FONDATION UPVD

Université de Perpignan Via Domitia

Research chair on renewable energy by La Caisse d'Epargne Languedoc Roussillon

ENVIRONMENTAL QUALITY COMPETITION: THE CASE OF THE FRENCH RETAIL ELECTRICITY MARKET

Sandra MORENO* Marion PODESTA†

*†ART-Dev, University of Perpignan, France

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1. Context

Liberalisation of the energy markets → French retail electricity market fully operational since 2007.

European climate and energy targets aiming to increase the share of electricity from renewable energy sources (RES) in gross electricity consumption.

→

Renewable electricity retailers entering the market, despite the higher cost of renewables (4 in 2007 vs 17 in 2020).

Greening up of some well-known conventional retailers: offering now green electricity contracts alongside their conventional ones.

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Increasing number of green contracts offered on the market (49 out of 75 in 2020).

Green electricity retailing is seen as one of the main vectors for the increased competition on the retail market (CRE, 2020).

2. Theoretical framework

Growing environmental concern →

- Higher willingness to pay (WTP) for environmentally friendly products: eco-engaged French consumers pay **up to 44% more** for this kind of goods (CGDD 2017).

Taking consumers' environmental awareness into account

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Green market competition studies:

- Going green seen as a firms' strategy to increase their profits and market shares (Cairncross, 1999 ; Levratto & Abbes, 2008).
- Mainly in the theoretical framework of vertical product differentiation (Brécard, 2014; André et al., 2009; Amacher et al., 2004; Arora and Gangopadhyay, 1995), where:
  - Consumers differ in terms of their preferences for product quality → willing to pay more for high quality products
  - Firms can choose to differentiate their products in order to relax price competition

2. Theoretical framework

With regard to electricity:

- Preference for *eco-friendly* electricity may have existed prior to liberalisation of the market, but was not taken into account because of the industry's specificities: historical price setting and organisation (Delmas et al., 2007).

- As electricity cannot be physically differentiated on the grid, consumers do not benefit directly from the higher environmental quality they are contributing to, unlike buying organic products. However, they are willing to pay a premium for electricity generated with renewable energy (Lee & Heo, 2016 ; Oerlemans et al., 2016).

- Consumers buying renewable electricity see themselves as contributing to a public good → enjoy a *warm-glow* (Andreoni, 1990) from their purchase.*(Kotchen and Moore, 2007).

- Sticky consumers: price alone may not suffice to induce consumers to switch electricity retailers. But, some environmentally-conscious consumers do switch, seeing renewable electricity as a significant differentiation among retailers.

3. Main issue

- To examine whether the strategy of providing renewable electricity is profitable for firms, given that some consumers are environmentally conscious and considering a higher marginal cost of supplying renewable electricity.

- To study social welfare outcomes: Do a renewable energy only scenario corresponds to the social optimum?

- To discuss an extension of the model considering a decreasing cost gap between the renewable and conventional energy supply.

4. Assumptions

- Consumers' environmental consciousness is explicitly taken into account in our analysis.
- Renewable electricity is considered as just another option available to consumers on the retail market → not all consumers consider that green electricity is of higher quality than conventional electricity.

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Duopoly model of horizontal product differentiation (Hotelling, 1929).

- Consumers are heterogeneous, in terms of their preference for different kinds of electricity, and uniformly distributed in terms of the level of greenness they want for their electricity consumption.
- Distance and transportation cost.*
- Population is normalised to unity and the market is covered.
- Firms are located at the edges of the interval [0,1].

5. The model

- Each consumer purchases only one unit of the good (or nothing at all) depending on:
    - their environmental consciousness
    - the degree of greenness preferred
    - the price paid for the electricity, which may or may not be tied to some good environmental quality.

Consumer net utility is then given by:

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

$\boldsymbol{v}$: gross utility

$\boldsymbol{t|x - x_i|}$: disutility related to consumption of the less preferred option*

$\boldsymbol{\beta}$: consumer environmental consciousness

$\boldsymbol{\alpha}$: captures the warm-glow effect*

- $\boldsymbol{\alpha = 1}$ when a conscious consumer buys renewable energy
- $\boldsymbol{\alpha = -1}$ when a conscious consumer cannot buy its preferred green option

$\boldsymbol{e \in [-1\ ,\ 1]}$: environmental externality that can be positive (less GHG emissions) or negative (pollution)

5. The model

A two-stage game

- 1st stage: firms choose whether to supply **conventional** or **renewable** electricity
- 2nd stage: price competition, $p_1^{s_1 s_2}$ vs $p_2^{s_1 s_2}$ with $\{s_1, s_2 = C, R\}$

Renewable electricity supply is considered to be more expensive than supplying conventional electricity:

$$\mathbf{C_C = c} \quad \text{and} \quad \boldsymbol{C_R = c + h}$$

The externality outcome depends on firms' strategy:

- $\boldsymbol{e = -1}$ If both firms provide conventional electricity
- $\boldsymbol{e = 1}$ If both firms supply renewable electricity
- $\boldsymbol{e \in \,]-1,1[}$ If one firm supplies conventional and the other renewable electricity*

6. Outcomes

CONVENTIONAL ONLY SUPPLY

Profit maximisation program:

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

Equilibrium prices and profits:

$$p_1^{CC} = t + c - \frac{1}{3}\beta; \quad p_2^{CC} = t + c - \frac{2}{3}\beta.$$

$$\Pi_1^{CC} = \frac{1}{9}\frac{(3t-\beta)^2}{2t-\beta}; \quad \Pi_2^{CC} = \frac{1}{9}\frac{(3t-2\beta)^2}{2t-\beta}.$$

Proposition 1: Consumers' environmental awareness β has a negative impact on equilibrium prices and profits when environmentally-conscious consumers do not have the option to buy green electricity on the retail market.
Lower than classic Hotelling's -> shortfall for retailers.

RENEWABLE ONLY SUPPLY

Profit maximisation program:

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

Equilibrium prices and profits:

$$p_1^{RR} = t + c + h + \frac{1}{3}\beta; \quad p_2^{RR} = t + c + h + \frac{2}{3}\beta.$$

$$\Pi_1^{RR} = \frac{1}{9}\frac{(3t+\beta)^2}{2t+\beta}; \quad \Pi_2^{RR} = \frac{1}{9}\frac{(3t+2\beta)^2}{2t+\beta}.$$

Proposition 2: Consumers' environmental awareness raises equilibrium prices and profits when both firms supply renewable electricity.
Higher profits can be expected when there is greater consumers' environmental awareness.

6. Outcomes

ENERGY MIX SUPPLY

Maximisation program:

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

Equilibrium prices and profits:

$$p_1^{CR} = t + c + \frac{1}{3}\beta + \frac{1}{3}h; \quad p_2^{CR} = t + c + \frac{2}{3}\beta + \frac{2}{3}h.$$

$$\Pi_1^{CR} = \frac{1}{9}\frac{(3t+\beta+h)^2}{2t+\beta}; \quad \Pi_2^{CR} = \frac{1}{9}\frac{(-3t-2\beta+h)^2}{2t+\beta}.$$

Firm 2 benefits from consumers' environmental awareness and the extra cost of the renewable supply, both raising their price and profits. Firm 1 benefits as well but not as much as firm 2.
Demand for green electricity is higher, so a positive environmental externality is expected.

NASH EQUILIBRIUM

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 consumers' environmental awareness β and the extra cost of the renewable electricity supply *h*. Among our scenarios, a unique Nash equilibrium is found for the case of maximum differentiation between firms. In addition, as long as *h*<β, choosing to supply renewable electricity is firm 2's strictly dominant strategy.*

7. Welfare analysis and social optimum

Aims to identify which of our scenarios maximises social welfare and how it is affected by consumers' environmental awareness and the environmental externality.

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

- **Conventional only supply:** *e=-1*. As no renewable energy option is available for environmentally-conscious consumers, increased environmental awareness generates a reduction in welfare.
- **Renewable only supply:** *e=1.* Increases of consumers' environmental awareness raise welfare, despite the extra cost of supplying renewable electricity and the higher prices paid by consumers.
- **Energy mix supply:** the environmental externality in this case is positive, i.e. *e=]0,1[.*

Under the assumption that h<β, we conclude that:

$$W^{CR} > W^{RR} > W^{CC}$$

- Social welfare will be maximised when firm 2 is the only renewable supplier.
- If h is sufficiently small, we could then expect W^{RR} to overtake W^{CR}. At which point, because its positive environmental externality is greater, it will be socially optimal to have a renewable electricity only supply.
- Although the conventional electricity only supply remains the cheapest scenario for consumers, it does not compensate for the negative environmental externality nor for the "negative warm-glow" effect.

8. Model extension and discussion

Model extension

- Seeks to determine whether removing the extra cost of supplying renewable energy could lead to an equilibrium scenario (and a social optimum), with a renewable electricity only supply.
- Tackling this extra cost however, will not be sufficient to guarantee this scenario at equilibrium (because one of the firms is indifferent to the kind of electricity to supply).
- Nonetheless, the renewable electricity only scenario is one of the two Nash equilibria found in this game. So, the cost decrease could be seen as an incentive for some firms to enter the market as green retailers, even if green retailers are already present.

→ How to provide a more realistic representation of the current state of the French retail electricity market, which seems to become greener?

- Examining how a growing number of environmentally-conscious consumers can explain the new hybrid retailers (conventional retailers who started offering green contracts alongside their conventional ones).
- While renewable electricity retailers remain on their current greenest level (offering only green contracts), without losing all their market shares.
- Limits of this kind of location models but may shed light on the conditions required to achieve a unique equilibrium scenario with a renewable energy only supply.

9. Conclusion

When at least one firm supplies renewable electricity, both firms benefit from consumers' environmental consciousness in the form of higher prices and consequently higher profits.

By taking the environmental externalities into account, we found that when the additional cost of supplying renewable electricity is positive, but lower than consumers' environmental consciousness, the maximum differentiation equilibrium scenario also corresponds to the social optimum.

When this cost is sufficiently small, because its positive environmental externality is greater, a renewable electricity only supply would be socially optimal. However, to tackle this cost may not suffice for this scenario to be guaranteed at equilibrium.

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