Environmental Quality Competition: The Case of the French Retail Electricity Market

Sandra MORENO
ART-Dev, University of Perpignan Via Domitia, France
sandra.moreno@univ-perp.fr

Marion PODESTA
ART-Dev, University of Perpignan Via Domitia, France
marion.podesta@univ-perp.fr

Abstract

Recent empirical studies have shown that as environmental concern grows among the population, consumers are willing to pay an extra fee for eco-friendly products such as those certified by an eco-label or such as green electricity. In this context, the aim of this paper is to examine whether the strategy of providing renewable electricity is profitable for firms, when we introduce consumer environmental consciousness explicitly into our model and considering a higher marginal cost related to renewable energy supply compared to the conventional energy one. We show that both elements lead to increased profits and maximum differentiation between firms, where one firm supplies conventional electricity while the other supplies the renewable variant. Regarding social welfare, because of a larger positive externality on the environment, the renewable energy only supply scenario would be socially optimal only when the additional cost related to its supply approaches zero.

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1 Introduction

Created following the liberalisation of energy markets, the French retail electricity market has been fully operational since 2007. Although electricity cannot be physically differentiated on the grid, over the past few years, an increasing number of firms have entered this market offering green or renewable electricity, i.e. generated from renewable sources, in order to compete mainly with the incumbents' conventional electricity produced from nuclear or fossil fuels. According to the French Commission of Electricity Regulation (CRE) reports, in 2007 only 4 firms were offering green only electricity contracts for retail consumers, whereas in 2020 there were already 18 of them. Going green has also been seen as a retailers' strategy to increase their market shares (Levratto & Abbes, 2008). This seems to be the case of some widely known conventional electricity suppliers that have been recently offering green electricity contracts along with their conventional ones. As a matter of fact, by the end of 2020, almost a third of the retailers present on the market were proposing both types of contracts. Moreover, during this period, 49 over the 75 electricity contracts available on the market were marketed as green ones, being one of the reasons why the French Commission of Electricity Regulation pointed out green electricity retailing as one of the main vectors behind the increasing competition observed in the retail market (CRE, 2020).

On the demand side, as environmental concern grows among the population, several empirical studies have shown that consumers are willing to pay an extra premium for eco-friendly products (Nakarado, 1996) such as those certified by an eco-label or such as green electricity (Lee & Heo, 2016; Oerlemans, Chang & Volschenk, 2016). Taking this evidence into account, recent research has focused on what we can call green market competition in general, within the vertical product differentiation theoretical framework (Brécard, 2014; André et al., 2009; Amacher et al., 2004; Arora and Gangopadhyay, 1995). This kind of models relies on two main assumptions. First, that consumers differ in their preferences for product quality and consequently, their willingness to pay for high quality products is higher than for low quality ones; second, that firms can decide to differentiate their products in order to relax price competition. Environmentally speaking, in this kind of models, green products can be seen as of higher quality compared to some widely known polluting ones.

Regarding the electricity sector specifically, as Delmas et al. (2007) pointed out, the preference for eco-friendly products might be already present among some environmentally conscious consumers regarding their electricity consumption before the market liberalisation. However, electricity producers could not take this preference into account as a strategic variable within their production program, mainly because of the industry specificities (historical price setting and organisation before liberalisation).

For the purposes of this paper and for the particular case of electricity seen as a commodity, we consider renewable electricity as just another option available to consumers in the retail market. This means that green electricity is not necessarily seen as of higher quality than the conventional one for all consumers (as it would be expected in a vertical product differentiation model), implying that some of them prefer conventional to renewable electricity.

Furthermore, we assume that consumers who buy renewable electricity and are willing to pay an extra fee for it, see themselves more as contributing to a public good and consequently, enjoying a "*warm-glow*" (Andreoni, 1990), rather than as just buying a higher quality product, environmentally speaking. The concept of "warm-glow" is commonly understood as a private benefit people enjoy when they contribute to a public good. In our case, it could be seen as the satisfaction that environmentally conscious consumers enjoy when they feel that they are doing their part against climate change by buying renewable electricity. This could be especially the case because the higher environmental quality they are contributing to is not directly appropriable for them (as would be the case when buying organic products, for instance). As explained in Kotchen and Moore, 2007 (pp.2-3) "Because increased production of green electricity (in the form of new generating capacity) implies a reduction in demand for conventional electricity, participants in green-electricity programs are responsible for a reduction in pollution emissions---a public good."

Moreover, as some empirical studies have shown, for many consumers price is not a sufficient trigger to switch from one electricity retailer to another (sticky consumers). However, they do switch when seeing a significant differentiation, as would be the case for those environmentally conscious consumers who buy renewable electricity, for instance.

On this basis, the aim of this paper is to examine whether the strategy of providing renewable electricity is profitable for firms, in the presence of environmentally conscious consumers and considering a higher marginal cost for the supply of renewable energy compared to that for the conventional one. We seek also to show how a variety of electricity tariffs could be available in the market for such a homogeneous good as electricity is. In order to do that, we introduce consumer environmental consciousness explicitly into our model.

The analysis is carried out as a two-stage game where firms choose first the environmental quality provision (whether to sell renewable or conventional electricity) and then compete in prices. In order to simplify and taking renewable electricity as just another option available to consumers in the market, we consider a duopoly model of horizontal product differentiation following the Hotelling (1929) tradition.

By taking consumer environmental consciousness into account, we find a unique Nash equilibrium for the case of maximum differentiation between firms. Regarding social welfare, by introducing the impact of the externalities resulting from the electricity provision outcome into the analysis, we found that as long as the additional cost of supplying renewable electricity remains positive, but lower than consumer environmental consciousness, this Nash equilibrium holds also for social optimum. Otherwise, when this extra cost approaches zero, it would be socially optimal to have a renewable energy only supply.

The paper is organised as follows. Section 2 introduces the assumptions of the model, which is then developed under three different scenarios in section 3. Section 4, presents the analysis of social welfare. In section 5 we discuss a possible extension of the model in the presence of a cost gap between renewable and conventional energy supply that has been recently decreasing on the market and finally, section 6 presents some conclusions.

2 Assumptions

We consider a product differentiation duopoly model following Hotelling (1929) to study the incentives of firms to propose conventional or renewable energy in the retail electricity market. We assume that consumers are heterogeneous in terms of preferences for each kind of electricity and that they are uniformly distributed in terms of degrees in the *greenness* they desire for their electricity consumption. Thus, distance here should be understood as the measure of greenness of electricity. Regarding the classic transportation cost, it should be understood as the degrees of disutility for consumers that buy an option more or less different from what they want, reflecting the strength of their preference for a particular kind of energy.

Population is normalized to unity and we suppose that the market is covered in order to better represent the reality of electricity markets. Finally, we consider that firms are located at the edges of the interval $[0, 1]$.

2.1 Consumer demand

Consumers would satisfy a need of lighting, heating or air conditioning for example, with an electric source of energy. Each consumer purchases only one unit of the good (or nothing at all) from firm i (with $i = 1,2$) depending on his environmental consciousness, on the degree of greenness preferred and, on the price paid for the energy tied or not with some environmental quality $p_i^{s_1 s_2}$ (with $s_i = \{C, R\}$, conventional or renewable electricity). Consumer net utility is then given by:

$$U = \begin{cases} v - p_i^{s_1 s_2} - t|x - x_i| + \alpha\beta x_i + \beta e \\ 0 \end{cases}$$

where v is the gross utility of electricity consumption and $t|x - x_i|$ represents the disutility related to the consumption of the less preferred option. As previously stated, we consider here a differentiation model in terms of tastes or preferences and not in terms of geographical location as in the classic Hotelling. Therefore, t denotes here the *intensity* of consumer preference for a degree of greenness in the electricity he consumes. Parameter β represents consumer environmental consciousness. We introduce α to capture either the "warm-glow" enjoyed from contributing to the protection of the environment (where $\alpha = 1$ if a conscious consumer buys renewable energy), either a sort of a "negative warm-glow effect", to be understood as the disutility that environmentally conscious consumers experience when they cannot buy their renewable preferred option (then $\alpha = -1$ in this case). In order to simplify the analysis regarding these "warm-glow effects", we consider that consumer environmental consciousness is perfectly correlated to the preference for renewable electricity. Finally, $e \in [-1,1]$ refers to an externality that can be positive as an improvement of environment (less GHG emissions in our case, conservation of bio-diversity, etc.) or it can be negative as an environmental damage (pollution, bio-diversity loss, species extinction...).

2.2 Firms' strategy

We consider a product differentiation duopoly model *à la* Hotelling in a two-stage game. At the first stage, firms choose whether to supply conventional or renewable energy tied with an environmental public good, and at the second stage, they compete in prices.

Regarding marginal costs, we assume that it is costly to provide renewable energy compared to the conventional energy supply, *i.e.* $c_C = c$ and $c_R = c + h$. The externality outcome depends on firms' strategy:

i. If both firms provide conventional energy, the environmental damage is maximum then $e = -1$.
ii. If both firms supply renewable energy, there is a positive externality on the

environment, therefore $e = 1$.

iii. If one firm supplies conventional energy and the other one supplies green energy, $e =]-1{,}1[$, its sign depending on the kind of energy (green or conventional) having the largest market share at the equilibrium.

3 The model

3.1 The benchmark: conventional energy only supply

To study the incentive for product differentiation for firms, we analyse first the benchmark situation. Our benchmark corresponds to the case where there is no differentiation between firms and only conventional electricity is provided. The consumer who is indifferent between buying electricity from firm 1 or from firm 2, is defined by:

$$v - p_1^{CC} - t\bar{x} + \beta e = v - p_2^{CC} - t(1-\bar{x}) - \alpha\beta\bar{x} + \beta e$$

$$\bar{x} = \frac{-p_1^{CC} + p_2^{CC} + t}{2t - \beta}$$

With both firms providing conventional energy, the environmental damage is maximum, so $e = -1$ and as any renewable option is available for those environmentally conscious consumers on the market preferring this variant, $\alpha = -1$ so we can capture the "negative warm-glow effect" for them. Since population is normalized to unity and the market is covered, we can deduce the demand functions as:

$$Q_1^{CC} = \bar{x} - 0 = \frac{-p_1^{CC} + p_2^{CC} + t}{2t - \beta} \quad \text{and}$$

$$Q_2^{CC} = 1 - \bar{x} = \frac{p_1^{CC} - p_2^{CC} + t - \beta}{2t - \beta}.$$

As we can see, demand for firm 2 located at 1, will be negatively affected by the consumer environmental consciousness of that portion of conscious consumers who expected to buy renewable energy.

Firms only care about their expected profits, and seek to maximize their price minus their constant marginal cost, taking the price of the other as given. Thereby, firms' profits can be rewritten as:

$$\underset{p_i^{CC}}{Max}\,\Pi_i^{CC} = (p_i^{CC} - c).Q_i^{CC} \quad \text{with } i = 1{,}2$$

Solving the maximization program for Nash Equilibrium, we find:

$$p_1^{CC} = t + c - \frac{1}{3}\beta;$$

$$p_2^{CC} = t + c - \frac{2}{3}\beta.$$

In the presence of environmentally conscious consumers who prefer renewable energy, a conventional energy supplier located next to them should fix a lower tariff compared to that of its competitor (who serve consumers preferring conventional energy), in order to capture a share of the market. Knowing that, firms share the market with the respective demands:

$$D_1^{CC} = \frac{1}{3}\frac{3t - \beta}{2t - \beta};$$

$$D_2^{CC} = \frac{1}{3}\frac{3t - 2\beta}{2t - \beta}.$$

And the equilibrium profits are:

$$\Pi_1^{CC} = \frac{1}{9}\frac{(3t - \beta)^2}{2t - \beta};$$

$$\Pi_2^{CC} = \frac{1}{9}\frac{(3t - 2\beta)^2}{2t - \beta}.$$

Firms' profits depend on t, the *intensity* of consumers preferences as well as on consumer environmental awareness, β.

Proposition 1 *Consumer environmental awareness has a negative impact on equilibrium prices and profits, in the presence of environmentally conscious consumers when any renewable energy option is available in the retail market.*

In this scenario, because of consumer environmental awareness β, both prices and profits are reduced compared to those from the classic Hotelling. This fact could be understood as a shortfall for firms who do not take advantage of the higher willingness to pay of those environmentally conscious consumers present in the market.

3.2 Renewable energy only supply

For the case where both firms choose to provide renewable energy, $\alpha = 1$ so the portion of environmentally conscious consumers who prefer renewable energy enjoy a *warm-glow* effect when buying it. In addition, with only renewable energy supply, all consumers benefit from the positive externality on the environment, so $e = 1$. The indifferent consumer between buying from firm 1 or firm 2 is then defined as:

$$v - p_1^{RR} - t\tilde{x} + \beta e = v - p_2^{RR} - t(1 - \tilde{x}) + \alpha\beta\tilde{x} + \beta e$$

$$\tilde{x} = \frac{-p_1^{RR} + p_2^{RR} + t}{2t + \beta}$$

And corresponding demands are given by:

$$Q_1^{RR} = \tilde{x} - 0 = \frac{-p_1^{RR} + p_2^{RR} + t}{2t + \beta}; \quad \text{and}$$

$$Q_2^{RR} = 1 - \tilde{x} = \frac{p_1^{RR} - p_2^{RR} + t + \beta}{2t + \beta}.$$

In this case, both firms support the additional cost of renewable energy supply, h, compared to the conventional only case, so $c_R = c + h$. This h should be understood as the costs to retailers resulting from the purchase of guarantees of origin associated with renewable power generation. We can then write firms' expected profits as:

$$\underset{p_i^{RR}}{Max} \Pi_i^{RR} = (p_i^{RR} - c - h).Q_i^{RR} \quad \text{with } i = 1{,}2$$

The result of the maximization program for Nash Equilibrium is given by:

$$p_1^{RR} = t + c + h + \frac{1}{3}\beta;$$

$$p_2^{RR} = t + c + h + \frac{2}{3}\beta.$$

Equilibrium prices depend not only on the marginal costs and on the disutility of not consuming the preferred variant, but depend also on consumer environmental awareness. In this case, firm 2 supplying renewable electricity and located next to the portion of the environmentally conscious consumers, benefits from this fact by fixing a higher price than firm 1.

Since the market is covered and equal to 1, the equilibrium demands are given by:

$$D_1^{RR} = \frac{1}{3}\frac{3t + \beta}{2t + \beta};$$

$$D_2^{RR} = \frac{1}{3}\frac{3t + 2\beta}{2t + \beta}.$$

Despite its higher price compared to firm's 1, consumers environmental awareness allows firm 2 to capture a larger market share than its competitor.

The corresponding profits are:

$$\Pi_1^{RR} = \frac{1}{9}\frac{(3t + \beta)^2}{2t + \beta};$$

$$\Pi_2^{RR} = \frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta}.$$

Proposition 2 *Consumer environmental awareness raises the equilibrium prices* $\{p_1^{*RR}, p_2^{*RR}\}$ *when both firms supply renewable energy compared to those when only conventional energy is provided on the market. These premium prices lead to a higher level of profits.*

Taking consumer environmental awareness into account allow firms to fix a premium price for the good, leading to higher equilibrium profits compared to those from the conventional energy only case. We can then expect higher profits for higher levels of consumer environmental awareness.

3.3 Asymmetric scenario: the energy mix supply

The asymmetric scenario corresponds to the case where one firm provides conventional energy while the other supplies renewable energy. As for the previous case, we specify $\alpha = 1$ so we can add the warm-glow effect term concerning only the portion of consumers who prefer and buy green energy. Regarding the externality parameter e, as we stated before, its value depends on the market share of each kind of energy (green or conventional) at the equilibrium, its sign is thus still unknow. We define here firm 1 as the *conventional supplier* and firm 2 as the *renewable* one. The consumer who is indifferent between buying from firm 1 or firm 2 is defined by:

$$v - p_1^{CR} - t\ \hat{x} + \beta e = v - p_2^{CR} - t\ (1-\hat{x}) + \alpha\beta\hat{x} + \beta e$$

$$\hat{x} = \frac{-p_1^{CR} + p_2^{CR} + t}{2t+\beta}$$

We can then deduce the corresponding demands:

$$Q_1^{CR} = \hat{x} - 0 = \frac{-p_1^{CR} + p_2^{CR} + t}{2t + \beta}; \quad \text{and}$$

$$Q_2^{CR} = 1 - \hat{x} = \frac{p_1^{CR} - p_2^{CR} + t + \beta}{2t + \beta}.$$

For this asymmetric scenario, only firm 2 supports the additional cost of the renewable energy provision. Thereby, firms' expected profits are:

$$\underset{p_1^{CR}}{Max}\Pi_1^{CR} = (p_1^{CR} - c).Q_1^{CR} \quad \text{and} \quad \underset{p_2^{CR}}{Max}\Pi_2^{CR} = (p_2^{CR} - c - h).Q_2^{CR}$$

Solving the maximization program for Nash Equilibrium, firms' equilibrium prices are given by:

$$p_1^{CR} = t + c + \frac{1}{3}\beta + \frac{1}{3}h;$$

$$p_2^{CR} = t + c + \frac{2}{3}\beta + \frac{2}{3}h.$$

We see here that firm 2 (*the renewable supplier*) benefits from consumer environmental awareness and from the extra-cost of renewable energy supply, both raising its equilibrium price. However, as firm 2 does not benefit by the entire amount of both elements, it creates a possibility for firm 1 (*the conventional supplier*) to increase its price as well, but not as much as firm 2 does it.

Equilibrium demands and profits are:

$$D_1^{CR} = \frac{1}{3}\frac{3t + \beta + h}{2t + \beta};$$

$$D_2^{CR} = \frac{1}{3}\frac{3t + 2\beta - h}{2t + \beta}.$$

$$\Pi_1^{CR} = \frac{1}{9}\frac{(3t+\beta+h)^2}{2t+\beta};$$

$$\Pi_2^{CR} = \frac{1}{9}\frac{(-3t-2\beta+h)^2}{2t+\beta}.$$

For the purposes of this paper, we assume $h < \beta$. This, in a context of a price gap between conventional and renewable electricity that has been decreasing over the last few years whereas environmental awareness continues to spread and intensify among consumers. Following this assumption, we conclude first, that taking consumer environmental consciousness into account allow firm 2 to make a higher profit that firm 1 even if the latter benefits also from consumer consciousness. Second, that demand for renewable energy is higher than demand for the conventional one, so we can expect a positive externality on the environment and therefore $e =]0,1[$.

3.4 Outcomes

The Nash equilibrium profits from our three cases[1] are displayed in table 1:

Firm 2

Firm 1		C	R
	C	$\left(\frac{1}{9}\frac{(3t-\beta)^2}{2t-\beta}\ ;\ \frac{1}{9}\frac{(3t-2\beta)^2}{2t-\beta}\right)$	$\left(\frac{1}{9}\frac{(3t+\beta+h)^2}{2t+\beta};\frac{1}{9}\frac{(-3t-2\beta+h)^2}{2t+\beta}\right)$
	R	$\left(\frac{1}{9}\frac{(-3t-2\beta+h)^2}{2t+\beta};\frac{1}{9}\frac{(3t+\beta+h)^2}{2t+\beta}\right)$	$\left(\frac{1}{9}\frac{(3t+\beta)^2}{2t+\beta}\ ;\ \frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta}\right)$

Table 1. Nash Equilibrium Profits

Proposition 3 *In a covered market, the outcome depends on the value of consumer*

[1] Proofs of Proposition 3 are in the Appendix.

environmental awareness as well as on the additional cost of renewable energy supply. After comparing the three different scenarios, a unique Nash equilibrium is found and corresponds to the case of maximum differentiation between firms. Precisely, when firm 1 (located at 0) supplies conventional energy and firm 2 (located at 1) supplies the renewable variant $s_1^*, s_2^* = \{C, R\}$. *Additionally, we can note that as long as* $h < \beta$, *choosing to supply renewable energy is a strictly dominant strategy for firm 2.*

We can also show that this strategy profile $s_1^*, s_2^* = \{C, R\}$ remains the only Nash equilibrium even if $h > \beta$. In this case, however, firm 2 would have no longer a strictly dominant strategy and being a conventional energy supplier would become the strictly dominant strategy for firm 1.

We conclude that, when consumers care for the environment and firms take this environmental consciousness into account within their profit maximization program, differentiation is in fact the more profitable strategy for firms.

4 Welfare analysis and social optimum

In this section we aim to identify among our previous scenarios, the one that maximizes social welfare and to analyse how social welfare is affected by environmental awareness and the externality on the environment. First, we define social welfare as the sum of consumer surplus (which includes here the environmental externality) and firms' profits:

$$W = CS^{s_1 s_2}(\beta, e) + \sum_{i=1}^{2} \Pi_i^{s_1 s_2} \quad \text{with } s_i = \{C, R\} \text{ and } i = \{1,2\}$$

We then calculate it for each one of the three scenarios previously developed[2].

For our first case, the *conventional energy only supply*, social welfare can be rewritten as:

$$W^{CC} = \int_0^{D_1^{CC}} (v - p_1^{CC} - t\bar{x} + \beta e)dx + \int_{D_1^{CC}}^{1} (v - p_2^{CC} - t(1 - \bar{x}) - \alpha\beta x_i + \beta e)dx + \sum_{i=1}^{2} \Pi_i^{CC}$$

As we stated before, for this case, where both firms provide conventional energy, $\alpha = -1$ in order to represent the *negative warm-glow* effect experienced by those conscious consumers who cannot buy their green energy preferred variant. In addition, the externality on the environment is at its maximum negative value $e = -1$. We solve first for welfare and then we replace e by its value.

Proposition 4 *When both firms provide conventional energy, the negative externality on the environment is maximum and as any renewable energy option is available for the portion of environmentally conscious consumers, increases of environmental awareness entail a welfare reduction.*

For our second case, the *renewable energy only supply*, social welfare can be rewritten as:

$$W^{RR} = \int_0^{D_1^{RR}} (v - p_1^{RR} - t\tilde{x} + \beta e)dx + \int_{D_1^{RR}}^{1} (v - p_2^{RR} - t(1 - \tilde{x}) + \alpha\beta x_i + \beta e)dx + \sum_{i=1}^{2} \Pi_i^{RR}$$

Again, as previously stated, when both firms provide renewable energy, the externality on the environment is at its maximum positive value $e = 1$. Once more, we solve first for welfare and then we replace e by its value. Furthermore, even if all consumers buy

[2]Proofs of Propositions are in the Appendix.

renewable energy, only those environmentally conscious benefit from the warm-glow effect of their purchase ($\alpha = 1$).

Proposition 5 *When both firms provide renewable energy, as the positive externality on the environment is maximum, environmental consciousness* β*, has a global positive impact on social welfare. Increases of* β *raise welfare despite the additional cost of renewable energy supply and the higher prices paid by consumers, compared to the conventional energy only supply case.*

Comparing our two symmetric scenarios, we can state that the positive effect of the externality on the environment plus the warm-glow effect of environmentally conscious consumers allow for social welfare of the renewable energy only scenario to be greater than the one of the conventional energy only case.

For the asymmetric scenario where firm 1 is the conventional energy supplier and firm 2 the renewable energy one, as indicated before, the value of parameter e depends on the type of energy (conventional or renewable) with the largest market share at the equilibrium. To evaluate this, we have compared both firms' demands in the asymmetric scenario section. Following the assumption that $h < \beta$ and more precisely, $h < \beta/2$, we found that demand for renewable energy is higher[3] than demand for the conventional one, thus we can expect a positive externality on the environment and therefore $e =]0{,}1[$. We introduce this positive effect explicitly into the social welfare function, so it can be rewritten as:

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[3]The difference in demands comparison is given by: $Q_1^{*CR} - Q_2^{*CR} = \frac{1}{3}\frac{-\beta+2h}{2t+\beta} < 0$.

$$W^{CR} = \int_0^{D_1^{CR}} (v - p_1^{CR} - t\hat{x} + \beta e)dx + \int_{D_1^{CR}}^1 (v - p_2^{CR} - t(1-\hat{x}) + \alpha\beta x_i + \beta e)dx + \Pi_1^{CR} + \Pi_2^{CR}$$

When comparing the different welfare outcomes characterized above, we found that:

Proposition 6 *Under the assumption that* $h < \beta$ *and that the externality on the environment for the asymmetric case is positive, i.e.* $e =]0{,}1[$, *then* $W^{CR} > W^{RR} > W^{CC}$. *In other words, as long as the additional cost of renewable energy supply remains small compared to consumer environmental consciousness, social welfare will be maximized when only firm 2 provides renewable energy. This is mainly explained because of the lower prices paid by consumers in the energy mix scenario compared to those paid in the renewable energy only one.*

We can note however, that the difference between W^{CR} and W^{RR} is barely positive and lying basically on the additional cost of renewable energy supply h. This implies that, the more this additional cost decrease, the more the difference between the welfare outcomes will decrease as well. Therefore, if h is sufficiently small, we could then expect W^{RR} to overtake W^{CR}. At that point, because of a larger positive externality on the environment, it will be socially optimal to have a renewable energy only supply.

Finally, even if the conventional energy only scenario remains the cheaper one for consumers, it does not compensate the negative effect of the externality on the environment, neither the "negative warm-glow" effect.

5 Model extension and discussion

Following our conclusions regarding social optimum, in this section we analyse how the unique Nash equilibrium found in section 3 could be modified under the assumption of an additional cost of renewable energy supply that approaches zero. We recalculate then the equilibria of our three previous scenarios by replacing h by zero. In doing so, we seek to determine whether, by removing this additional cost, the provision of renewable energy would become a dominant strategy for firms and therefore, we could expect the renewable energy only supply as the equilibrium scenario. Recalculated profits under this assumption are summarized in table 2:

Firm 2

Firm 1		C	R
	C	$\left(\frac{1}{9}\frac{(3t-\beta)^2}{2t-\beta}\ ;\ \frac{1}{9}\frac{(3t-2\beta)^2}{2t-\beta}\right)$	$\left(\frac{1}{9}\frac{(3t+\beta)^2}{2t+\beta};\frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta}\right)$
	R	$\left(\frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta};\frac{1}{9}\frac{(3t+\beta)^2}{2t+\beta}\right)$	$\left(\frac{1}{9}\frac{(3t+\beta)^2}{2t+\beta}\ ;\ \frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta}\right)$

Table 2. Nash Equilibrium Profits when h=0

From table 2 we conclude that, being a renewable energy retailer is still a strictly dominant strategy for firm 2. However, as long as firm 2 supplies renewable energy, firm 1 will be indifferent between conventional or renewable energy supply. Thus, two Nash equilibria are found for this variant of the game, one corresponding still to a asymmetric scenario where firm 1 is the conventional energy retailer and firm 2 is the renewable energy one ($s_1^*, s_2^* = \{C, R\}$) and the other one corresponding to the renewable energy only supply scenario ($s_1^*, s_2^* = \{R, R\}$), where both firms are renewable energy retailers. We can then conclude that, to tackle the additional cost of renewable energy supply h, will not be sufficient to assure that the renewable energy only supply case emerge as the equilibrium scenario.

So far, we have shown how a maximum differentiation represents the best strategy for electricity retailers in the presence of environmentally conscious consumers and considering a cost gap between conventional and renewable energy supply. We have also demonstrated that, even if this cost gap approaches zero, we cannot guarantee that a renewable energy only market will emerge. So, how could we explain a retail electricity market that seems to become greener nowadays? Indeed, as we indicated in the introduction, according to the CRE reports, by the end of 2020, 49 over the 75 electricity tariffs available in the market were marketed as green contracts. Furthermore, almost a third of the retailers were offering both conventional and renewable electricity contracts for consumers.

In this context and in order to better represent the observed reality of the retail electricity market, we tried to adapt our model to allow for the conventional retailer to become greener (providing green electricity contracts along with his conventional ones, for instance) by moving towards the renewable energy supplier in the greenness scale $[0,1]$. However, because of the model construction, allowing firm 1 to move towards the greenest side of the interval implies that firm 2 should be also allowed to move towards firm 1 in order to keep its market share, otherwise, firm 1 becomes the *only winner* of this game. Mathematically, we could do that and then find a unique Nash equilibrium where both firms choose to locate towards the centre of the scale. Nevertheless, what we currently observe in the market is that only some conventional retailers are moving towards the greener side (by offering renewable contracts), while the renewable energy ones remain on the greener end of the scale. That would mean that they do not need to move towards the left of the scale in order to keep their market shares. This statement could be read as a growing share of environmentally conscious consumers present on the market, preferring renewable energy over the conventional one. Such hypothesis is currently being formalized so our model could also represent this greening effect observed in the retail market.

6 Conclusion

In this paper, we have focused on how consumer environmental consciousness as well as a higher marginal cost related to renewable energy supply could determine a strategic opportunity for retailers to differentiate their electricity provision. We have shown that, when at least one firm supplies renewable energy, both firms benefit from consumer environmental consciousness in the form of higher prices and consequently higher profits compared to the conventional energy only supply scenario. Moreover, we have shown that as long as the additional cost of renewable energy supply remains small and lower than consumer environmental consciousness, a maximum differentiation would be the more profitable strategy for firms. More precisely, the firm who is the closest to the portion of environmentally conscious consumers in the market, firm 2 in our model, should supply renewable energy (following its strictly dominant strategy) while the other one should focus on conventional energy supply.

Furthermore, by taking the externalities on the environment (resulting from the electricity provision outcome) into account, we have analysed social welfare seeking to identify which of our three studied cases represented the better social optimum. We found that, as long as the additional cost of supplying renewable energy remains positive, but lower than consumers environmental consciousness, the maximum differentiation equilibrium scenario with firm 2 as the renewable energy retailer and firm 1 as the conventional energy one will emerge as the social optimum as well. Nevertheless, if this additional cost is sufficiently small, we could expect welfare from the renewable energy only case to become social optimum. In other words, because of a larger positive externality on the environment, without the burden of this additional cost over consumers, it would be socially optimal to have a renewable energy only supply.

Moreover, and following the last intuition regarding the additional cost of renewable energy supply, we have studied whether its maximum reduction could lead or not to the renewable energy only supply as the equilibrium scenario (and also social optimum). This, in a context of a price gap between both kinds of energy that has been decreasing over the last few years. We have then shown that even by completely removing this cost from the maximization program of firms, the renewable energy only scenario cannot be guaranteed at equilibrium, as one of the firms remains indifferent between both types of energy supply. Despite this, as two Nash equilibria result from this case, including the renewable energy only one, we could see this cost decreasing as one of the vectors behind the choice of some firms to enter the market as green retailers when some other green ones are already present.

Finally, further research should explore how a growing share of environmentally conscious consumers present on the market could explain the *greening* behaviour of some conventional retailers that have been recently offering green tariffs along with their conventional ones (namely becoming hybrid retailers), while renewable energy retailers remain on the greener edge of the scale. This might shed light on the conditions needed to achieve the renewable energy only supply as the unique equilibrium scenario.

7 References

Amacher, G., Koskela, E. and Ollikainen, M. (2004) "Environmental Quality Competition and Eco-labeling", *Journal of Environmental Economics and Management*, 47, 284-306.

Andreoni, J. (1990) "Impure Altruism and Donations to the Public Good: A Theory of Warm-glow Giving", *The Economic Journal*, 100, 464-477.

André, F., Gonzalès, P. and Porteiro, N. (2009) "Strategic Quality Competition and the Porter Hypothesis", *Journal of Environmental Economics and Management*, 57, 182-194.

Arora, S. and Gangopadhyay, S. (1995) "Toward a theoretical model of voluntary overcompliance", *Journal of Economic Behavior and Organization,* 28, 289--309.

Brécard, D. (2014) "Consumer Confusion over the Profusion of Eco-labels: Lesson from a double Differentiation Model", *Environmental and Resource Economics*, 37, 64-84.

Commission de régulation de l'énergie (2020) "Rapport 2018-2019. Le fonctionnement des marchés de détail français de l'électricité et du gaz naturel", available at *https://www.cre.fr/Documents/Publications/Rapports-thematiques/le-fonctionnement-des-marches-de-detail-francais-de-l-electricite-et-du-gaz-naturel-rapport-2018-2019*

Commission de régulation de l'énergie - Observatoire des marchés de détail 2007 - 2020, all reports available at *https://www.cre.fr/Documents*

Conrad, K. (2005) "Price Competition and Product Differentiation When Consumers Care for the Environment", *Environmental and Resource Economics*, 31, 1-19.

Delmas M., Russo, M. and Montes-Sancho, M. (2007) "Deregulation and Environmental Differentiation in the electric utility industry", *Strategic Management Journal*, 28, 189-209.

Eriksson, C. (2004) "Can Green Consumerism Replace Environmental Regulation? --- A Differentiated-Products Example", *Resource and Energy Economics*, 26, 281-293.

Hotelling, H. (1929) "Stability in Competition", *The Economic Journal,* 39, 41-57.

Kotchen, M. and Moore, M. (2007) "Private Provision of Environmental Public Goods: Household Participation in Green-electricity Programs", *Journal of Environmental Economics and Management*, 53, 1-16.

Lee, C-Y, and Heo, H. (2016) "Estimating Willingness to Pay for Renewable Energy in South Korea using the contingent valuation method", *Energy Policy*, 94, 150-156.

Levratto, N. and Abbes, N. (2008) "À qui profitent les certificats verts en France : à l'environnement ou aux fournisseurs d'électricité ?", *Revue de l'Organisation Responsable*, 2 (3), 4-18.

Nakarado, G. (1996) "A Marketing Orientation is the key to a Sustainable Energy Future", *Energy Policy*, 24 (2), 187-193.

Oerlemans, L., Chang, K-Y and Volschenk, J. (2016) "Willingness to Pay for Green Electricity: A Review of the Contingent Valuation Literature and its Sources of Error", *Renewable and Sustainable Energy Review*, 66, 875-885.

8 Appendix

8.1 Proof of Proposition 3

Profits' comparison for firm 1 with:

a) firm 2 as a conventional energy retailer:

$$\Pi_1^{CC} - \Pi_1^{RC} = -\frac{1}{9}\frac{18t^2\beta - 5\beta^3 - 12t^2h - 2th\beta + 4\beta^2h + 2h^2t - h^2\beta}{4t^2 - \beta^2} \lesseqgtr 0$$

This term can be positive or negative depending on the value of β and h. If $\beta > h$, then $\Pi_1^{CC} < \Pi_1^{RC}$.

b) firm 2 as a renewable energy retailer:

$$\Pi_1^{CR} - \Pi_1^{RR} = \frac{1}{9}\frac{h(6t + 2\beta + h)}{2t + \beta} > 0$$

Here, $\Pi_1^{CR} > \Pi_1^{RR}$, without any condition on β and h.

Profits' comparison for firm 2 with:

a) firm 1 as a conventional retailer:

$$\Pi_2^{CC} - \Pi_2^{CR} = -\frac{1}{9}\frac{30t^2\beta - 8\beta^3 - 12t^2h - 2th\beta + 4\beta^2h + 2h^2t - h^2\beta}{4t^2 - \beta^2} \lesseqgtr 0$$

This term can be positive or negative depending on the value of β and h. If $\beta > h$, then

$\Pi_2^{CC} < \Pi_2^{CR}$.

b) firm 1 as a renewable energy retailer:

$$\Pi_2^{RC} - \Pi_2^{RR} = \frac{1}{9}\frac{-6t\beta + 6th - 3\beta^2 + 2\beta h + h^2}{2t + \beta} \lesseqgtr 0$$

As for the previous case, this term can be positive or negative depending on the value of β and h. If $\beta > h$, then $\Pi_2^{RC} < \Pi_2^{RR}$. Being a renewable energy retailer is then a strictly dominant strategy for firm 2.

8.2 Proof of Welfare Analysis

Proof of Proposition 4:

$$W^{CC} = -\frac{1}{18}\frac{9t^2 - 36t\beta e - 36tv + 9t\beta + 36tc + 18\beta^2 e + 18v\beta - 8\beta^2 - 18c\beta}{2t - \beta}$$

$$\frac{\partial W^{CC}}{\partial \beta} = \frac{1}{18}\frac{-99t^2 + 104t\beta - 26\beta^2}{(2t - \beta)^2}$$

In this case, the negative externality on the environment is maximum, therefore $e = -1$. So, increases in consumer environmental consciousness entails welfare reductions.

Note that consumer's surplus can be written as:

$$CS^{CC} = -\frac{1}{18}\frac{45t^2 - 36t\beta e - 36tv - 27t\beta + 36tc + 18v\beta + 18\beta^2 e + 2\beta^2 - 18c\beta}{2t - \beta}$$

Proof of Proposition 5:

$$W^{RR} = -\frac{1}{18}\frac{9t^2 + 36th - 36tv - 36t\beta e + 36tc - 9t\beta + 18h\beta - 18\beta^2 e - 18v\beta - 8\beta^2 + 18c\beta}{2t + \beta}$$

$$\frac{\partial W^{RR}}{\partial \beta} = \frac{1}{18}\frac{99t^2 + 104t\beta + 26\beta^2}{(2t + \beta)^2}$$

Here, the positive externality on the environment is maximum, therefore $e = 1$. So, increases in consumer environmental consciousness increases welfare.

Note that consumer's surplus can be written as:

$$CS^{RR} = -\frac{1}{18}\frac{45t^2 + 36th - 36tv - 36t\beta e + 36tc + 27t\beta + 18h\beta - 18\beta^2 e - 18v\beta + 2\beta^2 + 18c\beta}{2t + \beta}$$

The optimal welfare with firm 1 as the conventional energy retailer and firm 2 as the renewable energy one is given by:

$$W^{CR} = -\frac{1}{18}\frac{9t^2 - 36tv + 18th + 36tc - 9t\beta - 36t\beta e - 5h^2 - 18\beta^2 e - 18v\beta + 14h\beta - 8\beta^2 + 18c\beta}{2t + \beta}$$

As indicated before, demand for renewable energy is higher than for conventional in this case, so $e =]0,1[$.

Consumers' surplus is:

$$CS^{CR} = -\frac{1}{18}\frac{45t^2 - 36tv + 18th + 36tc + 27t\beta - 36t\beta e - h^2 - 18\beta^2 e - 18v\beta + 10h\beta + 2\beta^2 + 18c\beta}{2t + \beta}$$

Proof of Proposition 6:

$$W^{CR} - W^{RR} = \frac{1}{18}\frac{18th - 36t\beta + 36t\beta e + 5h^2 + 18\beta^2 e + 4h\beta - 18\beta^2}{2t + \beta}$$

$$W^{RR} - W^{CC} = -\frac{1}{9}\frac{-99t^2\beta + 36ht^2 + 26\beta^3 - 9h\beta^2}{4t^2 - \beta}$$

We can conclude that:

$$W^{CR} > W^{RR} > W^{CC} \quad \text{when } h < \beta$$