Downstream Labeling and Upstream Competition

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Abstract

This paper analyses the impact of labeling in a context where the products come from a supply chain. We consider a case where there is an information problem about product quality in the downstream part of the chain, but not in the upstream part. We show that the implementation of a label to solve this information problem affects competition in the upstream part of the chain. In particular, competition may be softened up to a point where both the high- and the low-quality upstream suppliers benefit from labeling while all the intermediary producers or final consumers lose from labeling. This result is established on the basis of a simple model with two vertically related markets (a competitive downstream market which is supplied by an upstream duopoly) where the quality of the downstream output is determined by the quality of the upstream input.

Keywords: Label, Imperfect consumer information, Vertical product differentiation, Vertical relations, Regulation.

JEL classification: L15, L5.

1 Introduction

The current decade has witnessed a proliferation of labels providing information related to production attributes. In which region does production take place? Is the product produced without pesticides (organic product)? Does it contain ingredients with more than the allowed percentage of genetically modified organisms (GMO) (0.9 % in Europe)? Is the price paid to farmers involved in its production in line with fair trade criteria? In many cases, the product comes from a supply chain and the information problem may appear only at a specific point in this chain. Consider poultry production as an example. Farmers can feed animals with either cereals or plant meals. Consumers usually prefer poultry fed with cereals but, without labeling, they do not know what type of feed has been used by the farmer. In this example there is an information asymmetry in the downstream poultry meat market but not in the upstream feed market. Poultry farmers know very well what type of food they are purchasing. Labeling can be used to solve the problem related to information asymmetry. For instance, the "Label Rouge" in France requires farmers to use 70% to 80% of cereals in their animal feed. In this example, as in numerous other cases with long supply chains, the label solves an information problem at a particular stage of the chain. But at the same time, it has an economic impact on the entire supply chain. Poultry labeling affects not only poultry production and prices but also the demand for feeds by farmers and feed prices. Some farmers may gain from selling high-quality labeled poultry but part of this gain may be passed on to upstream suppliers because of higher feed prices. The aim of this paper is to analyze the impact of labeling implemented in the downstream part of a supply chain, by taking into account its effect on competition in the upstream markets where there is no information asymmetry.

In this paper we consider a supply chain with upstream input suppliers, intermediary producers, and final consumers. Two vertically differentiated types of input are available in the upstream market and their quality is exogenous and known by the intermediary producers. The quality of the input chosen by the intermediary producer determines the quality of the output sold on the downstream market. The quality of output downstream is unknown by the final consumers, unless a label is implemented. Each input is supplied by a single firm with market power, while the downstream market is competitive.

This setting is particularly suitable to analyze the labeling of different agricultural products. The poultry meat case presented above is one example; GMOs are another. Without labeling, consumers have no information about the proportion of GMOs used to produce the food they are buying (even after consumption). However, farmers do know whether they are buying GM seed or not, and there is market power in the supply of both types of seed.

Our main results are the following. By revealing the quality of final products, the two products are differentiated not only at the intermediary producer level but also at the final consumer level. As a consequence, labeling relaxes upstream price competition and enables high-quality upstream firms to extract more rent from the downstream market. Interestingly, when the consumers are heterogeneous enough, price competition is relaxed to a point where labeling increases the profits of both low- and high-quality upstream firms. Finally, we show that all downstream actors may be disadvantaged by labeling, even those that seem to suffer the most from the information asymmetry (high quality intermediary producers and final consumers with high willingness to pay for the quality).

This paper contributes to the recent economic literature on the impact of quality public certification. This literature concentrates on cases where there is no ex ante mechanism (e.g. advertising, price signaling or reputation) that can credibly inform consumers about the quality of each product, so that public certification is the only way to solve the information asymmetry (see, for instance, Garella and Petrakis, 2008; Bonroy and Constantatos, 2008; Marette, 2007; Roe and Sheldon, 2007). This literature examines settings where only the market with the information asymmetry is considered. It shows that public certification generally benefits consumers with high willingness to pay, and high-quality producers. However, in particular settings, public certification can benefit either all the producers (Garella and Petrakis, 2008; Mitrokostas and Petrakis, 2008) or none of them (see Bonroy and Constantatos, 2008). Our paper extends this literature by taking into account the impact on those markets that are vertically related to the one characterized by the information asymmetry.

The impact of labeling has also been addressed in the specific case of GMOs. Lapan and Moschini (2007) develop a supply chain model without, however, considering an upstream seed market (the cost function of the farmers is exogenous). Fulton and Giannakas (2004) consider an upstream seed market where there is no information asymmetry, as we do in this paper. However the strategic interaction between suppliers of GM seed and suppliers of traditional seed is absent in their analysis. These authors assume that only one of the two upstream suppliers (the life science company which supplies the GM seed) has some market power. Our paper considers a more realistic setting with an upstream duopoly.[1]

The paper is organized as follows: Sections 2 and 3 present the model and the equilibrium both with and without labeling. The impact of the labeling is analyzed in Section 4. Different extensions are then presented in Section 5, followed by the Conclusion

2 The model

We consider a supply chain with two vertically related markets. In the upstream market, there are two *firms* ($i \in \{1, 2\}$) each one supplying a particular type of input to a continuum of *producers*. The final production is sold on the downstream market to a continuum of *consumers*. Each intermediary producer or final consumer buys either zero or one unit of product. We assume that one unit of input is required to produce one unit of output, and that the quality of the final product is determined by the type of input used.

There is no information problem in the upstream market: each producer knows perfectly the quality q_i, $i = 1, 2$, of the available input types. Two environments are considered for the downstream market. In the *regulated* environment, labeling is introduced so that the quality of final products is common knowledge (the product i being produced by the producer who uses the input i). In the *unregulated* environment, consumers do not differentiate high quality from low quality.[2] We assume that consumers perfectly anticipate

[1] Fulton and Giannakas (2004) recognize that this setting is more realistic: "Industry evidence suggests, however, that the price of the traditional seed and pesticide packages may change after the introduction of the GM crops."(p.47)

[2] We assume that the production of low quality cannot be detected and punished, so that no producer can build a reputation as in the case of experience goods. Either consumers do not know the quality of the good bought after consumption (see Darby and Karni, 1973), or consumers may know the quality of the

the proportion of each quality and make their choice on the basis of the expected quality $q_e = \alpha q_1 + (1-\alpha) q_2$, where α is the (*endogenous*) proportion of the low-quality product.

Table 1. Consumer and producer surplus

Scenario	Unregulated	Regulated
Producer surplus	$\pi_i(\omega) = p - r_i - \omega q_i$	$\pi_i(\omega) = p_i - r_i - \omega q_i$
Consumer utility	$U(\theta) = \theta q_e - p$	$U_i(\theta) = \theta q_i - p_i$

The surplus of the producer and the consumer in both the regulated and unregulated cases are defined in Table 1. r_i and p_i are, respectively, the price in the upstream and downstream market. Consumers are uniformly distributed along a taste parameter $\theta \in [\underline{\theta}, \overline{\theta}]$, and producers are uniformly distributed along a cost parameter $\omega \in [\underline{\omega}, \overline{\omega}]$. The mass of both producer and consumer populations is normalized to one. Consumers (respectively producers) choose the product that provides them with the highest surplus and do not consume (respectively produce) if this surplus is negative. A central hypothesis in this model is that the high-quality product is less cost saving for the producer. Consider the GMO case. Several studies have shown that consumers consider that the quality of food produced using GMOs is lower than that of GM-free food. However, GMOs enable better protection against pests at the farmer's level, i.e. they decrease costs due to pests.[3]

Production costs of the two inputs are identical and normalized to 0. Product quality is exogenous and product 1 is supposed to represent the lower quality ($q_1 < q_2$).

The decisions sequence corresponds to a two-stage game. At stage 1, the upstream firms choose the input prices r_i simultaneously in a Bertrand game. At stage 2, all downstream producers and consumers act as price takers so that the downstream equilibrium price p_i is such that supply is equal to demand.

For the sake of simplicity, the analysis will first be limited to those cases where the two markets are covered in equilibrium: all consumers consume and all producers produce and

good bought after consumption but do not know its origin (for example tomatoes from different producers may be sold mixed, so that consumers do not know which producer supplies which tomato).

[3] In this example, ωq_i represents the cost of pests due to the yield loss. If we consider that ω captures the pest pressure level, it is coherent to suppose that farmers are heterogeneous with respect to this parameter because pest pressure level is known to vary significantly from one region to the other. In particular, it is recognized that GMOs are more valuable on farms with high pest pressure (Fernandez-Cornejo and Caswell, 2006).

sell.[4] Results with partially covered markets will be considered in the extension (Section 5).

For clarify, in this paper the term '*firms*' refers to upstream suppliers, the term '*producers*' refers to intermediary producers who supply the downstream market, and the term '*suppliers*' refers to all suppliers in the supply chain (i.e. all firms and producers).

3 Equilibrium on downstream and upstream markets

Stage 2 is solved first in the unregulated case and then in the regulated case. These solutions enable us to establish the demand function on the upstream market, that we then use to solve stage 1.

Only one product is sold in the downstream market with no regulation. The market is covered if both $\pi_i(\omega)$ and $U(\theta)$ are positive for all the producers and consumers, which requires $\pi_1(\overline{\omega}) > 0$ and $U(\underline{\theta}) > 0$. Any price $p \in [r_1 + q_1\overline{\omega}, q_e\underline{\theta}]$ fulfils these conditions and is consequently an equilibrium of stage 2.[5]

The demand functions on the upstream market when the two products are sold are given by:

$$\begin{cases} S_1(r_1, r_2) = \frac{1}{\overline{\omega}-\underline{\omega}} \left(\overline{\omega} - \frac{r_1-r_2}{q_2-q_1} \right) \\ S_2(r_1, r_2) = \frac{1}{\overline{\omega}-\underline{\omega}} \left(\frac{r_1-r_2}{q_2-q_1} - \underline{\omega} \right) \end{cases} \tag{1}$$

so that all producers with $\omega > \frac{r_1-r_2}{q_2-q_1} \equiv \omega_{12}$ strictly prefer to buy the input 1, and all producers with $\omega < \omega_{12}$ strictly prefer to buy the input 2. These derived demand functions do not depend on the price on the downstream market because, first, the characteristic of the indifferent producer does not depend on p and, second, we are only considering equilibrium where the market is covered. Note also that the market is preempted by firm 1 if $\omega_{12} < \underline{\omega}$: the demands are then $S_1(r_1, r_2) = 1$ and $S_2(r_1, r_2) = 0$. The market is covered iff $q_e\underline{\theta} > r_1 + q_1\overline{\omega}$.

[4] The assumption of a covered market is usually made in the literature (see Tirole, 1988; Crampes and Hollander, 1995; Boom, 1995 or Wang and Yang, 2001).

[5] Note that, as a consequence of the market atomicity assumption, the high-quality producers do not use a lower price to signal the true quality. Only one price level on the downstream market is possible at the equilibrium in the unregulated case.

We now consider the regulated market case: the two products are differentiated on the downstream market and their quality is known by the consumers. It can easily be shown that consumers prefer product 2 if $\theta > \frac{p_2-p_1}{q_2-q_1}$ and product 1 otherwise. Similarly, producers prefer the product 1 if $\omega > \frac{(p_2-p_1)-(r_2-r_1)}{q_2-q_1} \equiv \omega_{12}$ and product 2 otherwise. Hence, the demand functions are:

$$\begin{cases} D_1(p_1,p_2) = \frac{1}{\overline{\theta}-\underline{\theta}}\left(\frac{p_2-p_1}{q_2-q_1} - \underline{\theta}\right) \\ D_2(p_1,p_2) = \frac{1}{\overline{\theta}-\underline{\theta}}\left(\overline{\theta} - \frac{p_2-p_1}{q_2-q_1}\right) \end{cases} \tag{2}$$

and the supply functions are:

$$\begin{cases} S_1(p_1,p_2,r_1,r_2) = \frac{1}{\overline{\omega}-\underline{\omega}}\left(\overline{\omega} - \frac{(p_2-p_1)-(r_2-r_1)}{q_2-q_1}\right) \\ S_2(p_1,p_2,r_1,r_2) = \frac{1}{\overline{\omega}-\underline{\omega}}\left(\frac{(p_2-p_1)-(r_2-r_1)}{q_2-q_1} - \underline{\omega}\right) \end{cases} \tag{3}$$

As noted above in the unregulated case, the market is covered with a continuum of downstream price equilibriums. For the low-quality product, p_1 is bracketed here between $r_1+q_1\overline{\omega}$ and $q_1\underline{\theta}$. The price of the high-quality product is determined by equating $D_2(p_1,p_2)$ to $S_2(p_1,p_2,r_1,r_2)$ which yields $p_2 = \frac{(r_2-r_1)(\overline{\theta}-\underline{\theta})+(q_2-q_1)(\overline{\theta}\overline{\omega}-\underline{\theta}\underline{\omega})}{(\overline{\theta}-\underline{\omega})-(\underline{\theta}-\overline{\omega})} + p_1$.

The demand functions on the upstream market are determined by introducing the output prices in Equation 3.[6] Both products are sold if $\underline{\theta} - \overline{\omega} < \frac{r_2-r_1}{q_2-q_1}$ and demand functions are then:

$$\begin{cases} S_1(r_1,r_2) = \frac{1}{(\overline{\theta}-\underline{\omega})-(\underline{\theta}-\overline{\omega})}\left(\frac{r_2-r_1}{q_2-q_1} - (\underline{\theta} - \overline{\omega})\right) \\ S_2(r_1,r_2) = \frac{1}{(\overline{\theta}-\underline{\omega})-(\underline{\theta}-\overline{\omega})}\left((\overline{\theta} - \underline{\omega}) - \frac{r_2-r_1}{q_2-q_1}\right) \end{cases} \tag{4}$$

Conversely, when $\underline{\theta} - \overline{\omega} > \frac{r_2-r_1}{q_2-q_1}$ the market is preempted by firm 2: the demands are then $S_2(r_1,r_2) = 1$ and $S_1(r_1,r_2) = 0$. The market is covered iff $q_1\underline{\theta} > r_1 + q_1\overline{\omega}$.

We now move backwards to the stage 1 equilibrium. To simplify the resolution we assume that $\underline{\omega} = 0$. On the upstream market, firm i ($i = 1,2$) solves the following maxi-

[6] Producers' demand on the upstream market may also be built bearing in mind that any unit of input sold generates a surplus $\pi_p(\omega)$ for the producer and a surplus $U_i(\theta)$ for the consumer. Thus, is it possible to consider a continuum of input buyers maximizing the utility function $V_i(\lambda) = \lambda q_i - r_i$, with $V_i(\lambda)$ the aggregated utility of consumers and producers, and $\lambda \equiv \theta - \omega$ uniformly distributed on $\left[\underline{\theta} - \overline{\omega}, \overline{\theta} - \underline{\omega}\right]$.

mization problem:

$$\max_{r_i} \Pi_i = r_i \; S_i(r_i, r_j) \tag{5}$$

Let the superscript U indicate unregulated equilibrium values. There is only one possible unregulated equilibrium, corresponding to a duopoly with the following input prices:

$$r_1^U = \frac{2}{3}(q_2 - q_1)\overline{\omega} \text{ and } r_2^U = \frac{1}{3}(q_2 - q_1)\overline{\omega} \tag{6}$$

These prices reflect only the producers' cost saving attribute since the final products are undifferentiated on the downstream market. The low-quality is more cost saving and, consequently, priced at a higher level compared to the high quality product. The market is covered at the equilibrium whenever $\overline{\omega} < \frac{(q_2+2q_1)\underline{\theta}}{2q_2+q_1} \equiv \overline{\omega}^U_{Max}$.[7]

The equilibrium quantities are:[8]

$$S_1^U = \frac{2}{3} \text{ and } S_2^U = \frac{1}{3} \tag{7}$$

The equilibrium output price is:

$$p^U \in \left[r_1^U + q_1\overline{\omega}, q_e\underline{\theta} = \frac{1}{3}(q_2 + 2q_1)\underline{\theta} \right] \tag{8}$$

Let a superscript R indicate regulated equilibrium values. When the two products have positive sales, regulated equilibrium input prices are:

$$r_1^R = \frac{1}{3}(q_2 - q_1)\left(\overline{\theta} - 2(\underline{\theta} - \overline{\omega})\right) \text{ and } r_2^R = \frac{1}{3}(q_2 - q_1)\left(2\overline{\theta} - \underline{\theta} + \overline{\omega}\right) \tag{9}$$

[7]Note that another duopoly equilibrium candidate is possible if $q_2 - q_1$ is high enough, $\overline{\theta} - \underline{\theta}$ is low enough, and $\overline{\omega}$ is lower but very close to $\overline{\omega}^U_{Max}$. This candidate is derived under the alternative non-covered market condition. The compilation of this equilibrium is complex and can only be made numerically. By numerous simulations, we check that firm 1 has no incentive to deviate from r_1^U when its rival charges r_2^U. Moreover firm 2 does not deviate from the pair $\left(r_1^U, r_2^U\right)$ because its best response is the same, irrespective of the market configuration (covered or not). Finally, the equilibrium candidate that we are considering here under the covered market condition is a subgame perfect Nash equilibrium.

[8]Note that a monopoly equilbrium is not possible because $\omega^U_{12} = \frac{\overline{\omega}}{3} > 0 = \underline{\omega}$.

while output prices are:

$$\begin{array}{rll} & p_1^R & \in \left[r_1^R + q_1\overline{\omega}, q_1\underline{\theta}\ \right] \\ \text{and} & p_2^R & = p_1^R + \frac{(q_2-q_1)(\overline{\theta}^2+2\overline{\theta}\overline{\omega}-\underline{\theta}(\underline{\theta}-\overline{\omega}))}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})} \end{array} \tag{10}$$

Equilibrium quantities are given by

$$S_1^R = \frac{\left(\overline{\theta} - 2(\underline{\theta} - \overline{\omega})\right)}{3(\overline{\theta} - \underline{\theta} + \overline{\omega})} \text{ and } S_2^R = \frac{(2\overline{\theta} - \underline{\theta} + \overline{\omega})}{3(\overline{\theta} - \underline{\theta} + \overline{\omega})} \tag{11}$$

This equilibrium leads to a duopoly with a fully covered market if $\overline{\omega} \in \left[\max\left(0, \overline{\omega}_{Max}^{RP}\right), \overline{\omega}_{Max}^{R}\right]$ with $\overline{\omega}_{Max}^{RP} = \frac{2\underline{\theta}-\overline{\theta}}{2}$ and $\overline{\omega}_{Max}^{R} = \frac{(2q_2+q_1)\underline{\theta}-(q_2-q_1)}{2q_2-q_1}$. [9]

4 The impact of regulation

We first analyze the impact of labeling on the upstream market. The impact of labeling on equilibrium prices and quantities is summarized in Lemma 1. As we assume that the market is covered both before and after the label, $\overline{\omega}$ is restricted to the interval $\left[\max\left(0, \overline{\omega}_{Max}^{RP}\right), \overline{\omega}_{Max}^{R}\right]$. Note that $\overline{\omega}_{Max}^{R} < \overline{\omega}_{Max}^{U}$ is always true.

Lemma 1 *$S_1^R < S_1^U$, $S_2^R > S_2^U$, $r_2^R > r_1^R$, $r_2^R > r_2^U$, and $r_1^R > r_1^U$ if and only if $\overline{\theta} > 2\underline{\theta}$.*

Proof. $S_1^R - S_1^U = -\frac{\overline{\theta}}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})} < 0$, $S_2^R - S_2^U = \frac{\overline{\theta}}{3(\overline{\theta}-\underline{\theta}+\overline{\omega}))} > 0$, $r_2^R - r_1^R = \frac{1}{3}(q_2 - q_1)(\overline{\theta} + \underline{\theta} - \overline{\omega}) > 0$, $r_2^R - r_2^U = \frac{1}{3}(q_2 - q_1)(2\overline{\theta} - \underline{\theta}) > 0$, and $r_1^R - r_1^U = \frac{1}{3}(q_2 - q_1)(\overline{\theta} - 2\underline{\theta})$. ■

Regulation affects product ranking on the upstream market. Without regulation the final product is undifferentiated. All producers therefore prefer low-quality input for cost-saving reasons. As a result, the price of the lower-quality input is higher ($r_1^U > r_2^U$). By restoring full information in the downstream market, regulation reverses product ranking since all producers will then prefer the high-quality input, despite its higher cost. Hence, $r_2^R > r_1^R$ under regulation.

[9] If $\overline{\omega} > \overline{\omega}_{Max}^{R}$, the market is not covered or is covered with firm 1 defining a price which is just sufficient to cover the market. If $\overline{\omega} < \overline{\omega}_{Max}^{RP}$ the market is preempted by firm 2. The equilibria with these alternative conditions are presented in Appendix 1.

Regulation affects input prices as follows. Better valorization of the high-quality product leads, unsurprisingly, to an increase of the corresponding input price, i.e. $r_2^R - r_2^U > 0$. More interestingly, the regulation does not necessarily lead to a decrease of the low-quality input price, despite the decrease of the corresponding output price. The low quality input price is affected by the regulation through two opposite effects. The first effect (direct and negative) is based on the decrease of firm 1's demand[10]. The second effect (indirect and positive) comes from the increase of the high quality input price ($r_2^R - r_2^U > 0$) and the fact that the prices of the two inputs are strategic complements. When consumers heterogeneity is high enough ($\overline{\theta} > 2\underline{\theta}$), the indirect positive effect dominates the direct negative effect.

Lemma 2 *The high-quality firm always benefits from the regulation. The low-quality firm also benefits from the regulation iff* $\overline{\omega} < k_1 \equiv \frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}$. *A necessary condition for the latter is* $\overline{\theta} > 2\underline{\theta}$.

Proof. See Appendix 2. ■

The label is always desirable for the high-quality firm, but may also be profitable for the low-quality firm. By revealing the true quality of product 1, the label forces firm 1 to lower its price. However, when the degree of consumers' heterogeneity is high $\left(\overline{\theta} > 2\underline{\theta}\right)$, firm 2 considers it optimal to set a high price and to cater for a small market share of producers with a high level of willingness to pay. Firm 2 acts as a puppy-dog (see Fundenberg and Tirole, 1994), thus allowing firm 1 to increase its own price (see Lemma 1). For $\overline{\omega} < k_1$, the price increase compensates for the quantity decrease ($S_1^R < S_1^U$) so that the profit of firm 1 is greater with the label.

The light-grey zone in Figure 1 represents the parameter values for which the labeling benefits the low quality. Recall that we focus here on cases where the market is covered ($\overline{\omega} < \overline{\omega}_{Max}^R$) and both upstream firms produce positive quantities at the equilibrium ($\overline{\omega} > \overline{\omega}_{Max}^{RP}$).

[10] For any input prices, $S_1(r_1, r_2)$ is lower in the equation (4) compared to equation (1).

— Insert Figure 1 about here —

We now investigate the impact of regulation on the downstream market. Recall that there is a continuum of downstream price equilibrium when the market is covered. Our analysis will be restricted here to the two extreme equilibria that are characterized as follows:

- *Scenario A* (high downstream prices) where $p^U = q_e\underline{\theta}$ and $p_1^R = q_1\underline{\theta}$. The participation constraint of the consumer described by $\underline{\theta}$ is binding. Note that this equilibrium would be the only one if we assumed that the mass of consumers was greater than the mass of producers (normalized to 1)[11].
- *Scenario B* (low downstream prices) where $p^U = r_1^U + q_1\overline{\omega}$ and $p_1^R = r_1^R + q_1\overline{\omega}$. The participation constraint of the producer with $\overline{\omega}$ is binding. Note that this equilibrium would be the only one if we assumed that the mass of producers was greater than the mass of consumers (normalized to 1)[12].

It is important to note that these scenarios affect only output prices and, consequently, the surplus sharing between producers and consumers. The quality chosen by any producer or any final consumer is the same under the two scenarios. The following lemma describes the impact of the labeling on the output prices under the two scenarios :

Lemma 3 $(p_1^R - p^U)|_B > (p_1^R - p^U)|_A$ *and* $(p_2^R - p^U)|_B > (p_2^R - p^U)|_A > 0$

Proof. $(p_1^R - p^U)|_B - (p_1^R - p^U)|_A = (p_2^R - p^U)|_B - (p_2^R - p^U)|_A = \frac{(q_2-q_1)(\overline{\theta}-\underline{\theta})}{3} > 0$
$(p_2^R - p^U)|_A = \frac{(q_2-q_1)\overline{\theta}(\overline{\theta}-\underline{\theta}+2\overline{\omega})}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})} > 0$ ■

Regulation reveals the true value of the high-quality product in the downstream market. Its price is consequently higher than that of the undifferentiated product. The

[11] More precisely, we would need to consider a mass M of consumers ($M > 1$) uniformly distributed on $[\underline{\underline{\theta}}, \overline{\theta}]$ with $(\overline{\theta} - \underline{\underline{\theta}})/(\overline{\theta} - \underline{\theta}) = M$. In this case, all producers produce and only consumers such that $\theta \geq \underline{\theta}$ consume.

[12] More precisely, we would need to consider a mass M of producers ($M > 1$) uniformly distributed on $[\underline{\omega}, \overline{\overline{\omega}}]$ with $(\overline{\overline{\omega}} - \underline{\omega})/(\overline{\omega} - \underline{\omega}) = M$. In this case, all consumers consume and only producers such that $\omega \leq \overline{\omega}$ produce.

magnitude of the price differences is different in the two scenarios. With reference to the price of the undifferentiated product, the prices of the two differentiated products with regulation are higher in scenario B than in scenario A. From this result, we can expect the regulation to be generally more beneficial to producers under scenario B and to consumers under scenario A. In the following, we study more precisely who, among producers and consumers, benefits or loses from the regulation under the two scenarios.

We first investigate the impact of regulation on the profit of each producer. Producers are distributed in three categories, depending on their quality choice with or without regulation: low-ω producers ($\omega \in [0, \omega_{12}^U = \overline{\omega} S_2^U]$) always choose the high-quality product, intermediate-ω producers ($\omega \in [\omega_{12}^U, \omega_{12}^R = \overline{\omega} S_2^R]$) switch from the low- to the high-quality product with regulation, and high-ω producers ($\omega \in [\omega_{12}^R, \overline{\omega}]$) always choose the low quality product.

Lemma 4 *i) The producer's profit variation resulting from the regulation does not increase in ω.*

ii) In scenario A, regulation lowers the profits of all producers if they are not heterogeneous enough ($\overline{\omega} < k_2 \equiv \frac{(\overline{\theta}-\underline{\theta})^2}{\underline{\theta}}$). Otherwise, only the high-quality producers with low enough production costs ($\omega < \omega_{12}^R - \frac{\overline{\theta}-\underline{\theta}}{3}$) benefit from the regulation.

iii) In scenario B, the profits of the low-quality producers are not affected by the regulation and every high-quality producer benefits from regulation.

Proof. See Appendix 3. ■

Part i) of Lemma 3 states that those producers with the lowest ω are the ones who benefit (or lose) the most (the least) from the regulation. Consider first the producers who choose the same quality (either low or high) before or after regulation. Their profit variation depends only on the output and input prices. Compared to the low-quality producers, the high-quality producers benefit from higher output prices ($p_2^R - p^U > p_1^R - p^U$) but they experience higher input prices ($r_2^R - r_2^U > r_1^R - r_1^U$). When the two effects are aggregated, it can easily be shown that the profit variation of the high-quality producer is greater ($p_2^R - p^U - \left(r_2^R - r_2^U\right) > p_1^R - p^U - \left(r_1^R - r_1^U\right)$). Consider now the intermediate category of producers who switch from low to high quality. Their profit variation is decreasing in ω and bounded between the profit variation of high-quality producers (low ω) and the profit variation of low-quality producers (high ω).

Part ii) of Lemma 3 concerns the sign of the profit variation in scenario A. The profits of the producers that keep on selling low quality, even under regulation, are reduced. The price of their product is lower because its low quality is recognized, and this loss is never compensated by the (possible) gain from a decrease of the input price. More interestingly, Lemma 3 also states that the profit of the high quality producer may decrease. By increasing the high-quality downstream price, the label is considered to benefit high-quality producers ($p_2^R - p^U > 0$). But labeling also increases the high-quality upstream price ($r_2^R - r_2^U > 0$). For $\overline{\omega} < k_2$ the high-quality producers experience a profit loss. As these producers are also those who benefit (or lose) the most (the least) from regulation, we conclude that all the producers loose from regulation under this condition. Conversely, if $\overline{\omega} \geq k_2$ (dark-grey zone in Figure 1), all the producers who keep on producing high quality benefit from labeling as do some of those who switch from low to high quality.

In scenario B (part iii) of Lemma 3), the profit of the low-quality producer is not affected by the regulation. Recall that prices are defined here so that the participation constraint of the producer with the highest ω is binding ($p^U = r_1^U + \overline{\omega} q_1$ and $p_1^R = r_1^R + \overline{\omega} q_1$). As a consequence, any variation of the low-quality input price is directly transmitted to the low-quality output price, so that the markup of the low-quality producer is not affected by the regulation. As these producers are high-ω, we conclude, by using part i) of the Lemma, that all the other producers benefit from regulation.

We now investigate the impact of regulation on the consumers.

Lemma 5 *i) In scenario A: The regulation leads to an increase of the high-quality consumer surplus and a decrease of the low-quality consumer surplus. Regulation increases the overall consumer surplus.*

ii) In scenario B: The regulation leads to a decrease of the surplus of both high quality consumers and low-quality consumers.

Proof. See Appendix 4. ■

The surplus variation of the consumer who buy the product $i = 1, 2$ with regulation is broken down as an effect of the variation of the quality $(\theta(q_i - q_e))$ and an effect of the variation of prices $(p_i^R - p^U)$. In scenario A, the quality effect dominates the price effect so that low-quality consumers loses from regulation and high-quality consumers benefit from it. In scenario B, even high-quality consumers loses from regulation. Recall that the profit variation from one scenario to the other corresponds to a transfer between producers and consumers. Since regulation leads to higher prices under scenario B (cf. Lemma 3), it can easily be understood that its impact is more favorable to producers and less to consumers.

We now synthesize the overall impact of the regulation. As expected, the regulation leads to an increase of the total welfare. The following propositions synthesize who gains and who loses from regulation among the different actors.

Proposition 1 *In scenario A, i) when $\overline{\omega} > k_2 \equiv \frac{(\overline{\theta}-\underline{\theta})^2}{\underline{\theta}}$ the regulation benefits the high-quality supply chain (firms and producers) to the detriment of the low-quality supply chain; ii) when $\overline{\omega} < k_1 \equiv \frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}$ the regulation benefits all the upstream firms (low- and high-quality) to the detriment of all the producers; iii) when $\overline{\omega} \in [k_1, k_2]$ the regulation benefits the upstream high-quality firm to the detriment of both the low-quality firm and all producers.*

Proof. The proposition is derived directly from Lemmata 2 and 4. ■

Part i) of Proposition 1 is an expected result: regulation reveals the true product quality to the consumer and benefits the high-quality suppliers at the expense of the low-quality ones. The stated condition on parameters corresponds to the dark-grey zone of Figure 1. As observed earlier, regulation decreases the profit of a fraction of producers that switch to high quality.

When $\overline{\omega} < k_1$, the impact of regulation on the suppliers no longer depends on the quality they produce but on their level in the supply chain. Regulation enables the upstream oligopoly to extract more rent from all intermediary producers. Regulation softens price competition between upstream firms by enlarging downstream heterogeneity: products are not only differentiated at the producer level but also at the consumer level. When consumers' tastes are heterogeneous enough, this effect on upstream competition dominates the quality revelation effect described in part i) of Proposition 1. The stated condition on parameters corresponds to the light-grey zone of Figure 1.

Proposition 2 *In scenario B, the regulation is profitable (or neutral) for all firms and producers to the detriment of consumers iff* $\overline{\omega} < k_1 \equiv \frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}$. *Otherwise, the regulation is profitable only to the high-quality suppliers (firm and producers).*

Proof. See Lemma 5. ■

When the two upstream firms benefit from the regulation, we have observed (Proposition 1 ii)) that it is detrimental to all the producers in scenario A. With the same condition, we observe here that it is detrimental to all the consumers in scenario B. In summary, the scenario does not affect the condition under which the firms extract more rent from the downstream actors, but it affects the actor who is subject to this rent extraction. The profit of the producer is higher in the scenario A with no regulation, but the regulation is less beneficial than in scenario B. Conversely, the consumer surplus is higher in scenario B with no regulation, but the regulation is less beneficial to them compared to scenario A.

5 Extensions

This section extends the previous results to a larger set of parameters values. Until now, our analysis was limited to a base case where the equilibrium is a duopoly with a covered market, both with and without labeling ($\overline{\omega} \in \left[\max\left(0, \overline{\omega}^{RP}_{Max}\right), \overline{\omega}^{R}_{Max}\right]$, see Figure 1). Here, we still suppose that the equilibrium without labeling is a covered duopoly[13] ($\overline{\omega} \in \left(0, \overline{\omega}^{U}_{Max}\right]$), but no restriction is made concerning the structure at the equilibrium with labeling. The equilibrium with labeling under the different structures is presented

[13] Without labeling, we do not consider the equilibrium with a non-covered market because its compilation is very complex and can only be made numerically.

in Appendix 1. We first discuss the impact of the regulation under far downstream price scenario A.[14]

— Insert Figure 2 about here —

If $\overline{\omega} < \overline{\omega}^{RP}_{Max}$, the labeling leads to the exit of the low-quality firm, so that all producers and consumers use high quality after labeling. By construction, labeling cannot benefit both upstream firms ($k_1 = 0$). All the producers lose from labeling if they are homogeneous enough ($\overline{\omega} < \theta/4$) because firm 2 can then define a higher input price.

If $\overline{\omega} > \overline{\omega}^{RU}_{Max}$, labeling leads to an equilibrium with a duopoly and an uncovered market. As in the base case considered above, there are two threshold values on $\overline{\omega}$ under which labeling leads to a gain of both upstream firms ($\overline{\omega} < k_1$) or to a loss of all the farmers ($\overline{\omega} < k_2$). Importantly, labeling can now lead to a decrease of the consumer surplus if $\overline{\omega} > k_3$. This non-covered situation leads to a new source of loss: the low-θ consumers no longer buy some product after labeling. Note, finally, that there is an intermediate case when $\overline{\omega} \in [\overline{\omega}^{R}_{Max}, \overline{\omega}^{RU}_{Max}]$. At the equilibrium, the price defined by the low-quality firm leads exactly to the market coverage. The properties with this equilibrium are identical to those obtained in the base case where the market is covered in the usual sense.

The same extensions have been carried out when scenario B is considered, and the results are qualitatively the same as in Proposition 2. In summary, the two propositions elaborated in the base case are robust with respect to these extensions. In figure 2 we see that the two threshold values (k_1 and k_2) are non decreasing in $\overline{\theta}/\underline{\theta}$. As the consumer heterogeneity increases, labeling leads to a more important relaxation of the competition between the upstream firms. The zone of parameters where both upstream firms gain from labeling is more important, as is the zone where all the farmers lose from labeling.

6 Conclusions

The present paper considers the effects of labels in a supply chain with two vertically related markets: a competitive downstream market which is supplied by an upstream

[14] The detailed calculus behind this figure can be provided by the authors upon request.

duopoly. The analysis above has shown that, by increasing the final market heterogeneity, labeling may help the upstream firms to extract more rent from the downstream actors. More specifically, labeling may soften upstream price competition to the detriment of each downstream producer or all consumers. Unlike high-quality upstream firm, high-quality downstream producers and consumers with a high level of willingness to pay are not sure to benefit from labeling. To our knowledge, these are original results.

The policy implications of our analysis are also important. The present paper sheds light on who in the supply chain will receive the benefits and who will bear the burden of regulation. We show that a label is justified if the objective function is welfare maximization but may be inefficient if the regulator assigns a large weight to downstream market actors that apparently suffer from asymmetric information (high-quality intermediary producers or final consumers with high marginal utility of quality). By introducing labels to eliminate asymmetric information in the downstream market, regulators may reduce competition in the upstream market and fail to improve the outcome for high-quality producers or final consumers. Moreover, if the label is not mandatory, it may be avoided by high-quality producers, in which case it is inefficient.

Our analysis is carried out for a covered markets structure, but we have shown that our results are robust if we assume that regulation leads to the exit of the low-quality firm or to uncovered markets. We are nevertheless aware of the limitations of this analysis. Among other things, the robustness of our results should also be checked in a framework where the upstream costs of improving quality are positive.

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Appendix

Appendix 1: The subgame perfect Nash equilibriums when the market is regulated.

In the paper we compute the equilibrium candidate corresponding to the covered market in the usual sense. In this appendix we present three equilibrium candidates corresponding to the other market configuration, and we determine the subgame perfect Nash equilibria.

1) When $\underline{\theta}-\overline{\omega} > \frac{r_2-r_1}{q_2-q_1}$, the firm 2 preempts the market. Firm 2 chooses the maximum price $r_2 = (q_2-q_1)(\underline{\theta}-\overline{\omega})$ that reduces its rival's market share to zero. As in the covered duopoly case there is a range of downstream prices ($p_2 \in [r_2+q_2\overline{\omega}, q_2\underline{\theta}]$) that corresponds to the downstream equilibrium.

Let the superscript RP indicate regulated equilibrium under preemption. For $\overline{\omega} \in \left(0, \overline{\omega}^{RP}_{Max} \equiv \frac{2\underline{\theta}-\overline{\theta}}{2}\right]$, the equilibrium prices are:

$$r_1^{RP} = 0,\ r_2^{RP} = (q_2-q_1)(\underline{\theta}-\overline{\omega}) \text{ and } p_2^{RP} \in \left[r_2^{RP}+q_2\overline{\omega}, q_2\underline{\theta}\right]$$

2) When $q_1\underline{\theta} < r_1 + q_1\overline{\omega}$, the regulated market is not covered. the demand functions are:

$$\begin{cases} D_1(p_1,p_2) = \frac{1}{\overline{\theta}-\underline{\theta}}\left(\frac{p_2-p_1}{q_2-q_1} - \frac{p_1}{q_1}\right) \\ D_2(p_1,p_2) = \frac{1}{\overline{\theta}-\underline{\theta}}\left(\overline{\theta} - \frac{p_2-p_1}{q_2-q_1}\right) \end{cases}$$

and the supply functions of intermediary producers are:

$$\begin{cases} S_1(p_1,p_2,r_1,r_2) = \frac{1}{\overline{\omega}-\underline{\omega}}\left(\frac{p_1-r_1}{q_1} - \frac{(p_2-p_1)-(r_2-r_1)}{q_2-q_1}\right) \\ S_2(p_1,p_2,r_1,r_2) = \frac{1}{\overline{\omega}-\underline{\omega}}\left(\frac{(p_2-p_1)-(r_2-r_1)}{q_2-q_1} - \underline{\omega}\right) \end{cases}$$

with by assumption $\underline{\omega} = 0$.

Both downstream price of the high quality and low quality are determined by equating $D_2(p_1,p_2)$ to $S_2(p_1,p_2,r_1,r_2)$ and $D_1(p_1,p_2)$ to $S_1(p_1,p_2,r_1,r_2)$. Using theses prices and the supply functions of intermediary producers we determine the following demand functions on the upstream market:

$$\begin{cases} S_1(r_1,r_2) = \frac{1}{(\overline{\theta}-\underline{\omega})-(\underline{\theta}-\overline{\omega})}\left(\frac{r_2-r_1}{q_2-q_1}-\frac{r_1}{q_1}\right) \\ S_2(r_1,r_2) = \frac{1}{(\overline{\theta}-\underline{\omega})-(\underline{\theta}-\overline{\omega})}\left(\left(\overline{\theta}-\underline{\omega}\right)-\frac{r_2-r_1}{q_2-q_1}\right) \end{cases}$$

Let a superscript RU indicate regulated equilibrium in the uncovered solution. For $\overline{\omega} \in \left[\max\left(0, \overline{\omega}^{RU}_{Max} \equiv \frac{(4q_2-q_1)\underline{\theta}-(q_2-q_1)\overline{\theta}}{(4q_2-q_1)}\right), \infty\right)$[15], the equilibrium prices are:

$$\begin{aligned} r_1^{RU} &= \frac{(q_2-q_1)\,q_1\overline{\theta}}{4q_2-q_1} \text{ and } r_2^{RU} = \frac{2\,(q_2-q_1)\,q_2\overline{\theta}}{4q_2-q_1} \\ p_1^{RU} &= q_1\overline{\theta}\left(1-\frac{3q_2\left(\overline{\theta}-\underline{\theta}\right)}{(4q_2-q_1)\left(\overline{\theta}-\underline{\theta}+\overline{\omega}\right)}\right) \\ \text{and } p_2^{RU} &= q_2\overline{\theta}\frac{2\,(q_2-q_1)\left(\overline{\theta}-\underline{\theta}\right)+(4q_2-q_1)\,\overline{\omega}}{(4q_2-q_1)\left(\overline{\theta}-\underline{\theta}+\overline{\omega}\right)} \end{aligned}$$

3) For some values of parameters, a corner solution prevails where the regulated market is covered with firm 1 quoting the price $r_1 = (\underline{\theta}-\overline{\omega})\,q_1$ which is just sufficient to cover the market.[16] Conversely to the duopoly case where the market is covered in the usual sense (the case developed in the paper), there is an unique downstream price equilibrium. Indeed, both participation constraint of the producer with the highest production cost and participation constraint of the consumer with the lowest willingness to pay are binding, $p_1 = r_1 + q_1\overline{\omega} = q_1\underline{\theta}$.

Let a superscript RC indicate regulated equilibrium in this corner solution. For $\overline{\omega} \in \left[\max\left(0, \overline{\omega}^{R}_{Max}\right), \overline{\omega}^{RU}_{Max}\right]$, the equilibrium prices are:

$$\begin{aligned} r_1^{RC} &= (\underline{\theta}-\overline{\omega})\,q_1 \text{ and } r_2^{RC} = \frac{q_2\overline{\theta}-q_1\left(\overline{\theta}-\underline{\theta}+\overline{\omega}\right)}{2} \\ p_1^{RC} &= q_1\underline{\theta} \text{ and } p_2^{RC} = \frac{q_2\overline{\theta}\left(\overline{\theta}-\underline{\theta}+2\overline{\omega}\right)-q_1\left(\overline{\theta}-\underline{\theta}\right)\left(\overline{\theta}-\underline{\theta}+\overline{\omega}\right)}{2\left(\overline{\theta}-\underline{\theta}+\overline{\omega}\right)} \end{aligned}$$

As the parameters constellations are specific to each market configuration ($\overline{\omega}^{RP}_{Max} <$

[15] This condition ensures that $q_1\underline{\theta} < r_1^{RU} + q_1\overline{\omega}$ (i.e. $\overline{\omega} > \frac{p_1^{RU}-r_1^{RU}}{q_1}$ and $\underline{\theta} < p_1^{RU} q_1$).

[16] See Gabszewicz and Thisse, 1979, Shaked and Sutton, 1982 and Wauthy, 1996.

$\overline{\omega}^{R}_{Max} < \overline{\omega}^{RU}_{Max}$), each equilibrium candidate is a subgame perfect Nash equilibrium. We may note that when $\overline{\omega}$ tends to 0, we recognize the Nash equilibrium in prices and the associated parameters domains of a duopoly model of vertical product differentiation without vertical relation (see Wauthy, 1996).

Appendix 2: Proof Lemma 2.

Assuming that the market is covered both before and after the label, $\overline{\omega}$ is restricted to lie within the interval $\left[\max\left(0, \overline{\omega}^{RP}_{Max}\right), \overline{\omega}^{R}_{Max}\right]$. Note that $\frac{(2q_2+q_1)\underline{\theta}-(q_2-q_1)\overline{\theta}}{2q_2+q_1} \equiv \overline{\omega}^{R}_{Max} < \frac{(q_2+2q_1)\underline{\theta}}{2q_2+q_1} \equiv \overline{\omega}^{U}_{Max}$ is always true.

1. The impact of label on firm 2's profit is given by $\Pi^R_2 - \Pi^U_2 = \frac{1}{9}(q_2-q_1)\left(\overline{\theta}\left(\frac{4\overline{\theta}-3(\underline{\theta}-\overline{\omega})}{\overline{\theta}-\underline{\theta}+\overline{\omega}}\right)-\underline{\theta}\right)$, as $4\overline{\theta}-3(\underline{\theta}-\overline{\omega}) > \overline{\theta}-\underline{\theta}+\overline{\omega}$ then $\Pi^R_2 - \Pi^U_2 > 0$,
2. The impact of label on firm 1's profit is given by $\Pi^R_1 - \Pi^U_1 = \frac{(q_2-q_1)\left((\overline{\theta}-2\underline{\theta})^2-4\underline{\theta}\overline{\omega}\right)}{9(\overline{\theta}-\underline{\theta}+\overline{\omega})}$. Two case may arise: i) when $\overline{\omega} \in \left[\max\left(0, \overline{\omega}^{RP}_{Max}\right), \frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}\right]$ then $\Pi^R_1 - \Pi^U_1 > 0$, and ii) when $\overline{\omega} \in \left[\frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}, \overline{\omega}^{R}_{Max}\right]$ then $\Pi^R_1 - \Pi^U_1 < 0$. We may note that the interval $\left[\max\left(0, \overline{\omega}^{RP}_{Max}\right), \frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}}\right]$ exists iff $\overline{\theta} > 2\underline{\theta}$ (i.e. $\frac{(\overline{\theta}-2\underline{\theta})^2}{4\underline{\theta}} > \overline{\omega}^{RP}_{Max}$), so $\overline{\theta} > 2\underline{\theta}$ is a necessary condition to have $\Pi^R_1 - \Pi^U_1 > 0$.

Appendix 3: Proof Lemma 4.

- Scenario A (proof of part i) and ii))

Recall that $\omega^U_{12} = \frac{\overline{\omega}}{3}$ and $\omega^R_{12} = \frac{(2\overline{\theta}-\underline{\theta}+\overline{\omega})\overline{\omega}}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})}$. The producers population may be decomposed in three groups:

1. Producers defined by $\omega \in \left[0, \omega^U_{12}\right]$ supply high-quality output both without and with regulation. The regulation leads to the following profit variation $\left(p^R_2 - r^R_2\right) - \left(p^U - r^U_2\right) = \frac{(q_2-q_1)\left(\underline{\theta}\overline{\omega}-(\overline{\theta}-\underline{\theta})^2\right)}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})}$. This profit variation does not depend on ω and is consequently non increasing in ω. It is negative when $\overline{\omega} \in \left[\max\left(0, \overline{\omega}^{RP}_{Max}\right), \frac{(\overline{\theta}-\underline{\theta})^2}{\underline{\theta}}\right]$, and positive when $\overline{\omega} \in \left[\frac{(\overline{\theta}-\underline{\theta})^2}{\underline{\theta}}, \overline{\omega}^{R}_{Max}\right]$.

2. Producers defined by $\omega \in \left[\omega_{12}^{U}, \omega_{12}^{R}\right]$ switch from the low to the high quality because of the regulation. Their profit variation from the regulation is given by $\left(p_2^R - r_2^R - \omega q_2\right) - \left(p^U - r_1^U - \omega q_1\right) = \frac{(q_2-q_1)\left(\overline{\omega}^2+\overline{\theta}\overline{\omega}-(\overline{\theta}-\underline{\theta})^2\right)}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})} - \omega\left(q_2 - q_1\right)$. This profit variation is decreasing in ω, positive for $\omega \in \left[\omega_{12}^{U}, \omega_{12}^{R} - \frac{\overline{\theta}-\underline{\theta}}{3}\right]$ and negative for $\omega \in \left[\omega_{12}^{R} - \frac{\overline{\theta}-\underline{\theta}}{3}, \omega_{12}^{R}\right]$. Note that the profit variation is always negative for all these producers if $\overline{\omega} \in \left[\max\left(0, \overline{\omega}_{Max}^{RP}\right), \frac{(\overline{\theta}-\underline{\theta})^2}{\underline{\theta}}\right]$ because we then have $\omega_{12}^{R} - \frac{\overline{\theta}-\underline{\theta}}{3} < \omega_{12}^{U}$.

3. Producers defined by $\omega \in \left[\omega_{12}^{R}, \overline{\omega}\right]$ supply high-quality output both without and with regulation. The impact of regulation on their profit is given by $\left(p_1^R - r_1^R\right) - \left(p^U - r_1^U\right) = -\frac{1}{3}\left(q_2 - q_1\right)\left(\overline{\theta} - \underline{\theta}\right) < 0$. This profit variation does not depend on ω and is consequently non increasing in ω.

- *Scenario B (proof of part i) and iii))*

As in scenario A, producers are distributed in three categories:

1. Producers, defined by $\omega \in \left[0, \omega_{12}^{U}\right]$, supply high-quality output before and after the regulation. The impact of regulation on their profit is given by $\left(p_2^R - r_2^R\right) - \left(p^U - r_2^U\right) = \frac{(q_2-q_1)\overline{\theta}\overline{\omega}}{3(\overline{\theta}-\underline{\theta}+\overline{\omega})} > 0$.

2. Producers, defined by $\omega \in \left[\omega_{12}^{R}, \overline{\omega}\right]$, supply low-quality output before and after the regulation; the impact of the label on their profit is given by $\left(p_1^R - r_1^R\right) - \left(p^U - r_1^U\right) = 0$.

3. The profit of any producer who switch from low- to high-quality product (defined by $\omega \in \left[\omega_{12}^{U}, \omega_{12}^{R}\right]$) is necessarily positive, because he would otherwise keep on producing the low quality.

Note that the profit variation is non increasing in ω since it is independent from ω in the first and the third category and $\frac{\partial\left(\left(p_2^R - r_2^R - \omega q_2\right) - \left(p^U - r_1^U - \omega q_1\right)\right)}{\partial \omega} = -\left(q_2 - q_1\right) < 0$ for the second category ($\omega \in \left[\omega_{12}^{U}, \omega_{12}^{R}\right]$).

Appendix 4: Proof Lemma 5.

- *Scenario A (proof of part i))*

In the unregulated market consumer surplus is given by: $SC^U = \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\overline{\theta}} (\theta q_e - p^U) d\theta$.

In the regulated market we have : $SC^R = SC_1^R + SC_2^R$ with $SC_1^R = \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\frac{p_2^R - p_1^R}{q_2 - q_1}} (\theta q_1 - p_1^R) d\theta$ and $SC_2^R = \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\frac{p_2^R - p_1^R}{q_2 - q_1}}^{\overline{\theta}} (\theta q_2 - p_2^R) d\theta$.

- The impact of regulation on the low-quality consumer surplus is given by : $SC_1^R - \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\frac{p_2^R - p_1^R}{q_2 - q_1}} (\theta q_e - p^U) d\theta = \frac{(q_1-q_2)(\overline{\theta}-\underline{\theta})\left(\overline{\theta}-2\underline{\theta}+2\overline{\omega}\right)^2}{54(\overline{\theta}-\underline{\theta}+\overline{\omega})^2} < 0$
- The impact of regulation on the high-quality consumer surplus is given by : $SC_2^R - \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\frac{p_2^R - p_1^R}{q_2 - q_1}}^{\overline{\theta}} (\theta q_e - p^U) d\theta = \frac{(q_2-q_1)(\overline{\theta}-\underline{\theta})\left(\overline{\theta}+\underline{\theta}-\overline{\omega}\right)\left(2\overline{\theta}-\underline{\theta}+\overline{\omega}\right)}{27(\overline{\theta}-\underline{\theta}+\overline{\omega})^2} > 0$
- The impact of regulation on the total consumer surplus, given by SC^R, is positive iff $\left(\overline{\theta}^2 + 2\overline{\theta}(\underline{\theta}-\overline{\omega}) - 2(\underline{\theta}-\overline{\omega})^2\right) > 0$ this condition is always respected in a duopoly equilibrium.

- *Scenario B (proof of part ii))*

The impact of regulation on the low-quality consumer surplus is given by :

$$SC_1^R - \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\underline{\theta}}^{\frac{p_2^R - p_1^R}{q_2 - q_1}} (\theta q_e - p^U) d\theta = \frac{(q_1 - q_2)\left(\overline{\theta}-\underline{\theta}\right)\left(\overline{\theta}-2\underline{\theta}+2\overline{\omega}\right)\left(7\overline{\theta}-8\underline{\theta}+8\overline{\omega}\right)}{54(\overline{\theta}-\underline{\theta}+\overline{\omega})^2} < 0$$

The impact of regulation on the high-quality consumer surplus is given by :

$$SC_2^R - \frac{1}{\overline{\theta}-\underline{\theta}} \int_{\frac{p_2^R - p_1^R}{q_2 - q_1}}^{\overline{\theta}} (\theta q_e - p^U) d\theta = \frac{2\left(q_1 - q_2\right)\left(\overline{\theta}-\underline{\theta}\right)\left(\overline{\theta}-2\underline{\theta}+2\overline{\omega}\right)\left(2\overline{\theta}-\underline{\theta}+\overline{\omega}\right)}{27(\overline{\theta}-\underline{\theta}+\overline{\omega})^2} < 0$$

Figure

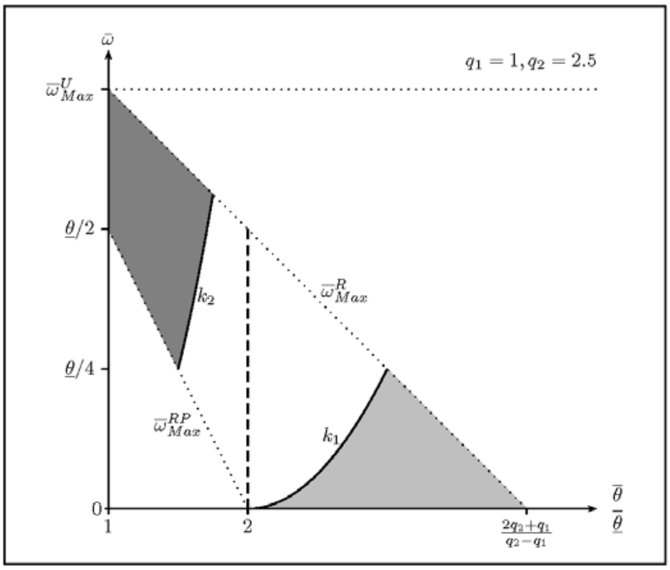

Figure 1: The partition of regulated equilibrium when the market is covered

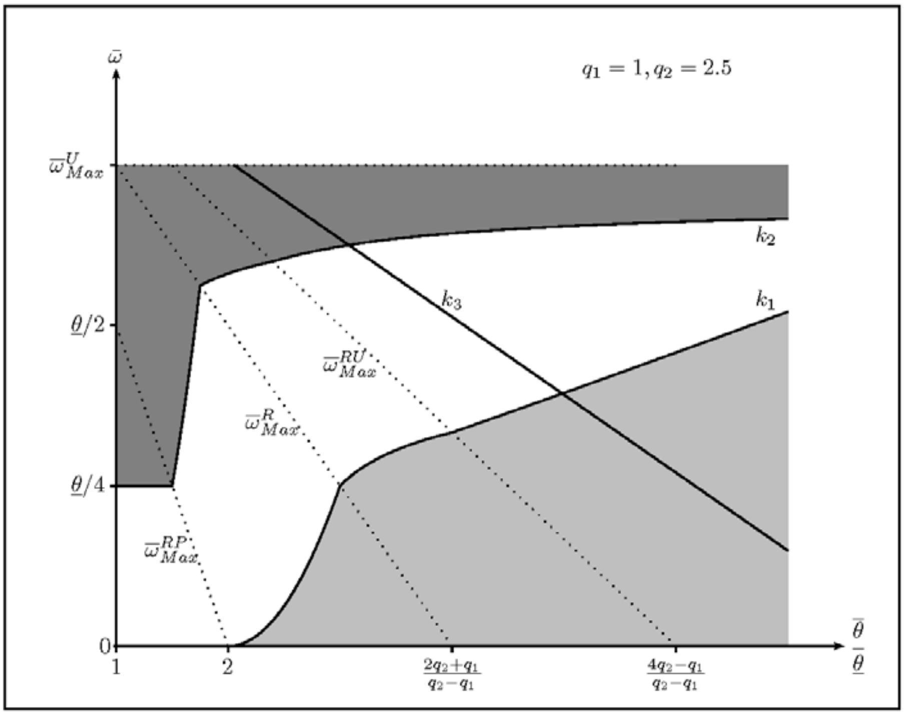

Figure 2: The partition of regulated equilibrium when no restriction is made concerning the market structure