impact on the environment.

A second group of works have studied the behavior of consumers face to the green electricity product. Indeed, in most of the studies, consumers are willing to pay more for green electricity. This behavior has a positive effect. But in several european countries where green electricity exists the number of consumers who use the green electricity remain very low. For example, in Finland 30% of household consider that green electricity is good but in 2004 only 0.2% of them use it. Suvi Salmela, and Vilja Varho (2006) have realized different experiences on consumer behavior face to green electricity in Finland. They have searched to determine consumers' barriers in buying green electricity. They equally tried to explain the gap between positive attitude and passive behavior. They have shown that consumers' passivity is due to their low environmental conscious, to their ignorance of the green market, too high prices of green elelctricity product, and finally the lack of information, proofs and certifications.

The third group of authors study the necessary regulation in this sector in order to increase green electricity sales. Indeed, renewable energy part produced in USA has decreased going from 12% in 1990 to 9% in 2002. Frederci C. Menz (2005), has reviewed public US policies. There exists a governmental policy for renewable energies. Governements have supported renewable energies (taxes, public funds,credits, certifications...) in order to permit to consumers to choose the green electricity product. But the authors have conclued that the most important barrier is the cost of the green electricity and the very expensive costs of this product. Despite these governmental efforts the green electricity part produced and consumed remain very low. Lin Gan, Gunnar S.,et Hans H. Kolskus (2007), have analyzed how policies and instruments have been implemented to promote green electricity in different countries: Germany, Suisse and USA. For each country, they have analyzed how policies and instruments have been implemented and how they have been used. They have conclued that there is a low penetration of green electricity. This is due to high costs of renewable energy and the low costs fossils energy. Finon D. and Perez Y.(2006) analyze the regulatory instruments used to promote renewable energy sources in electricity generation, taking into consideration their role in promoting the preservation of collective goods. They show that neither instruments offer an optimal solution. The government will thus select an instrument in accordance with the relative importance of its objectives.

Finally, we conclude that green electricity litterature is especially empirical (econometrical). Most of the articles have stressed on the reasons of the modest penetration of the green electricity and on the regulation necessary but not on the link between the access charges and the low green electricity demand .

3. The structure of the model

In this section, we introduce the main assumptions of a vertical differentiation model where the environmental quality is the element of discrimination. We begin by analyzing firms' behaviour.

3.1. Firm' behaviour

In this work, the electricity network is composed by two segments. A segment which is a natural monoply because of its technical characteristics.This segment is called transportation segment or network. The network monopoly produces the good 0. The second segment is competitive: it is the generation segment or network. In this segment, we observe the production of two imperfect substitutes: a good H which represents the green electricity and offered by a rival firm and a good L which represents conventional electricity offered by a competitive firm L . The dominant operator i.e. the network monopoly controls the bottleneck facility required to interconnection with entrants competing on the complementary segment. Therefore, the provision of good H by the competing green electricity firm requires access to the local network in order to reach final consumers. So the rival firm needs to pay an access charge noted a' to the natural monopoly in order to use the bottleneck facility. Firm L has also to pay an access charge noted a to the natural monopoly to reach final consumers.

We assume that there are two firms in the electricity market. A firm H offering a labellised good (L_H) with high environmental quality q^H and price p^H and a firm L offering conventional electricity with quality q^L and price p^L.

We assume also that $q^H > q^L$ and that $q^i \in [0,1]$ where $i = H, L$.

As Zhou and al. (2001), we assume that firm H has a fixed investment cost $F(q^H) = \beta^H q^{H^2}$ to have the eco-label L_H where $\beta^H > 0$.

We assume also, that firm L has a fixed investment cost $F(q^L) = \beta^L q^{L^2}$. This cost is due to the use of conventional electricity (maintenance, installation,...)

We assume furthermore that $\beta^H < \beta^L$. This asumption implies that the green electricity firm is more efficient in investment than the network monopoly.

Like Ronnen (1991) we assume that fixed costs $F(q^i)$ where $i = H, L$ and that marginal fixed costs $F^{'}(q^i)$ where $i = H, L$ are increasing for all $q^i \in [0, \infty]$ $(i = H, L)$.This asumption is necessary for the existence and unicity of equilibrium.

Finally we have:

$F'(q^i) > 0$ et $\lim_{q \to +\infty} F'(q^i) = +\infty$, $F'''(q^i) > 0$ $i = H, L$.

In order to focus on investment decisions in quality, we assume that the marginal cost of quality is constant and for simplicity we let this cost be zero: $c_H = c_L = 0$.

3.2. Consumers' Side

We assume that consumers are aware of the importance of the environment for the current and future generations, in the sense that they all prefer the most environment friendly product if they have the choice between several "environmental qualities" when sold at same price. Thus a vertical differentiation model seems to correspond to our situation. In this model, all consumers buy almost one unit of the product. The consumers are identified by a taste parameter θ for the environmental quality. We assume that θ is uniformly distributed on $[0, 1]$. The consumers pay p^i for environmental quality q^i $(i = H, L)$.

We consider as Mussa and Rosen (1978) that indirect utility of a consumer of type θ buying from firm i $(i = H, L)$ a unit good of environmental quality q^i at price p^i is given by:

$U(q^i, p^i; \theta) = \theta q^i - p^i$ where $i = H, L$.

We let $\tilde{\theta}$ the taste parameter which represents the consumer indifferent between high or low environmental quality.

We have $\tilde{\theta} = \frac{p^H - p^L}{q^H - q^L}$. Since all consumers use electricity we assume that the demand is totally covered in this market. Thus consumers as $\theta \in \left[\tilde{\theta}, 1\right]$ buy good of quality q^H. Consumers as $\theta \in \left[0, \tilde{\theta}\right]$ buy good of quality q^L.

Demand functions of low and high environmental qualities are thus given by:

$D^L(p^L, p^H, q^L, q^H) = \tilde{\theta} - 0 = \frac{p^H - p^L}{q^H - q^L}$ (2.1)

$D^H(p^H, p^L, q^H, q^L) = 1 - \tilde{\theta} = 1 - \frac{p^H - p^L}{q^H - q^L}$ (2.2)

To have access to the network, the green electricity and the conventional electricity firms must pay a unit access charge noted a' and a respectively to the natural monopoly. L and H profits are then respectively:

$\pi^L(p^L, p^H, q^L, q^H) = p^L D^L(p^L, p^H, q^L, q^H) - a D^L(p^H, p^L, q^H, q^L) - \beta^L {q^L}^2$

$\pi^H(p^H, p^L, q^H, q^L) = p^H D^H(p^H, p^L, q^H, q^L) - a' D^H(p^H, p^L, q^H, q^L) - \beta {q^H}^2$

These profits are equal to:

$\pi^L(p^L, p^H, q^L, q^H) = \left(p^L - a\right) D^L(p^L, p^H, q^L, q^H) - \beta^L {q^L}^2$

$\pi^H(p^H, p^L, q^H, q^L) = \left(p^H - a'\right) D^H(p^H, p^L, q^H, q^L) - \beta^H {q^H}^2$

In this section, we will develop a two stage game. The game is as follows: in the first step, firms H and L compete in environmental qualities. In the second stage, the two firms compete in prices. The aim of this section is to analyze the link between equilibrium in qualities, prices equilibrium and access charges.

4. Price competition and access charges

In this section, we are interested by price competition. The aim of this section is to analyze the link between price equilibrium and acces charges.

4.1. Price equilbrium

Firms' L and H profits are repectively:

$$\pi^L(p^L, p^H, q^L, q^H) = \left(p^L - a\right) D^L(p^L, p^H, q^L, q^H) - \beta^L {q^L}^2 \qquad (3.1)$$
$$\pi^H(p^H, p^L, q^H, q^L) = \left(p^H - a'\right) D^H(p^H, p^L, q^H, q^L) - \beta^H {q^H}^2 \qquad (3.2)$$

Nash Equilibrium must satisfy the following first order conditions:

$$\frac{\partial \pi^H(p^H, p^L, q^H, q^L)}{\partial p^H} = 0 \qquad (3.3)$$
$$\frac{\partial \pi^L(p^L, p^H, q^L, q^H)}{\partial p^L} = 0 \qquad (3.4)$$

By resolving equations (3.3) and (3.4), we obtain the following reaction functions:

$$p^H(p^L) = \frac{1}{2}\left[(q^H - q^L) + p^L + a'\right] \qquad (3.5)$$
$$p^L(p^H) = \frac{1}{2}\left[p^H + a\right] \qquad (3.6)$$

Finaly the equilibrium prices[3] are given by (3.7) and (3.8):

$$p^{H^*} = \frac{2}{3}\left[(q^H - q^L) + \frac{1}{2}a + a'\right] \qquad (3.7)$$
$$p^{L^*} = \frac{1}{3}\left[(q^H - q^L) + 2a + a'\right] \qquad (3.8)$$
$$p^{H^*} - p^{L^*} = \frac{1}{3}\left[(q^H - q^L) + (a' - a)\right] \qquad (3.9)$$

4.2. Price equilibrium and Access Charges

Results (3.7) and (3.8) imply that prices of firms H and L depend on the access charges a' and a . Secondly, the equation (3.9) implies that the difference in prices is composed by two parts:

(i)- the difference in qualities $(q^H - q^L)$ and,

(ii)- the difference in access charges $(a' - a)$.

Result (3.9) needs several comments.

First, if $a' < a$ then $p^{H^*} - p^{L^*} > 0$ if and only if $(q^H - q^L) > (a' - a)$.

Second, if $a' > a$ then $p^{H^*} - p^{L^*}$ is always positive.

We suppose here that the natural monopoly will impose an access charge a' that is inferior to a [4] $(a' < a)$.

In the next part, we are interested by quality competition and by the link between quality equilibrium and access charges

5. Quality Competition and Access Charges

The profit equilibrium of firm H is:

$$\tilde{\pi}^H(q^H, q^L) = \frac{1}{9}\left[4(q^H - q^L) - \frac{(a - a')^2}{q^H - q^L}\right] - \beta^H q^{H^2} \qquad (3.10)$$

The profit equilibrium of firm L is:

[3] The proof is given in annex 1. Concavity and stability conditions are verified.

[4] This asumption can be justified in the following manner.If firm H is constrained to construct a network that is far from the transmission network , the network monopoly can impose an access charge a' inferior to a in order to compensate the costs of the construction of a new network on the one hand and for the obligation to build far from the transmission network.

$$\tilde{\pi}^L(q^L, q^H) = \tfrac{1}{9}\left[(q^H - q^L) + 2(a' - a) + \frac{(a' - a)^2}{q^H - q^L}\right] - \beta^L q^{L^2} \qquad (3.11)$$

The profits of firms L and H are composed by three terms:

(i)- a term which depends on $(q^H - q^L)$,

(ii)- a term which depends on a and a',

(iii)- a term which depends on the investment cost in quality $\beta^i q^{i^2}$ where $i = H, L$.

We let $\tilde{R}^H(q^H, q^L)$ and $\tilde{R}^L(q^L, q^H)$ the revenues of L and H respectively. We have:

$$\tilde{R}^H(q^H, q^L) = p^{H^*} D^{H*} = \frac{1}{9}\left[4(q^H - q^L) + 6a' - \frac{(a + 2a')(a - a')}{q^H - q^L}\right] \qquad (3.12)$$

$$\tilde{R}^L(q^L, q^H) = p^{L^*} D^{L*} = \tfrac{1}{9}\left[(q^H - q^L) + 2a' + a + \frac{(2a + a')(a' - a)}{q^H - q^L}\right] \qquad (3.13)$$

The derivatives of $\tilde{R}^H(q^H, q^L)$ and $\tilde{R}^L(q^L, q^H)$ with q^H and q^L, are given by:

$$\frac{\partial \tilde{R}^H}{\partial q^H} = \frac{1}{9}\left[4 + \frac{(a + 2a')(a - a')}{(q^H - q^L)^2}\right] > 0 \qquad (3.14)$$

$$\frac{\partial \tilde{R}^H}{\partial q^L} = \frac{1}{9}\left[-4 - \frac{(a + 2a')(a - a')}{(q^H - q^L)^2}\right] < 0 \qquad (3.15)$$

$$\frac{\partial \tilde{R}^L}{\partial q^L} = \tfrac{1}{9}\left[-1 + \frac{(2a + a')(a' - a)}{(q^H - q^L)^2}\right] < 0 \qquad (3.16)$$

$$\frac{\partial \tilde{R}^L}{\partial q^H} = \tfrac{1}{9}\left[1 - \frac{(2a + a')(a' - a)}{(q^H - q^L)^2}\right] > 0 \qquad (3.17)$$

(3.15) implies that an reduction in q^L increases firm's H revenue.

(3.17) implies that an increase in q^H increases firm's L revenue.

These results mean that the more the products are differentiated in term of environmental qualities the more competition in prices is relaxed and the more the firms increase their revenues.

In the next section, we will study the equilibrium environmental qualities.

5.1. Quality Equilibrium and Access Charges

The aim of this section is to study the relation between the equilibrium environmental qualities and the access charges.

5.1.1. Quality Equilibrium

We turn now to the first step of the game where firms compete in quality.

Nash equilibrium must satisfy first order conditions:

$$\frac{\partial \tilde{\pi}^H(q^H, q^L)}{\partial q^H} = 0 \qquad (3.18)$$

$$\frac{\partial \tilde{\pi}^L(q^L, q^H)}{\partial q^L} = 0 \qquad (3.19)$$

By resolving (3.18) and (3.19) we obtain the two following equations:

$$2\beta^L q^L = 2\beta^H q^H - \frac{5}{9} \qquad (3.20)$$

$$\frac{1}{9}\left[-1+\frac{(a'-a)^2}{(q^H-q^L)^2}\right]-2\beta^L q^L=0 \qquad (3.21)$$

The optimal qualities equalize marginal costs of investments to marginal revenues. The stability and concavity conditions are satisfied[5]. The equilibrium in quality is unique.

5.1.2. Effect of the choice of the access charges on qualities

The resolution of quality equilibrium equalizes marginal costs to marginal revenues:

$$\frac{\partial \tilde{R}^H}{\partial q^H}=\frac{\partial C^H}{\partial q^H} \qquad (3.22)$$

$$\frac{\partial \tilde{R}^L}{\partial q^L}=\frac{\partial C^L}{\partial q^L} \qquad (3.23)$$

Marginal costs of H and L respectively are given by:

$$C^H(q^H,q^L)=a'D^H+\beta^H q^{H^2}=\frac{1}{3}a'\left[2-\frac{(a'-a)}{(q^H-q^L)}\right]+\beta^H q^{H^2} \qquad (3.24)$$

$$C^L(q^L,q^H)=aD^L+\beta^L q^{L^2}=\frac{1}{3}a\left[1+\frac{(a'-a)}{(q^H-q^L)}\right]+\beta^L q^{L^2} \qquad (3.25)$$

The equations (3.22) and (3.23) become:

$$\frac{\partial \tilde{R}^H}{\partial q^H}=\frac{\partial C^H}{\partial q^H}=\frac{1}{3}a'\left[\frac{(a'-a)}{(q^H-q^L)^2}\right]+2\beta^H q^H \qquad (3.26)$$

$$\frac{\partial \tilde{R}^L}{\partial q^L}=\frac{\partial C^L}{\partial q^L}=\frac{1}{3}a\left[\frac{(a'-a)}{(q^H-q^L)^2}\right]+2\beta^L q^L \qquad (3.27)$$

The equations (3.22) to (3.27) induce several remarks.

In deciding on quality, the firms face three basic considerations. The first is the profitability of the location in quality space based on revenues and the cost of investment in quality for a given distance from the rival's quality. The second is the effect of a change in the difference between the two qualities proposed. Indeed, a reduction in the gap between qualities increases the associated price competition and therefore limits the gain of the two firms. The conventional electricity firm will not be incited to increase its quality level q^L . The green electricity firm is incited to increase its quality q^H but it must be aware on its fixed cost $\beta^H q^{H^2}$.The third consideration is the level of the access charges payed by the two firms to the network monopoly in order to access to the transmission network. We have:

$$\frac{\partial C^H}{\partial a'}=\frac{2}{3}+\frac{1}{3}\frac{a}{q^H-q^L}-\frac{2}{3}\frac{a'}{q^H-q^L} \qquad (3.28)$$

$$\frac{\partial R^H}{\partial a'}=\frac{1}{9}\left[6-\frac{a-4a'}{q^H-q^L}\right] \qquad (3.29)$$

$$\frac{\partial C^L}{\partial a}=\frac{1}{3}\left[1+\frac{a'}{q^H-q^L}-\frac{2a}{q^H-q^L}\right] \qquad (3.30)$$

$$\frac{\partial R^L}{\partial a}=\frac{1}{9}\left[1+\frac{a'-3a}{q^H-q^L}\right] \qquad (3.31)$$

The signs of $\frac{\partial R^H}{\partial a'}$ and $\frac{\partial R^L}{\partial a}$ depend on the signs of $\left[6-\frac{a-4a'}{q^H-q^L}\right]$ and $\left[1+\frac{a'-3a}{q^H-q^L}\right]$ respectively. We have:

$$\frac{\partial R^H}{\partial a'}>0 \text{ if } \quad a'<\frac{1}{4}\left[a-6\left(q^H-q^L\right)\right]=x \qquad (3.32)$$

[5] The proof is given in the annex 2.

$\dfrac{\partial R^L}{\partial a} > 0$ if $\quad a < \dfrac{1}{3}\left[\left(q^H - q^L\right) - a'\right] = y \qquad (3.33)$

In the same manner, the signs of $\dfrac{\partial C^H}{\partial a'}$ and $\dfrac{\partial C^L}{\partial a}$ depend on the signs of $\left[\dfrac{2}{3} + \dfrac{1}{3}\dfrac{a}{q^H - q^L} - \dfrac{2}{3}\dfrac{a'}{q^H - q^L}\right]$ and $\left[1 + \dfrac{a'}{q^H - q^L} - \dfrac{2a}{q^H - q^L}\right]$ respectively. We have:

$\dfrac{\partial C^H}{\partial a'} > 0$ if $a' < \left(q^H - q^L\right) + \dfrac{1}{2}a = t \qquad (3.34)$

$\dfrac{\partial C^L}{\partial a} > 0$ if $a < \dfrac{1}{2}\left[\left(q^H - q^L\right) + a'\right] = z \qquad (3.35)$

The comparison of the inequalities (3.32) to (3.35) induces the following conclusion:

If $a' < \frac{7}{5}(q^H - q^L)$ then we have $x > z > t > y \qquad (3.36)$

This result can be resumed in the following table:

If a	<y	>y	<t	>t	<z	>z	<x	>x
$\dfrac{\partial R^H}{\partial a'}$	>0	>0	>0	>**0**	>**0**	>0	>0	<0
$\dfrac{\partial C^H}{\partial a'}$	<0	<0	<0	>**0**	>**0**	>0	>0	>0
$\dfrac{\partial R^L}{\partial a}$	>0	<0	<0	<**0**	<**0**	<0	<0	<0
$\dfrac{\partial C^L}{\partial a}$	>0	>0	>0	>**0**	>**0**	<0	<0	<0

Table 1: Main results

Inequalities (3.34) and (3.35) are always satisfied because the access charges a and a' are costs: they always increases total costs. Therefore, we have $a > t$ and $a < z$. This implies that the network monopoly will always set an access charge a to the firm L so that:

$t < a < z \qquad (3.37)$

The next table presents the sign of the marginal revenue and the marginal cost of the green electricity firm:

	$\dfrac{\partial R^H}{\partial a'}$	$\dfrac{\partial C^H}{\partial a'}$
H	>0	>0

Table 2: Sign of the marginal revenue and the marginal cost of the green electricity firm

The results of the table 2 imply that a unit increase of the access charge a' increases the marginal revenue and the marginal cost of the firm H and conversely.

The next table gives the sign of the marginal revenue and the marginal cost of the conventional electricity firm:

	$\dfrac{\partial R^L}{\partial a}$	$\dfrac{\partial C^L}{\partial a}$
L	<0	>0

Table 3: Sign of the marginal revenue and the marginal cost of the conventional electricity firm

The results of the table 3 imply that a unit increase of the access charge a decreases the marginal revenue of firm L and increases its marginal cost and conversely.

The price difference is given by equation (3.9):

$p^{H^*} - p^{L^*} = \frac{1}{3}\left[(q^H - q^L) - (a - a')\right]$ where $a' < a$

This result induces several comments:

(i) - If $a' = a$ then the price difference will be high and the two firms will not be incited to increase their respective qualities.

(ii) - The more a' decreases and a increases and the more the price difference is low. In this case firm H will be incited to increase its environmental quality to relaw price competition. In the same manner, the conventional electricity firm will be incited to decrease its quality.

(iii) - The more a' increases and a decreases and the more the price difference is high because $(a' - a < 0)$. In this case, the green electricity firm will be incited to increase its environmental quality because the price difference is high.

(4i) - If a' and a increase then the price difference will decrease[6].

(5i)- If a' and a decrease then the price difference will increase[7]

Finally, the choice of the access charges level by the natural monopoly is crucial (four cases).

(1)- If he diminishes the access charge of the green electricity producer and increases the access charge of the conventional electricity one, then the marginal revenues of firm H and L will decrease (because $\frac{\partial R^H}{\partial a'} > 0$ and $\frac{\partial R^L}{\partial a} < 0$), and the price difference will fall. The green electricity firm will be incited to increase its quality level and the conventional electricity one will be incited to decrease its quality level in order to alleviate price competition. We must notice here, that the green electricity producer can't increase its quality level a lot because of the fixed costs that are very high. So despite the efforts of the two firms to alleviate the price competition, the price difference will always remain very low. This case will induce confusion of the consumers which will think that the two firms offer the same product and that there is not a green electricity product .

(2)- If the network monopoly increases the access charge of the green electricity producer and diminishes the access charge of the conventional electricity one, then the marginal revenues of firm H and L will increase and the price difference will go up. In this case none of the two firms is incited to increase its quality level. Facing a high price difference, the consumers will not be ready to buy the green product.

(3)- If the network monopoly increases the two respective access charges,then the marginal revenue of firm H will increase, the marginal revenue of firm L will decrease and the price difference will fall. In this case, the green electricity firm will not be incited to increase its quality level because its marginal revenue is increasing. This case will induce confusion of the consumers which will think that the two firms offer the same product and that there is not a green electricity product because the small price difference.

(4)-If the network monopoly diminishes the two access charges, then the marginal revenue of firm H will decrease and the marginal revenue of firm L will increase and the price difference will be very high. The green electricity firm is incited to increase its environmental quality. Consumers could not buy the green electricity product because of its high price.

[6] We let $a_1' = (1+\alpha)\,a'$ and $a_1 = (1+\alpha)\,a$ the access charges. We see that the prices decrease because :

$p^{H^*} - p^{L^*} = \frac{1}{3}\left[(q^H - q^L) - (1+\alpha)(a - a')\right]$ where $a' < a$

[7] We can argue this case in the same manner then precedently.

The next table resumes the preceding results:

	H	**L**	$\mathbf{p}^{H^*} - \mathbf{p}^{L^*}$	**Consequences**
$\searrow a'$ **and** $\nearrow a$	$\partial R^H \searrow$	$\partial R^L \searrow$	$\searrow$	small price difference
Incitement	$\nearrow q^H$	$\searrow q^L$		lack of confidence
$\nearrow a'$ **and** $\searrow a$	$\partial R^H \nearrow$	$\partial R^L \nearrow$	$\nearrow$	High price difference
Incitement	not incited	not incited		GE[8]expensive
$\nearrow a'$ **and** $\nearrow a$	$\partial R^H \nearrow$	$\partial R^L \searrow$	$\searrow$	small price difference
Incitement	not incitated	$\searrow q^L$		lack of confidence
$\searrow a'$ **and** $\searrow a$	$\partial R^H \searrow$	$\partial R^L \nearrow$	$\nearrow$	high price difference
Incitations	$\nearrow q^H$	not incited		GE expensive

Table 4: Main results

The choice of the access charges level by the network monopoly induces two kind of problems:

-Confusion and the lack of confidence of the green electricity product,

-The high price difference between green electricity and conventional electricity.

In all cases, consumers prefer to buy the conventional electricity product then the green electricity one.

6. Promoting green electricity by authority

There are several problems in the electricity market. First, there is the access charges problem which have an important part in the prices functions. Secondly, there is the lack of confidence of the conumers for the green electricity product. These problems don't incited the network monopoly and the competitive firms ti invest in green electricity.

The authority must play an important part in promoting green electricity product. If network monopoly invests in renewable energy by using public funds, the authority can regulate the access charge. It can impose a fix environmental access charge to competitive firm. This access charge will permit to the network operator to cover the lost in conventional electricity. The authority can also impose "eco-taxes" to incite consumers to choose green electricity and to make them in confidence for the green electricity product. Consumers who use green electricty don't pay these eco-taxes and the others pay it.

There are several economic policies that have been used to promote green electricity. The most important instruments are financial incitation and public funds. Indeed, the actual part of renewable energy sources in the total brut consumption in the UE is equal to 6 percent. The objective fixed by the UE is to double this part until 2010. This global objective implies an important implication of all UE states which must encourage the use of renewable energy sources.

But these efforts can't be judged at short notice because the most important barriers are green electricity costs and very expensive prices.

7. Conclusion

The object of this article is to analyze theoretically the behavior of a network monopoly when two firms compete in the electricity market. One firm offers the green electricity product whereas the

[8]GE: green electricity

other proposes the conventional electricity one. Each firm pays an access charge to the natural monopoly in order to access to the transportation network. Through a vertical differentiation model, we try to analyze the link between the access charges payed by the two firms and the qualities offered. We also attempt to understand why the green electricity product is not chosen by the consumer. Finaly, we suggest some ideas that lead the consumers to choose the green electricity product instead of the conventional elctricity one.

We suppose in this article that there are two competitive firms in the electricity market. One of the two firms proposes the green electricity product and the other offers the conventional electricity one. each firm has to pay an access charge to a natural monopoly in order to access to the generation network and to offer its product to consumers. The game is as following: in the first step firms compete in quality. The second step is consecrated to a simultaneous price competition.

The main results that we have obtained are the following. In deciding on quality, the firms face three basic considerations. The first is the profitability of the location in quality space based on revenues and the cost of investment in quality for a given distance from the rival's quality. The second is the effect of a change in the difference between the two qualities proposed. Indeed, a reduction in the gap between qualities increases the associated price competition and therefore limits the gain of the two firms. Conventional electricity firm will not be incited to increase its quality level. The third consideration is the level of the access charges payed by the two firms to the network monopoly in order to access to the transportation network. The choice of the access charges level by the natural monopoly is crucial (four cases).

If he diminishes the access charge of the green electricity producer and increases the access charge of the conventional electricity one, then the difference in prices will fall. The green electricity firm will be incited to increase its quality level and the conventional electricity one will be incited to decrease its quality level in order to alleviate the price competition. We must notice here, that the green electricity producer can't increase its quality level a lot because of the fixed costs that are very high. So despite the efforts of the two firms to alleviate the price competition, the price difference will always remain very low. This case will induce confusion of the consumers which will think that the two firms offer the same product and that there is not green electricity product .

If the network monopoly increases the access charge of the green electricity producer and diminishes the access charge of the conventional electricity one, then the difference in prices will go up. In this case none of the two firms is incited to increase its quality level. Facing a high price difference, the consumers will not be ready to buy the green product.

If the network monopoly increases the two respective access charges, then the price difference will fall. The green electricity firm will not be incited to increase its quality level because its marginal revenue is increasing in this case.

Finally, if the natural monopoly diminishes the two access charges, then the price difference will be very high. Consumers could not buy the green electricity product because its price is very high.

The choice of the access charge level by the network monopoly induces two kind of problems:

-Confusion and the lack of confidence of the green electricity product,

-The high price difference between green electricity and conventional electricity.

In all cases, consumers prefer to buy the conventional electricity product then the green electricity one.

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Annexes:

7.1. ANNEX 1:Proof of concavity and stability conditions for price equilibrium

(i)- Concavity:

The concavity conditions must satisfy:

$\frac{\partial^2 \pi^L(p^L, p^H, q^L, q^H)}{\partial p^{L^2}} < 0$ and $\frac{\partial^2 \pi^H(p^H, p^L, q^H, q^L)}{\partial p^{H^2}} < 0$

We have $\frac{\partial^2 \pi^L(p^L, p^H, q^L, q^H)}{\partial p^{L^2}} = -\frac{2}{q^H - q^L} < 0$

and $\frac{\partial^2 \pi^H(p^H, p^L, q^H, q^L)}{\partial p^{H^2}} = -\frac{2}{q^H - q^L} < 0$

Concavity conditions are verified

(ii)- Stability:

The stability conditions must satisfy:

$\frac{\partial^2 \pi^L(p^L,p^H,q^L,q^H)}{\partial p^{L^2}} \frac{\partial^2 \pi^H(p^H,p^L,q^H,q^L)}{\partial p^{H^2}} - \frac{\partial^2 \pi^L(p^L,p^H,q^L,q^H)}{\partial p^L \partial p^H} \frac{\partial^2 \pi^H(p^H,p^L,q^H,q^L)}{\partial p^H \partial p^L} > 0$

$\left(-\frac{2}{q^H-q^L}\right)\left(-\frac{2}{q^H-q^L}\right) - \left(-\frac{1}{q^H-q^L}\right)\left(-\frac{1}{q^H-q^L}\right) = \frac{3}{(q^H-q^L)^2} > 0$

Stability conditions are verified

CQFD.

7.2. ANNEX 2: Proof of concavity and stability conditions:

(i)- Concavity:

We have

$\frac{\partial^2 \tilde{\pi}^H(q^H, q^L)}{\partial q^{H^2}} = -\frac{2(a-a')^2}{(q^H - q^L)^3} - 2\beta^H < 0$

$\frac{\partial^2 \tilde{\pi}^L(q^L, q^H)}{\partial q^{L^2}} = \frac{2(a'-a)^2}{(q^H - q^L)^3} - 2\beta^L < 0$ if and only if $\beta^L > \frac{(a'-a)^2}{(q^H - q^L)^3}$

Concavity conditions are verified

(ii)- Stability Conditions:

The stability conditions must satisfy:

$\frac{\partial^2 \tilde{\pi}^H(q^H, q^L)}{\partial q^{H^2}} \frac{\partial^2 \tilde{\pi}^L(q^L, q^H)}{\partial q^{L^2}} - \frac{\partial^2 \tilde{\pi}^H(q^H, q^L)}{\partial q^H \partial q^L} \frac{\partial^2 \tilde{\pi}^L(q^L, q^H)}{\partial q^L \partial q^H} > 0$

$\left[-\frac{2(a-a')^2}{(q^H-q^L)^3} - 2\beta^H\right]\left[\frac{2(a'-a)^2}{(q^H-q^L)^3} - 2\beta^L\right] - \left[-\frac{2(a-a')^2}{(q^H-q^L)^3}\right]\left[\frac{2(a'-a)^2}{(q^H-q^L)^3}\right] > 0$

The system is globally stable and concave if $\beta^L > \frac{(a'-a)^2}{(q^H-q^L)^3}$. It admits a unique solution (q^{L*}, q^{H*}).

stability connditions are satisfied.