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RESEARCH ARTICLE

The agro-food industry, public health, and environmental protection: investigating the Porter hypothesis in food regulation

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Abstract Sustainable food concerns have pushed public authorities to act by means of regulations, standards and other devices, and businesses to innovate in their products and production processes. We argue that the Porter hypothesis—which asserts that properly designed and implemented environmental regulation might be good for society as well as the targeted firms—might well be verified in this context. After reviewing and illustrating the working principles and main criticisms of this hypothesis, we provide a more in-depth discussion of nutritional issues. While the literature generally points to organizational imperfections and market failures to validate the Porter hypothesis, we submit and model another rationale for the agro-food industry, a rationale that is based on consumer behavior.

Keywords Sustainable food · Regulation · Innovation · Consumer behavior · Porter hypothesis

JEL classification L13 · L51 · Q55 · Q58

Introduction

Initially proposed more than 20 years ago (Porter 1991; Porter and van der Linde 1995), the Porter hypothesis asserts that well-conceived environmental regulation can be beneficial not only for society, but also for the targeted businesses. The underlying argument is that appropriate regulatory constraints will induce firms to innovate at various stages of their value chain (purchasing processes, production modes, product lines, and distribution networks), which will end up making them more competitive.[1]

Right from the beginning, the Porter hypothesis has faced strong criticism on the part of economists. While acknowledging its validity under some circumstances, Hanemann (2009) summarizes the most commonly held viewpoint in the literature that such "win-win" outcomes are rather accidental. As Palmer et al. (1995) note, no one challenges the fact that there are cases in which regulations can have a positive impact on some companies' profits. Making this a general rule rather than an exception, however, amounts to saying that firms systematically avoid to maximize long-term profits (through the under-exploitation of resources, poor allocation of production factors, undervaluing co-products, and so on). It would rather appear that well-managed firms in sufficiently competitive industries should spontaneously seek, find, and implement profitable innovations without being pushed to do so by government.

Several researchers have now sought to estimate the possible linkage between more stringent environmental regulations, innovativeness, and competitiveness (Jaffe and Palmer 1997; Popp 2006). As it turns out, empirical research does not systematically corroborate the idea that environmental regulations bring about innovations which more than compensate firms for the costs of compliance (Lanoie et al. 2011). In a

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[1] According to Porter and van der Linde (1995, p. 98 and 105): "Pollution is a manifestation of economic waste and involves unnecessary or incomplete utilization of resources. (…) Reducing pollution is often coincident with improving productivity with which resources are used. (…) Properly designed environmental regulation can trigger innovation that may partially or more than fully offset the costs of complying with them."

recent paper, however, Huiban and Musolesi (2012) remark that measuring economic performance on the heels of green innovations is not uncontroversial. It seems important, in particular, to distinguish between (i) pollution abatement efforts by firms and (ii) R&D efforts more directly related to an innovation process. Indeed, there is no guarantee that these two activities are complementary (the need to depollute could lead firms to engage in less R&D), while this is a key element in understanding the area of validity of the Porter hypothesis (a point made by Blanchard et al. 2013).

Whether there exists a virtuous process from regulation to innovation to firm profits is thus largely debatable. This remains, nevertheless, a major issue for many sectors that would have a hard time sacrificing company profits to comply with regulation.

The agro-food sector, the focus of this article, is particularly faced with the need to maintain productivity gains. Firms in this sector already respond to growing health and environmental requirements in multiple ways. Many examples can be found, for instance, in the various differentiation strategies which are implemented in specific markets, through biological certification, short channels of marketing, nutritional and health claims, etc. However, regulation continues to be required to foster the evolution of production processes and food supply in all market segments, not only in those which target consumers who are willing and able to pay for healthier or more environmentally-friendly products. Should regulations or any form of public intervention be viewed here as inhibiting innovation and competitiveness? Or, to the contrary, can regulations act as a catalyst for virtuous innovations that would not naturally occur because of behavioral rigidity on the part of businesses or consumers?

Theoretical works and empirical findings which support the Porter hypothesis involve two kinds of mechanism: (i) business routines and other organizational rigidities that public intervention renders obsolete, thereby inducing firms to review their products, processes, and standard operating procedures; (ii) other market imperfections (in addition to externalities), caused by information asymmetry, coordination problems, etc. "Two common rationales—organizational inefficiencies and multiple market failures" section below explains and illustrates these (now standard) arguments in the agro-food context.

We then propose a third mechanism. A key stylized fact, reported in "A third rationale—addressing consumers' resistance" section, indicates that consumers often exhibit resistance and suspicion towards new food products. We claim that certain regulations can alleviate this phenomenon, thereby enhancing innovation throughout the agro-food sector. "Modeling nutritional regulations" section develops a model which supports and clarifies this assertion. General conclusions and some avenues for future research are presented in "Concluding remarks" section.

Two common *rationales*—organizational inefficiencies and multiple market failures

Ambec and Barla (2007) and Ambec et al. (2013) provide exhaustive and accurate reviews of the debate surrounding the Porter hypothesis. They conclude that the hypothesis can only be valid in the presence of another source of inefficiency, in addition to the environmental externality. One such inefficiency could be that managers do not always maximize their firm's profits, in a risky context.[2] In this case, proper regulation will favor R&D activities which, while a priori profitable in the long term, seem too risky in the short run and would not, for this reason, be undertaken by risk averse managers. Another inefficiency could be charged on a specific competitive environment that deters innovation. In this case, regulations that foster competition (see, e.g., Aghion et al. 1997) or hinder it (see, e.g., d'Aspremont and Jacquemin 1988) could have beneficial effects. We shall now examine these *rationales* further, in the agro-food context.

Routines, communication costs, and labeling policies

The management literature provides compelling evidence that firms and their managers are subject to standard operating procedures and other production habits (see, e.g., Cyert and March 1992). Acknowledging this fact, Gabel and Sinclair-Desgagné (1998) argue that individuals and organizations tend to "routinize" certain tasks (viewed as elementary or less important) to better manage complexity.[3] Bringing current routine procedures into question, as new regulatory constraints can do, might then reveal opportunities that were typically overlooked; such opportunities, which often constitute "low-hanging fruits," have been well documented.

Considering organizational inefficiencies, other economic models have emphasized communication problems that engender systematic errors and losses for firms (Sah and Stiglitz 1986; Radner 1992; Bolton and Dewatripont 1994). These studies suggest that regulatory requirements regarding the production of information could have a significant impact on a firm's activities.

In the agro-food industry, asking firms to disclose the characteristics of their products is likely to make them revise the making and characteristics of those products, hence their ingrained habits and jargon.

[2] In this connection, see the debate surrounding agent behavior *vis-à-vis* risk initiated by Maurice Allais' (1953) seminal article.

[3] This was put forward early on by the philosopher Alfred North Whitehead, in the following provocative statement: "It is a profoundly erroneous truism, repeated by all copy-books and by eminent people making speeches, that we should cultivate the habit of thinking of what we are doing. The precise opposite is the case. Civilization advances by extending the number of operations which we can perform without thinking about them."

Policies of this sort amount to informing consumers about what they are eating, via the sales denominator that defines a product (e.g., "Extra Raspberry Jam"), the product's origin (e.g., "Made in France" or "*Appellation d'Origine Contrôlée Bordeaux*"), the respective name and quantity of the enclosed ingredients (sugar, salt, lipids, carbohydrates, etc.), additives and flavors (E150 coloring, E955 sweetener, etc.), the product's net quantity, the use-by date for perishables or shelf-life date for canned goods, the directions for use, whether the product must be used or stored in a certain way (kept in a dry place, for instance), the identification of the manufacturer or the manufacturing lot number for traceability purposes, and so on. The list is long and increases from one year to the next given consumers' growing demands.

In Europe, the environmental labeling requirements envisioned by some countries (like France, since 2010 and the *Grenelle de l'Environnement*) focus on a product's environmental performance (Vergez 2012).[4] Some studies confirm indeed that European consumers are concerned about this non-verifiable aspect of an end product; according to Ceci-Renaud and Thao Khamsing (2012), 74 % of French citizens would like to have environmental information about the products they purchase. The effectiveness of these policies may seem unclear, however, particularly in times of economic hardship or if the environmentally-friendly product does not taste as good as the conventional one.[5] But, if it is doubtful that in the long run consumers will adopt products that perform well in ecological terms, why should businesses invest in seeking to improve this performance considering all the challenges involved?[6] It seems, nevertheless, that certain upstream and downstream companies have begun to significantly invest in analyses of the life cycle of their products and are ready to coordinate their efforts with one another (in this regard, see "*Le Point*" by the French General Commissioner for Sustainable Development). This is the case, notably, for seed companies, which are actively seeking to quantify the environmental performance of agricultural production systems (like *Pioneer*'s Sem'Expert), and for some distribution companies (like *Casino*), which offer their suppliers ways to convey the environmental performance of their products.

All in all, feedback on the French experience published in the MEDDE (2013) report shows that, out of 163 selected companies (including more than 40 % from the agro-food sector), no less than 90 % of them fully persevered and 74 % of these operations went as initially expected. Companies' interest was also confirmed in *ex post* surveys. These studies show that 73 % of company managers feel that labeling is a significant source of competitiveness, because it ends up lowering costs through packaging reduction, savings on raw resources and energy, logistical optimization, etc.

Food safety

Crises triggered by consumers' health and safety concerns are recurrent in the agro-food sector; from the bovine spongiform encephalopathy (BSE) crisis in 1996 and 2000, the aphthous fever (hoof-and-mouth disease) one in 2001, the avian influenza one in 2005, the 2011 cucumber crisis, the GMO accusations in 2012, the 2013 "horsegate" scandal, and so on. Yet, there is a profusion of regulations on food safety. Starting with the *Codex Alimentarius*, dozens of international standards have been implemented at all levels of the value chain. Regulations based on a principle of responsibility set objectives to be met by professionals while leaving them some leeway on how to meet them (e.g., Maximum Residue Limits (MRL), the European Union's "Hygiene Package" and the *Food Safety Modernization Act* in the USA). The produce traceability obligation now requires firms to identify all their suppliers and distributors and to guarantee the possibility of retrieving any source of eventual fraud or food poisoning. All these requirements have led to the establishment of good-hygiene practices guides (e.g., FAMI-QS for animal feed safety) and a significant number of private standards, both in the processing segment (e.g., Danone's *Quality, Safety and Environmental Charter*, and Nestlé's *Quality Management System*, etc.) as well as in the large-scale food distribution one. In the latter case, GFSI standards (with regard to processed foods and, in particular, distributors' brands) and GlobalGAP (for fresh produce) have been implemented just about everywhere, thanks to the creation of private standardization associations.

The empirical literature (see, in particular, Minten et al. 2009 and Maertens and Swinnen 2009) confirms the innovativeness of companies and their suppliers which initiated a standardization process. There are indeed many examples showing that the benefits of private standards to producers are higher than the additional costs. Moreover, suppliers are often found to be producers from southern hemisphere countries who, contrary to widespread opinion, have not been excluded from the market due to the inability to afford and fulfill private standards. This is confirmed, notably, by Henson et al. (2011), who focus on the production and export of fresh produce in ten sub-Saharan African countries and study the determinant of GlobalGAP certification. This investigation reveals that farmers who adopted this certification ultimately get higher revenues than their neighbors, with a significant ROI. Similar facts are reported by Ouma (2010) and Asfaw

[4] http://affichage-environnemental.afnor.org/

[5] To our knowledge, very few studies in experimental economics have examined this assertion. A notable exception is Bougherara and Combris (2009).

[6] The first difficulty relates to the nature of the *criteria* used for attesting environmental performance. How does one assess the carbon footprint or the impact on the water table and biodiversity (which are particularly difficult to measure) throughout the value chain? Next, improving product performance along these *criteria* often means amending the firm's activities significantly.

et al. (2010) in Kenya, where standardization translated into stable commercial relations within value chains and greater export markets. Even though one may still qualify these findings (as Subervie and Vagneron 2013, for instance, do), it would be hard to argue that strengthening health and safety regulatory constraints in the agro-food area is systematically detrimental to business.

To understand the facts, as far as traceability is concerned, for instance, it is important to note that this requirement raises the importance of data exchanges between and among commercial partners at all stages throughout the supply chain. This has led firms to (i) strengthen selection *criteria* for raw materials (thereby fostering product innovation) and (ii) overcome the traditional power struggles between suppliers and distributors so as to promote production and logistics efficiency (enhancing organizational innovation). Giraud-Héraud et al. (2012) provide a theoretical analysis of this phenomenon, with an explanation for the creation of collective private standards in response to strengthened public policy.

A third *rationale*—addressing consumers' resistance

As noted above, the current literature on the Porter hypothesis centers on the firm's internal operations or additional market imperfections that inhibit innovation and that proper regulation could alleviate. The latter section, however, brings out the consumer as a key player in the agro-food industry. Food customers are typically hypersensitive to information and tend to mistrust novelty. They exhibit irrational fears towards innovations, especially when there is extensive media coverage.[7] Competition can exacerbate this behavior, when product quality is not recognizable (i.e., when food is a credence good) or when people have complex and changing preferences. While it is generally accepted that competition can be detrimental to innovations in the presence of large non-appropriable spillovers,[8] it is usually overlooked that competition can have a similar effect via the exploitation of consumers' biases. The rest of this paper will now develop this point (a more detailed presentation can be found in Réquillart and Soler 2014).

In the agro-food industry, innovations are particularly exposed to the absence of consumer receptiveness (Académie des technologies 2012). Certain radical innovations (such as the introduction of GMOs, food irradiation, and nanotechnologies) have been rejected right away by a worried public. Consumers also feel an intrinsic tension between the hedonic, health, and environmental attributes of food, which makes convincing them by appealing to environmental arguments or some possible long-term benefits a tricky exercise. The regulator's positive contribution may then lie in surmounting these hurdles.

To contribute to the reduction of chronic diseases and to curb obesity and excess weight in developed countries, for instance, public authorities have adopted policies on two fronts. The first one deals with increasing consumer awareness of the health impacts of certain dietary habits, in order to change consumer behavior and induce people to take into account the nutritional value of their food basket. Information campaigns and nutritional labeling are key instruments on this front. The second front tackles consumers' dietary environment via food-price related actions (nutritional taxes) or by engendering improvements in food quality so as to reduce the content of nutriments (salt, added sugar, unsaturated fats, etc.) viewed as harmful.

Whether they focus on consumer demand or on the supply of food products, these policies have so far had only modest effects in curbing the progression of obesity (Brambila-Macias et al. 2011; Traill et al. 2013). In the case of breakfast cereals, reduced sugar and fat content or increased fibers are not necessarily appreciated by consumers (OQALI 2013). In the cheese sector, salt and fat levels are even viewed as indicators of hedonic quality (Saulais and Ruffieux 2012). One recent study shows that, while the implementation in the USA in 1994 of nutritional labeling requirements had a positive effect on the nutritional quality of products for which such improvements carried little commercial risk (like products with small market shares), it led to a degradation of the quality of products for which amelioration was commercially risky (Moorman et al. 2012).

As far as this article is concerned, we shall retain two main reasons for the slow adjustment of the food supply chain to nutritional issues.

The first one has to do with the costs of product reformulation. In processed meat products, for example, salt content affects water retention and therefore the product's final weight (He and MacGregor 2009). Altering some ingredients can then turn out to be more costly. And, changing recipes entails significant prior R&D investment (Traill et al. 2012; Traill 2012). In the case of *Mars UK*, for instance, reducing the amount of saturated fats in chocolate bars has cost the company €10M.

Beyond the cost issue, one significant hurdle lies in how consumers perceive and trade off the health and the hedonic dimensions. The idea that consumers look for products with better nutritional values and would buy them if they had the necessary information and budget is preconceived at best.

[7] This was the case in the 2011 Spanish cucumber crisis. This highly-publicized condemnation by German authorities of cucumber imports from Spain—a gesture that soon proved to be mistaken, as the problem stemmed from spouted seeds contaminated by verotoxin-producing *E. coli* strains—led to the collapse of vegetable consumption throughout Europe (Jourdan and Hobbis 2013).

[8] D'Aspremont and Jacquemin (1988) show that, in this case, firms would face a prisoner's *dilemma*, which explain the paucity of investment in R&D; regulations that protect innovations or that require the adoption of a new technology can then benefit all businesses (see also Ambec and Barla 2007).

While in blind testing, consumers cannot always taste the difference between products with varying degrees of fat or sugar, in real consumption situations product-related expectations stemming from labeling, brand names and related information can affect not only the subjective representation but also the sensorial perception of these products (Wansink et al. 2004; Vadiveloo et al. 2013). It is therefore unusual to be able to modify product characteristics to fulfill some health demands without at the same time facing rejection by certain consumers, the latter seeing the improvement in nutritional value as a degradation of the product's taste.

Public authorities and businesses in some countries have cooperated to get around these difficulties. In the UK, government agencies and industry representatives collaborate in setting objectives for product reformulation and encouraging business associations and firms to meet them. Consultations with stakeholders resulted in establishing targets for salt levels in 2006; these targets were revised and made stricter over the following years. By 2010, 75 organizations were committed to the goals, including some major distributors for their own brands. The upshot is rather positive; between 2007 and 2009, there was an average 5.3 % reduction in salt levels. However, population-wide intake of salt went from 9.5 g/day in 2000 to 8.6 g/day in 2008, which still remains above the 6 g/day target.

In France, within the framework of the *Programme National Nutrition Santé* (Hercberg et al. 2008), the undertaken challenge consisted in promoting "Nutritional Progress Commitment Charters," to be signed by businesses and public authorities, which aimed at improving the nutritional value of food products. Between 2008 and 2013, 30 agro-food companies and professional unions signed these charters (Sebillotte 2013). Although the initiatives that then followed led to consumption changes for eight food products, the variations in average energy intake remain modest: −11.4 kcal/day for men and −10.6 kcal/day for women (the average total caloric intake ranging from 1800 to 2200 kcal/day) (OQALI 2012).[9]

These experiences are revealing of the obstacles to be lifted in order to bend the evolution of all food products towards seeking higher nutritional values. Outside of the few *niche* markets harboring consumers concerned with and willing to pay for healthy food, economic incentives to improve the nutritional characteristics of food products are weak in most cases, because a sizeable portion of consumers associate higher nutritional value with poor hedonistic quality. No company would then pursue improvements only by itself, for fear of losing part of its market to competitors who did not alter their products. The challenge for public authorities is to enable inter-company coordination in improving the quality of all food products. We will now explore and articulate this point further by way of a model.

[9] For more details, see www.oqali.fr

Modeling nutritional regulations

The literature on the possibilities of validating the Porter hypothesis presented at the beginning of this article is largely focused on the production side of things. These studies put the emphasis on difficulties in realizing innovations that would reduce production costs or would improve the company's internal organization. To our knowledge, there are few studies of the competitive context in relation to making these products appealing to consumers.[10] Nevertheless, several studies (Mohr 2002; Greaker 2006) focus on the problem of inter-firm coordination and between a given industry's general interests and particular interests. In this case, the focus is on the effects of the prisoner's dilemma, such as found in André et al. (2009) and Constantatos and Herrmann (2011) who conduct theoretical analysis within the framework of models of product differentiation.

Regarding nutrition-related issues, successful innovations might not be implemented because of a'lock-in' problem induced by the behavior of recalcitrant consumers. To determine to what extent a public intervention is needed to favor product innovations, we propose a simple model that illustrates this possibility of conflict between industrial competition (deleterious for nutritional values) and cooperation that fosters both corporate profits and the nutritional values resulting from their actions. This model is in the line of the model developed by André et al. (2009, pp. 191–192), in that we retain the idea that consumers are weakly attached to a company in relation to its extrinsic characteristics (by way of its brand name in a context of horizontal differentiation or by way of its location in a context of spatial differentiation) and, moreover, that they must make choices about the qualities of the products offered by companies. Nevertheless, in our model, consumers may devalue innovative products and have a lower willingness-to-pay for them (in comparison to conventional products).

Consider a market with two firms indexed by $i = 1,2$, these firms are located at the extremities of a segment [0,1] upon which consumers are evenly distributed. Each firm i has the choice of sticking to conventional production ("Conv" strategy) with a constant marginal cost $\overline{c}$, or undertaking innovation ("Innov" strategy) with a constant marginal cost $\underline{c}$. In the first case, the company's product is perceived by all consumers as having a level of quality k_H. In the second case, the produced is not appreciated as much by some consumers; a proportion I of the public feels that the quality of the innovative product is similar to that one produced by conventional production (this public is referred to as *health-consumers*, for whom health issues are a priority and who do not necessarily assign less

[10] Some articles examine the possibility that regulations could put certain companies in a market leadership position by inducing R&D. Simpson and Bradford (1996) make this case in the context of international competition.

value to products of a lower sensorial quality) and a proportion (1-I) that feels the quality of the innovative product is inferior, at level $k_L < k_H$ (this public is referred to as *taste-consumers*, for whom a product's hedonic, sensorial dimension is the priority).

Consumers individually decide to purchase a unit of a product from a firm *i* which they prefer. We note the product price from each firm i as p_i ($i = 1,2$). We denote k_i the perceived quality of firm *i*'s product, which can take one of two values (k_L or k_H), depending on whether consumers are taste-consumers or health-consumers. Consumers located in y on [0,1] thus have the indirect utility $U_1 = k_1 + \alpha_1$ (1-y)–p_1 if they purchase the product from firm 1 and $U_2 = k_2 + \alpha_2\, y$–p_2 if they purchase the product from firm 2.[11] Parameter α_i represents an "attachment" consumers have for the extrinsic qualities of firm *i*'s product and is associated with linear transportation costs in Hotelling-type models (1929). To simplify matters, we assume that they are identical, postulating that $\alpha = \alpha_1 = \alpha_2$.

Illustration of the Porter hypothesis (competition with covered market)

The illustration of Porter hypothesis is obtained when no consumer boycott the new product because if there is no other alternative on the market (for example, when all consumers want to buy bread despite the fact that all the breads available on the market are processed with less salt). This context is represented by a covered market in all *scenarii* of competition between firms. This hypothesis is made in the papers mentioned above. It signifies that all consumers have a positive *surplus* in purchasing from one company or another in the market. Such is the case for consumers located close to either of these two firms. It is also the case for the remotest consumers situated in the center of the market. Within the framework of our model, this hypothesis must apply as much to health-consumers, who value the product at level k_H, as taste-consumers, who hold the product in lower esteem (at level k_L). In contrast, there can be situations less typically considered in the literature (but which are particularly interesting to us as illustrations of our argument) in which consumers in the center of the market do not obtain a positive *surplus* when purchasing the product at the *equilibrium* price (they either decide not to purchase anything or turn to "an outside good," as noted in Salop 1979). This uncovered market concerns above all taste consumers who hold the product low esteem.

We consider a two-stage game. In stage 1, firms simultaneously choose the 'Conv' strategy or the 'Innov' strategy. At stage 2, firms compete with one another in terms of price. The game is resolved by backward induction. The resolution for stage 2 is provided in the Appendix for situations allowing for the existence of a price *equilibrium* between the two firms, knowing that it is possible to obtain *equilibria* for which the market is covered or, to the contrary, uncovered. The Appendix presents all these situations according to *equilibrium* type, noted as Ei ($i = 1,\ldots 7$), giving the conditions of realization of such *equilibria*. Stage 2 of the game can be easily represented by a normal-form game with only two possible firm strategy configurations (Conv or Innov).

The reference matrix given below (Fig. 1) occurs within the framework of the hypothesis for which the market is always covered, whatever the strategy configurations adopted by companies at stage 1 of the game. To obtain the result, the level of the qualities perceived by consumers must be sufficiently high relative to unit production costs: $k_H \geq \overline{c} + \frac{\alpha}{2}$ and $k_L \geq \underline{c} + \frac{\alpha}{2}$. Firm 1's profits are indicated by the value displayed in the upper-left corner of each square of the matrix displayed below, and those for firm 2 in the lower-right corner:

As indicated in the Appendix, the Conv-Conv outcome entails an E1 *equilibrium* for which the market is covered. The Innov-Innov outcome entails an E3 *equilibrium* for which the market is covered. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E5 *equilibrium* for which the market is covered.

The profits from the two dissymmetrical situations (Innov-Conv and Conv-Innov) are written as:

$$\left| \begin{array}{l} \Pi^{Conv} = \frac{1}{18\alpha}\left[3\alpha + (1\text{-}I)(k_H\text{-}k_L)\text{-}\left(\overline{c}\text{-}\underline{c}\right)\right]^2 \\ \Pi^{Innov} = \frac{1}{18\alpha}\left[3\alpha\text{-}(1\text{-}I)(k_H\text{-}k_L) + \left(\overline{c}\text{-}\underline{c}\right)\right]^2 \end{array} \right.$$

As shown in Fig. 1, the profits of companies obtained by simultaneously innovating are identical to the profits obtained in a *status quo* situation in which no one innovates ($\frac{\alpha}{2}$). Yet, under no circumstances can this strategy emerge whenever $(1\text{-}I)(k_H\text{-}k_L) > (\overline{c}\text{-}\underline{c})$, which is the only condition for obtaining $\Pi^{Innov} < \frac{\alpha}{2}$ or $\Pi^{Conv} > \frac{\alpha}{2}$. It is interesting to note in this regard that in the simplest case, in which $\overline{c} = \underline{c}$, this condition is always verified (since $k_L < k_H$). Hence, even if the innovative product does not engender higher costs, the adoption of an innovation strategy by both firms cannot occur. We obtain in this way an illustration of the Porter hypothesis with a prisoner's *dilemma* situation in which the innovation strategy is a dominant strategy, while the Innov-Innov outcome (the one preferred by the regulator) is weakly Pareto dominant.[12]

[11] In these conditions, the higher the quality of the product offered by firm *i* is, the more consumers will tend to be "loyal" to the preferred firm. It should be noted that, in contrast to André et al. (*op. cit.*), we retain an additive indirect utility between brand effects and taste quality effects.

[12] Although not explicitly taken into account in the model, a complete illustration of the Porter hypothesis assumes, to be sure, that the social cost implicit in the conventional strategy (cost for the health of the population) is sufficiently high to justify the search for the results of innovations.

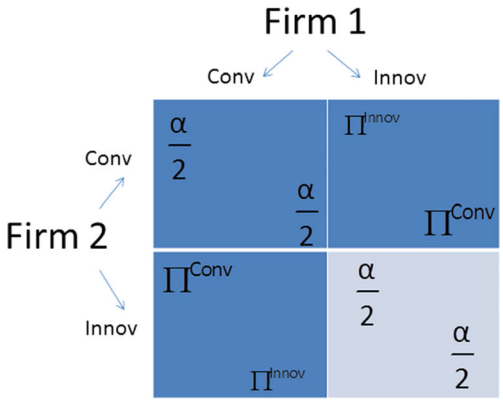

Fig. 1 *Equilibrium* profits obtained for all strategy *scenarii* for the two firms in which the market is systematically covered

Therefore, it follows that a nutritional policy that imposes a penalty $T > \Pi^{Conv} - \frac{\alpha}{2}$ on any firm producing the conventional variant of the good can yield to a win-win situation. Under this condition, the penalty T will be high enough to make Innov-Innov a Nash *equilibrium* of the regulated quality choice game.

Uncovered market when both firms innovate

This simple illustration of the Porter hypothesis in the covered market context shows why public regulation should seek to encourage firms to innovate while guaranteeing their profits at least equal to those obtained in the absence of regulation.

We consider now the case in which the market gets uncovered when both firms innovate. Our goal is to determine to what extent a public intervention is required and discuss which policy may be the most efficient to favor product innovation. We will consider some of the policies mentioned in "A third rationale—addressing consumers' resistance" section, either focused on the demand or on the supply sides. We will determine to what extent they might be substitutes or complements, and finally pay a particular attention to a 'carrot-and-stick' policy combining taxation and consumer information.

The new baseline matrix illustrates a more complicated starting point in which the market is not necessarily covered. Initially, consumers skepticism about or rejection of innovation can lead to a generalized loss of profits if both firms innovate simultaneously. To keep things simple, we settle for keeping precise parameter values making possible to guarantee price *equilibrium* at the game's second stage,[13] and which efficiently illustrates this competition problem linked to public regulations. The new benchmark is the following:

As indicated in the Appendix, the Conv-Conv outcome entails an E1 *equilibrium* for which the market is covered. The Innov-Innov outcome entails an E4 *equilibrium* for which the market is only uncovered for taste-consumers. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E5 *equilibrium* for which the market is covered.

In the *status quo* outcome in which both firms maintain a conventional strategy (Conv-Conv outcome), the market is covered and consumers are distributed between the two firms who obtain identical profits (0.65). In contrast, if the two firms innovate simultaneously, there is an overall decrease in the number of consumers in the market. The fact that the market is uncovered leads to a collapse in profits at level 0.28; the Innov-Innov outcome is thus Pareto-dominated by the Conv-Conv outcome. Moreover, if a firm unilaterally innovates, it obtains an intermediate profit of 0.50 whereas its competitor who maintains a conventional strategy sees its profit increase relative to the *status quo* (0.82 > 0.65). With the covered market in *equilibrium*, the conventional firm attracts the consumers disappointed with the innovative firm. It follows that the conventional strategy is the dominant one for each firm, which means that innovation cannot emerge in *equilibrium* under any circumstances.

We now show how it would be possible to modify the profits of the Fig. 2 matrix with the help of public policies: (i) either by increasing consumer acceptance of innovations, or (ii) by reducing the profits obtained through the conventional strategy.

Raising consumer awareness

A first policy aims at increasing the number of health-consumers through information campaigns that highlight the benefits engendered by consuming products containing less

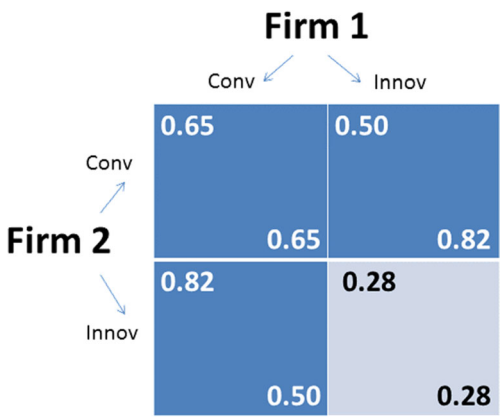

Fig. 2 *Equilibrium* profits obtained in an uncovered market in the case of simultaneous innovation. (Parameter values: $\alpha = 1.3$; $\overline{c} = \underline{c} = 0.05$; $k_H = 1.2$; $k_L = 0.25$; $I = 0.5$)

[13] The stage 2 resolution corresponds to resolution of the price competition in the production differentiation model considered above. However, our decision to remain with a linear transportation cost for consumers makes it impossible to completely resolve this game by pure strategy *equilibria* (absence of an *equilibrium* of this kind for certain parameter values). This hypothesis has, however, the advantage of a simple treatment of the covered-uncovered market alternatives that are of interest to us here.

fat, sugar, and salt ('5-a-day' campaigns are a good example of such information campaigns). Their impact in our model is an increase of the parameter I. Obviously, this increase improves profits from innovation strategies in all the *equilibria*. This action on the part of public authorities leads to profit increases in the Innov-Innov outcome while re-equilibrating the Innov-Conv outcome.

As indicated in the Appendix, the Conv-Conv outcome entails an E1 *equilibrium* for which the market is covered. The Innov-Innov outcome entails an E4 *equilibrium* for which the market is not covered for taste-consumers. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E5 *equilibrium* for which the market is covered.

In Fig. 3, the conventional outcome always remains in *equilibrium* for dominant strategies while being Pareto-dominant *vis-à-vis* the simultaneous innovation outcome. Our simulations show that the increase in I has two effects; the increase in the number of health-consumers increases market coverage in Innov-Innov on the one hand, and the price increase tends to reduce this market coverage on the other hand. This latter effect is initially dominant, which translates into a reduction of market coverage for weak increases in I. Subsequently, the first effect dominates, and for $I=1$, the market is completely covered. It is only for the value $I=1$ that the Innov-Innov outcome emerges in *equilibrium*.

Labeling innovative products

Another solution consists in modifying the level of quality perceived by taste-consumers in cases of innovation, for example, thanks to labels that highlight the benefits and risks associated with product consumption. The "traffic lights" policy used in the UK is an example of such a policy. This public policy requires colored logos (red, yellow, or green) as a function of nutritional value. Strictly speaking, this solution is not equivalent to the previous one to the extent that it is not a case of raising consumer awareness of food-related health issues but of using product labeling to modify their appreciation of a reformulated product. Figure 4 below, in which there is an increase in quality k_L, shows that it is thus possible to return to a covered market state in cases of innovation that enables firms to reacquire the profits of the conventional situation.

As indicated in the Appendix, the Conv-Conv outcome entails an E1 *equilibrium*. The Innov-Innov outcome entails also an E1 *equilibrium*. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E5 *equilibrium*. For all *equilibria*, the market is covered.

As such, actions taken by public authorities with regard to product labeling improve innovation-related profits. We can now find a value $k_L<k_H$, such that the Innov-Innov outcome yields the same profits as the initial situation. Once again, however, each firm obtains a higher profit when only the other firm innovates. As in the case of Fig. 1, we get a situation similar to the prisoner's *dilemma*; the outcome (Innov-Innov) preferred by public authorities is no longer Pareto-dominated because the market is always covered (there is no loss of consumers when every firm does the same thing). However, the Conv solution is preferred by each firm when the other one innovates. Ultimately, the Innov-Innov outcome cannot be implemented because the Conv strategy remains the dominant one for each firm.

Taxing conventional products

Taxation is an oft-used tool to induce firms to change their behavior by making the conventional strategy less attractive. Firms pay for the tax in a linear fashion, which, for us, means an increase of marginal production costs. In our case, we determine whether the tax is wholly passed along to consumers in the Conv-Conv and Innov-Innov outcomes, which does not alter the *equilibrium* profits relative to baseline case 2 (Fig. 5):

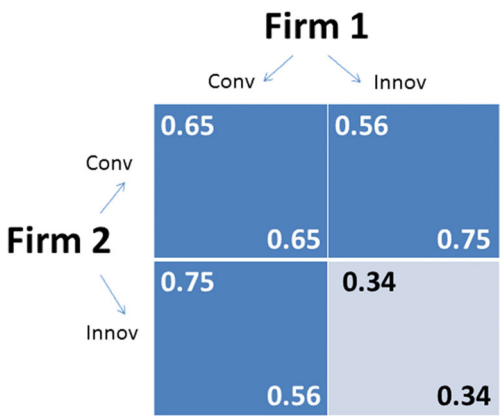

Fig. 3 *Equilibrium* profits obtaining by increasing the number of *health* consumers. (Parameter values: $\alpha=1.3$; $\overline{c}=\underline{c}=0.05$; $k_H=1.2$; $k_L=0.25$; $I=0.7$)

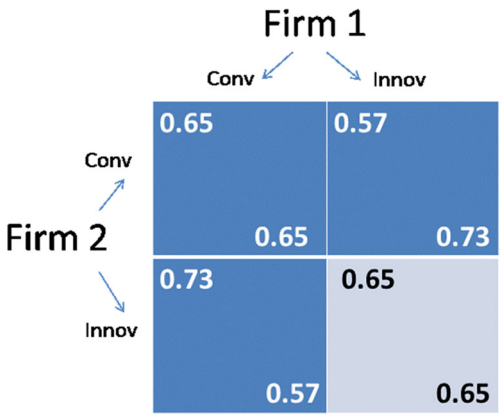

Fig. 4 *Equilibrium* profits obtained with innovation labeling. (Parameter values: $\alpha=1.3$; $\overline{c}=\underline{c}=0.05$; $k_H=1.2$; $\boldsymbol{k_L=0.71}$; $I=0.5$)

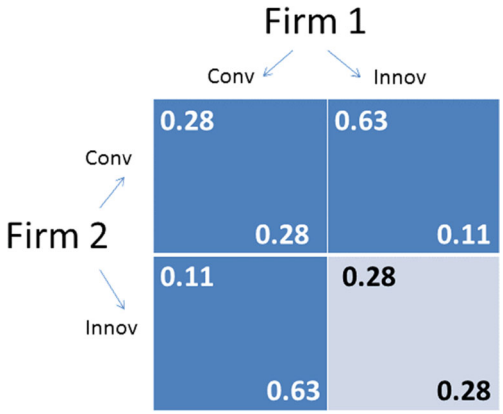

Fig. 5 *Equilibrium* profits obtained with the tax on the conventional product. (Parameter values: $\alpha = 1.3$; $\underline{c} = 0.05$; $\bar{c}$=**1.58**; $k_H = 1.2$; $k_L = 0.25$; $I = 0.5$)

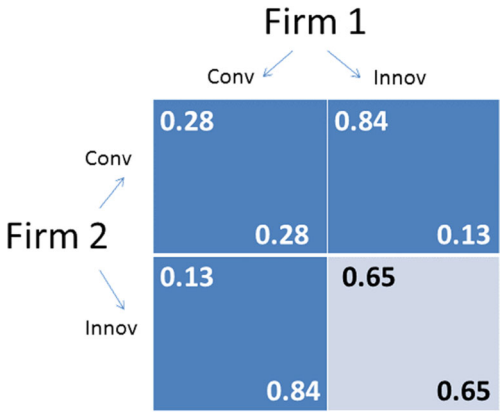

Fig. 6 *Equilibrium* profits obtained by combining taxation and labeling. (Parameter values: $\alpha = 1.3$; $\underline{c} = 0.05$; $\bar{c}$=1.58; $k_H = 1.2$; $k_L = 0.71$; $I = 0.5$)

As indicated in the Appendix, the Conv-Conv outcome entails an E2 *equilibrium* for which the market is covered. The Innov-Innov outcome entails an E7 *equilibrium* for which the market is only uncovered for taste-consumers. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E4 *equilibrium* for which the market is also only uncovered for taste-consumers.

Given that the tax does not apply to the Innov-Innov situation, the market remains uncovered in this situation for a k_L value identical to that found in Fig. 2. However, the tax alters the Innov-Conv *equilibrium* by naturally favoring the firm that innovates, such that its profits are now higher than those obtained in the Innov-Innov outcome. It is interesting to note that the tax does not act as a threat here since it is not applied to the Innov-Innov *equilibrium*. In fact, it serves only to prevent a return to a Conv-Conv situation. In the final analysis, while the tax suffices to induce a simultaneous innovation strategy by the two firms, it is a dominant strategy *equilibrium* which is Pareto-dominated by the Conv-Conv found in the benchmark of Fig. 2. To improve overall performance, the two instruments (i.e., taxation and innovative product labeling) must be combined.

Labeling innovative products and taxing conventional products

We turn our attention now to a combination of government actions with regard to innovative product labeling and taxation. As shown above, certification improves market coverage and thus strengthens the Innov-Innov situation relative to the Conv-Conv situation. For its part, taxation has a detrimental effect on conventional strategies. By combining the two action levers, we obtain the following situation:

As indicated in the Appendix, the Conv-Conv outcome entails an E2 *equilibrium* for which the market is uncovered. The Innov-Innov outcome entails an E7-type *equilibrium* for which the market is only uncovered for taste-consumers. And, the Innov-Conv (and by symmetry Conv-Innov) outcome entails an E3 *equilibrium* for which the market is covered.

In the final analysis, if we compare the Fig. 2 situation to the Fig. 6 situation, we can see that the combination of policies with regard to labeling reformulated products and taxing conventional products enables the emergence of the Innov-Innov outcome by maintaining the same profits for firms as are obtained in the *equilibrium* of Fig. 2, with simultaneous choices of the conventional strategy.

Other 'carrot-and-stick' policies may ensure the promotion of the Innov solution while lowering the value attached to the conventional alternative. Note that it is important here to ensure two conditions: (1) improving, relative to the initial situation, the Innov-Innov situation's profits while guaranteeing that the market is covered; and (2) reducing profits in cases where the conventional strategy is maintained.

Concluding remarks

The agro-food sector is facing several important environmental, health, and nutritional issues, which will henceforth be associated with the food sustainability question and require significant changes to production and consumption practices. For businesses, the steps to be taken could either engender significant additional costs likely to negatively impact their competitiveness or entail the development of innovations that might be poorly accepted by consumers.

In this context, the debate surrounding the Porter hypothesis is quite relevant, as there are still conflicting viewpoints on the legitimacy and effectiveness of public intervention. Our objective in this article was to examine the main mechanisms that could support this hypothesis, in the context of the agro-

food sector. In addition to the main arguments in the literature which stress the existence of organizational and market failures, we have emphasized the persistence of consumer habits and biases. The tension between the hedonic and health dimensions of food illustrates these features quite clearly. Based on several case studies and a theoretical model, we then sought to identify the innovation development conditions which could be introduced through public interventions.

Our model showed that, in the absence of public intervention, the industry will not undertake an innovation process leading to making food products with high nutritional value because of the existence of some recalcitrant consumers (even if they are not that many). It is interesting to note that, in the 'uncovered market' case, a public policy must combine several policies to support product innovations, by ensuring the promotion of the new products while lowering the value attached to the conventional alternative. At *equilibrium*, all firms innovate and maintain their profit levels relative to the baseline situation.

This paper has addressed what seems to be a major feature of the agro-food sector—the acute sensitivity of consumers' perceptions. To be sure, a good grasp of the regulation-innovation interaction in this sector requires an in-depth understanding of consumer behavior. While there is a vast literature on cognitive biases in decision-making (see Ariely 2008, among many others), only a few studies examine the consequences of these biases in food-related decisions. There is here significant room for theoretical, empirical, and policy-orientated research.

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Appendix

Covered market condition

$U_1 > 0$ if and only if $y < \overline{y}_1 = 1\text{-}\frac{p_1\text{-}k_1}{\alpha}$ and $U_2 > 0$ if and only if $y > \overline{y}_2 = \frac{p_2\text{-}k_2}{\alpha}$

Moreover, $U_1 > U_2$ if and only if $y < \hat{y}(k_1, k_2) = \frac{p_2\text{-}p_1\text{-}k_2+k_1+\alpha}{2\alpha}$

The market is covered if and only if $\overline{y}_2 \leq \hat{y}(k_1, k_2) \leq \overline{y}_1$, that is to say:

$$p_1 + p_2 \leq \alpha + k_1 + k_2 \qquad (C)$$

The market is covered whenever the offered qualities are sufficiently high relative to product selling price.

Case in which both firms adopt the Conv strategy

In this case, consumers unanimously feel that the quality offered by each firm is at level K_H.

Equilibrium with a covered market

The demand for firm 1's products is such that $D_1 = \hat{y}(k_H, k_H)$ and the profit $\Pi_1 = (p_1\text{-}\overline{c})\,\hat{y}(k_H, k_H)$.

The condition for first-order maximization of firm 1's profits gives $p_1 = \frac{1}{2}(p_2 + \overline{c} + \alpha)$.

By symmetry, we obtain the equivalent condition for firm 2, which gives the equilibrium price $p_1^* = p_2^* = \overline{c} + \alpha$ and the market shares $D_1^* = D_2^* = \frac{1}{2}$. The covered market condition is thus equivalent to:

$$k_H \geq \overline{c} + \frac{\alpha}{2} \qquad (C1)$$

E1 equilibrium: firms choose a conventional strategy, and under condition (C1), there is a single equilibrium with a covered market such that $p_1^* = p_2^* = \overline{c} + \alpha$, $D_1^* = D_2^* = \frac{1}{2}$ and $\Pi_1^* = \Pi_2^* = \frac{\alpha}{2}$. In this equilibrium, profits do not depend on variable production costs.

Equilibrium with an uncovered market

The demand for firm 1's products can now be written as $D_1 = \overline{y}_1 = 1\text{-}\frac{p_1\text{-}k_H}{\alpha}$ The condition for first-order maximization of profit gives $p_1 = \frac{1}{2}(k_H + \overline{c} + \alpha)$.

By symmetry, we obtain the equivalent condition for firm 2. The uncovered market condition is thus equivalent to:

$$k_H < \overline{c} - \alpha \qquad (C2)$$

Both firms obtain a strictly positive profit in equilibrium if and only if:

$$k_H > \overline{c} - \alpha \qquad (C2')$$

We can note that the conditions (C1) and (C2) are never compatible with one another.

E2 equilibrium: firms choose a conventional strategy, and under conditions (C1) and (C2)', there is a single equilibrium with an uncovered market in which both firms make a strictly positive profit. This equilibrium is such that $p_1^* = p_2^* = \frac{1}{2}(k_H + \overline{c} + \alpha)$, $D_1^* = D_2^* = \frac{\alpha + k_H - \overline{c}}{2\alpha}$ and $\Pi_1^* = \Pi_2^* = \frac{1}{4\alpha}(\alpha + k_H - \overline{c})^2$.

Case in which both firms adopt an Innov strategy

In this case, only informed consumers feel that the quality offered by both firms is at level K_H. A proportion (1-I) of consumers feels that the quality is at level K_L.

Equilibrium with a covered market

The demand for firm 1's products is written as:

$$D_1 = I\hat{y}(k_H, k_H) + (1\text{-}I)\Big) \quad \hat{y}(k_L, k_L) = \frac{p_2\text{-}p_1 + \alpha}{2\alpha}$$

The *equilibrium* can thus be deduced form the first situation in the E1 *equilibrium*, but this time with a marginal production cost at level $\underline{c}$. The *equilibrium* prices are such that $p_1^* = p_2^* = \underline{c} + \alpha$ and the market shares $D_1^* = D_2^* = \frac{1}{2}$. The covered market conditions for both consumer types are written as:

$$\begin{cases} p_1 + p_2 \leq \alpha + 2k_H \\ p_1 + p_2 \leq \alpha + 2k_L \end{cases} \Leftrightarrow k_L \geq \underline{c} + \frac{\alpha}{2} \qquad (C3)$$

E3 equilibrium: firms choose a conventional strategy, and under condition (C3), there is a single equilibrium with a covered market, such that: $p_1^* = p_2^* = \underline{c} + \alpha$, $D_1^* = D_2^* = \frac{1}{2}$ and $\Pi_1^* = \Pi_2^* = \frac{\alpha}{2} - F$. In this equilibrium, profits do not depend on variable production costs.

Equilibrium with an uncovered market for uninformed consumers

We now assume that for the proportion I of consumers, the market is covered whereas it is uncovered for the proportion (1-I) of consumers. In this hypothesis, the demand for firm 1's products is written as:

$$D_1 = I\left(\frac{p_2\text{-}p_1 + \alpha}{2\alpha}\right) + (1\text{-}I)\left(1\text{-}\frac{p_1\text{-}k_L}{\alpha}\right)$$

The first-order profit maximization condition $\Pi_1 = (p_1\text{-}\underline{c})$ $D_1\text{-}F$ gives:

$$2(2\text{-}I)p_1\text{-}Ip_2 = (2\text{-}I)\left[\underline{c}\text{-}Ik_L(\alpha + k_L)\right]$$

We thus obtain the symmetrical equilibrium:

$$p_1^* = p_2^* = \frac{1}{4\text{-}3I}\left[(2\text{-}I)\left(\underline{c} + \alpha\right) + 2(1\text{-}I)k_L\right]$$

The covered market condition for informed consumers gives:

$$2(4\text{-}3I)k_H\text{-}4(1\text{-}I)k_L \geq 2\underline{c}(2\text{-}I) + \alpha I \qquad (C4)$$

The uncovered market condition for uninformed consumers gives:

$$k_L < \underline{c} + \frac{\alpha I}{2(2\text{-}I)} \qquad (C4)')$$

E4 equilibrium: firms choose an innovation strategy, and under conditions (C4) and (c4)', there is a single equilibrium with an uncovered market, such that:

$$p_1^* = p_2^* = \frac{1}{4\text{-}3I}\left[(2\text{-}I)\left(\underline{c} + \alpha\right) + 2(1\text{-}I)k_L\right]$$
$$D_1^* = D_2^* = \frac{(2\text{-}I)}{2\alpha(4\text{-}3I)}\left[\alpha(2\text{-}I) + 2(1\text{-}I)\left(k_L\text{-}\underline{c}\right)\right]$$
$$\Pi_1^* = \Pi_2^* = \frac{(2\text{-}I)}{2\alpha}\left[\frac{\alpha(2\text{-}I)\text{-}2(1\text{-}I)\left(k_L\text{-}\underline{c}\right)}{(4\text{-}3I)}\right]^2 \text{-}F$$

In this equilibrium, the market is covered for informed consumers and uncovered for uninformed consumers.

Case in which only firm 2 adopts an Innov strategy

In this case, all consumers feel that the quality offered by firm 1 is at level k_H whereas only informed consumers feel that the quality offered by firm 2 is at level k_H. A proportion (1-I) of consumers feel that the quality offered by firm 2 is at level k_L.

Equilibrium with a covered market

In a covered market hypothesis, both informed and uninformed consumers decide to buy from one or the other of these two firms. We obtain a demand addressed to each firm:

$$\begin{cases} D_1 = \dfrac{p_2\text{-}p_1 + \alpha + (1\text{-}I)(k_H\text{-}k_L)}{2\alpha} \\ D_2 = 1\text{-}D_1 \end{cases}$$

The first-order profit maximization condition $\Pi_1 = (p_1\text{-}\overline{c})$ D_1 gives:

$$p_1 = \frac{1}{2}p_2 + \frac{1}{2}\left[\alpha + \overline{c} + (1\text{-}I)(k_H\text{-}k_L)\right]$$

The first-order profit maximization condition $\Pi_2 = (p_2\text{-}\underline{c})$ D_2 gives:

$$p_2 = \frac{1}{2}p_1 + \frac{1}{2}\left[\alpha + \underline{c} + (1\text{-}I)(k_H\text{-}k_L)\right]$$

We thus obtain the *equilibrium*:

$$\begin{cases} p_1^* = \dfrac{1}{3}\left[2\overline{c} + \underline{c} + 3\alpha + (1\text{-}I)(k_H\text{-}k_L)\right] \\ p_2^* = \dfrac{1}{3}\left[\overline{c} + 2\underline{c} + 3\alpha\text{-}(1\text{-}I)(k_H\text{-}k_L)\right] \end{cases}$$

The covered market condition for informed and uniformed consumers gives:

$$k_H + k_L \geq \alpha + \underline{c} + \overline{c} \quad \text{(C5)}$$

E5 equilibrium: firm 1 chooses a conventional strategy and firm 2 an innovation strategy. Under condition (C5), there is a single equilibrium with a covered market, such that:

$$\begin{cases} p_1^* = \frac{1}{3}\left[2\overline{c} + \underline{c} + 3\alpha + (1\text{-}l)(k_H\text{-}k_L)\right] \\ p_2^* = \frac{1}{3}\left[\overline{c} + 2\underline{c} + 3\alpha\text{-}(1\text{-}l)(k_H\text{-}k_L)\right] \\ D_1^* = \frac{1}{6\alpha}\left[\underline{c}\text{-}\overline{c} + 3\alpha + (1\text{-}l)(k_H\text{-}k_L)\right] \\ D_2^* = \frac{1}{6\alpha}\left[\overline{c}\text{-}\underline{c} + 3\alpha\text{-}(1\text{-}l)(k_H\text{-}k_L)\right] \\ \Pi_1^* = \frac{1}{18\alpha}\left[\underline{c}\text{-}\overline{c} + 3\alpha + (1\text{-}l)(k_H\text{-}k_L)\right]^2 \\ \Pi_2^* = \frac{1}{18\alpha}\left[\overline{c}\text{-}\underline{c} + 3\alpha\text{-}(1\text{-}l)(k_H\text{-}k_L)\right]^2\text{-}F \end{cases}$$

Equilibrium with an uncovered market for informed and uninformed consumers

In the uncovered market hypothesis for both kinds of consumer, we obtain a demand for both forms' products:

$$\begin{cases} D_1 = 1\text{-}\frac{p_1\text{-}k_H}{\alpha} \\ D_2 = l\left(1\text{-}\frac{p_2\text{-}k_H}{\alpha}\right) + (1\text{-}l)\left(1\text{-}\frac{p_2\text{-}k_L}{\alpha}\right) \end{cases}$$

The first-order profit maximization condition $\Pi_1 = (p_1\text{-}\overline{c})\, D_1$ gives:

$$p_1 = \frac{1}{2}\left(\alpha + \overline{c} + k_H\right)$$

The first-order profit maximization condition $\Pi_2 = (p_2\text{-}\underline{c})\, D_2$ gives:

$$p_2 = \frac{1}{2}\left[\alpha + \underline{c} + lk_H + (1\text{-}l)k_L\right]$$

The uncovered market conditions are written as:

$$\begin{cases} \overline{y}_1(k_H) < \overline{y}_2(k_H) \\ \overline{y}_1(k_L) < \overline{y}_2(k_L) \end{cases} \Leftrightarrow p_1 + p_2 > \alpha + 2k_H$$

We obtain:

$$(3\text{-}l)k_H\text{-}(1\text{-}l)k_L < \underline{c} + \overline{c} \quad \text{(C6)}$$

E6 equilibrium: firm 1 chooses a conventional strategy and firm 2 an innovation strategy. Under condition (C6), there is a single uncovered market equilibrium, such that:

$$\begin{cases} p_1^* = \frac{1}{2}\left(\overline{c} + \alpha + k_H\right) \\ p_2^* = \frac{1}{2}\left[\underline{c} + \alpha + lk_H + (1\text{-}l)k_L\right] \\ D_1^* = \frac{1}{2\alpha}\left(\alpha\text{-}\overline{c} + k_H\right) \\ D_2^* = \frac{1}{2\alpha}\left[\alpha\text{-}\underline{c} + lk_H + (1\text{-}l)k_L\right] \\ \Pi_1^* = \frac{1}{4\alpha}\left[\alpha\text{-}\overline{c} + k_H\right]^2 \\ \Pi_2^* = \frac{1}{4\alpha}\left[\alpha\text{-}\underline{c} + lk_H + (1\text{-}l)k_L\right]^2\text{-}F \end{cases}$$

Incompatibility of constraints (C5) and (C6)

We can easily show that (C5) and (C6) are incompatible with one another if and only if:

$$k_L < \frac{(2\text{-}l)\left(\underline{c} + \overline{c}\right) + \alpha(3\text{-}l)}{2(2\text{-}l)} \quad \text{(C7)}$$

Equilibrium with an uncovered market only for uninformed consumers

In the uncovered market hypothesis for uninformed consumers, we obtain the demand for both firms' products:

$$\begin{cases} D_1 = l\left(\frac{p_2\text{-}p_1 + \alpha}{2\alpha}\right) + (1\text{-}l)\left(1\text{-}\frac{p_1\text{-}k_H}{\alpha}\right) \\ D_2 = l\left(1\text{-}\frac{p_2\text{-}p_1 + \alpha}{2\alpha}\right) + (1\text{-}l)\left(1\text{-}\frac{p_2\text{-}k_L}{\alpha}\right) \end{cases}$$

The first-order profit maximization condition $\Pi_1 = (p_1\text{-}\overline{c})\, D_1$ gives:

$$2(2\text{-}l)p_1 = lp_2 + (2\text{-}l)\left(\alpha + \overline{c}\right) + 2\,(1\text{-}l)k_H$$

The first-order profit maximization condition $\Pi_2 = (p_2\text{-}\underline{c})\, D_2$ gives:

$$2(2\text{-}l)p_2 = lp_1 + (2\text{-}l)\left(\alpha + \underline{c}\right) + 2\,(1\text{-}l)k_L$$

We thus obtain the equilibrium:

$$\begin{cases} p_1^* = \frac{l(2\text{-}l)\left(\alpha + \underline{c}\right) + 2(2\text{-}l)^2\left(\alpha + \overline{c}\right) + 2l(1\text{-}l)k_L + 4(1\text{-}l)(2\text{-}l)k_H}{(4\text{-}l)(4\text{-}3l)} \\ p_2^* = \frac{l(2\text{-}l)\left(\alpha + \overline{c}\right) + 2(2\text{-}l)^2\left(\alpha + \underline{c}\right) + 2l(1\text{-}l)k_H + 4(1\text{-}l)(2\text{-}l)k_L}{(4\text{-}l)(4\text{-}3l)} \end{cases}$$

The market coverage condition for uninformed consumers is written as:

$$p_1^* + p_2^* \leq \alpha + 2k_H \quad \text{(C7)}$$

which is equivalent to:

$$(6\text{-}5\mathrm{l})k_H\text{-}2(1\text{-}\mathrm{l})k_L > \alpha\mathrm{l} + (2\text{-}\mathrm{l})\left(\underline{c} + \overline{c}\right) \quad \text{(C7)}$$

The uncovered market condition for uninformed consumers is written as:

$$p_1^* + p_2^* > \alpha + k_H + k_L \quad \text{(C7')}$$

which is equivalent to:

$$\alpha\mathrm{l} > \left(k_H + k_L\text{-}\underline{c}\text{-}\overline{c}\right)(2\text{-}\mathrm{l}) \quad \text{(C7')}$$

E7 equilibrium: firm 1 chooses the convention strategy and firm to the innovation strategy. Under conditions (C7) and (C7)', there is a single uncovered market equilibrium for uninformed consumers, such that:

$$\begin{cases} p_1^* = \dfrac{\mathrm{l}(2\text{-}\mathrm{l})\left(\alpha + \underline{c}\right) + 2(2\text{-}\mathrm{l})^2\left(\alpha + \overline{c}\right) + 2\mathrm{l}(1\text{-}\mathrm{l})k_L + 4(1\text{-}\mathrm{l})(2\text{-}\mathrm{l})k_H}{(4\text{-}\mathrm{l})(4\text{-}3\mathrm{l})} \\ p_2^* = \dfrac{\mathrm{l}(2\text{-}\mathrm{l})\left(\alpha + \overline{c}\right) + 2(2\text{-}\mathrm{l})^2\left(\alpha + \underline{c}\right) + 2\mathrm{l}(1\text{-}\mathrm{l})k_H + 4(1\text{-}\mathrm{l})(2\text{-}\mathrm{l})k_L}{(4\text{-}\mathrm{l})(4\text{-}3\mathrm{l})} \\ D_1 = \mathrm{l}\left(\dfrac{p_2\text{-}p_1 + \alpha}{2\alpha}\right) + (1\text{-}\mathrm{l})\left(1\text{-}\dfrac{p_1\text{-}k_H}{\alpha}\right) \\ D_2 = \mathrm{l}\left(1\text{-}\dfrac{p_2\text{-}p_1 + \alpha}{2\alpha}\right) + (1\text{-}\mathrm{l})\left(1\text{-}\dfrac{p_2\text{-}k_L}{\alpha}\right) \end{cases}$$

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