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Credence Goods, Efficient Labelling Policies, and Regulatory Enforcement

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Abstract. We analyse the optimality of information revelation of hidden attributes of "credence goods" via alternative labelling procedures. When consumers are heterogeneous in their willingness to pay for the hidden attribute, producers can either self-label their products, or have them certified by a third party. The government can impose self or third party labelling requirements on either the "green" or the "brown" producers. Our benchmark model develops a condition that links the optimal imposition of third party labelling to the relative market share of each type of the good under complete information. We extend our analysis to incorporate asymmetric information and cheating by the producers. When corrupt producers can affix spurious labels, the government needs to supplement the labelling policy with costly monitoring activities. We find that mandatory self-labelling schemes generally dominate mandatory third party labelling, unless the "market share effect" greatly exceeds the "incentive-to-cheat effect".

Key words: corruption, credence goods, eco-labelling, monitoring, self-labelling, third party labelling

JEL classification: Q58, L15, D82

1. Introduction

There are numerous instances when consumers care about, and are willing to pay more for, an attribute of a product that is unobservable to them even after consumption. The hidden attribute may be one that has environmental or health consequences, or an aspect of its production process that violates notions of "fair trade" or human rights. Such products are called *credence goods*. An example is genetically modified (GM) food, since genetic modification is usually unobservable (unless revealed by the producer) to consumers. Due to the unsettled state of the science of GM organisms, many consumers have concerns about the long-term ecological and health impacts of GM crops, and are willing to pay more for the non-GM variety.[1]'Dolphin-safe' tuna is another example. Here, as in many other similar situations, consumers' concern for the environment is manifested in their willingness to pay a premium for the "greener" product (Forsyth et al. 1999; Amacher et al. 2004; Bjorner et al. 2004). This willingness of consumers to pay more for environment-friendly goods amounts to their voluntarily contributing to a public good, and has been called "impure altruism" by Andreoni (1990).[2]

When a desirable attribute (such as the environmental friendliness of a product) is private information to the producers, even "non-green" producers will have an incentive to pretend to be green in order to profit from the consumers' higher willingness to pay. Therefore, in the absence of credible information disclosure mechanisms, consumers will find it difficult to believe firms' claims about the greenness of their products, and firms will in turn find it difficult to sell greener products that are costlier to produce. One possible way to break this deadlock is the use of eco-labels by firms. Such strategies to increase information on the environmental friendliness of products have been called the "third wave" in environmental policy (Tietenberg 1998).[3]

The growing popularity of eco-labels has recently led economists to formally analyse them.[4] A common analytical approach has been to treat eco-labels as another means of vertical product differentiation available to firms. Quality competition (using eco-labels) among firms is modelled as another stage preceding price or output competition in a multi-stage game.[5] Amacher et al. (2004) model eco-labelling as an investment in a three-stage game with quality and price competition. Sedjo and Swallow (2002) find that consumers' higher willingness to pay is insufficient for a price premium to exist for certified goods. In another study, they show that eco-labelling may have undesirable ecological consequences (Swallow and Sedjo 2000). Other studies examine various issues such as "voluntary overcompliance" (Arora and Gangopadhyay 1995; Kirchhoff 2000) and eco-labels as trade barriers (Tian 2003; Greaker 2006).

Our paper focuses on the design of optimal regulatory policy and its enforcement. In a binary case, where there are only two possible types of producers of a good, "green" (i.e. producers whose products have a desirable, but hidden, attribute) and "brown" (i.e. producers whose products lack the desirable attribute), labelling by *any* one type is sufficient to solve the information asymmetry problem.[6] The questions we address are: (i) which *type* of producers should label their product, and (ii) what *method* of labelling should be followed. While it is true that if labelling was perfect and voluntary only green firms would seek eco-labels, the government could impose mandatory labelling requirement on the brown firms if this turned out to be welfare enhancing.[7]

Two methods of labelling are considered in this paper – "self-labelling" and "third party labelling". These, respectively, correspond to ISO 14021 (or

"Type II") and ISO 14024 (or "Type I") types of environmental claims.[8] In self-labelling, firms make claims about some hidden attribute of their product that consumers care about (such as "made from $x\%$ recycled material", "organic", etc.). Although such *cheap talk* is generally costless, there is an adverse selection problem associated with it. In fact, to prevent misleading advertising by firms, organisations such as the US Federal Trade Commission and the EU have issued guidelines for making environmental claims. In third party labelling, on the other hand, firms obtain permission, in return for a payment, to use the logo or seal of approval issued by a labelling agency (such as EU's *Eco-Label* and Canada's *EcoLogo*). The labelling agency is often a governmental or quasi-governmental organisation. Such *costly signals* are, in general, more credible to consumers.

We consider the following manner in which the different labels are applied. When they self-label their products, the firms print claims (e.g. "phosphate-free detergent") about their product's hidden attribute on the product's packaging. Hence, self-labelling imposes negligible additional costs on the firms. Under third party labelling, the firms have to pass the labelling agency's initial certification process before getting permission to affix the agency's seal of approval on their product.[9] Thus, under both methods of labelling, the labels are affixed by the firms themselves. This leaves both self- and third party labelling open to misuse by brown firms, which have an incentive to pass off as green. Under self-labelling, a brown firm can cheat by simply making false claims. On the other hand, under third party labelling, brown firms can cheat either by using fake labels or by evading labelling rules, depending upon the regulatory policy. For example, when only green firms are required to get their product labelled by a labelling agency, brown firms can affix spurious look-alike labels to their product (without the agency's knowledge or approval), in order to feign greenness.[10] Alternatively, when the regulatory policy requires brown firms to carry a third party label, these firms can pretend to be green by simply ignoring this rule. Either way, when brown firms can circumvent the labelling process, the government has to monitor the green firms in order to deter brown firms from cheating. Monitoring can be done by scrutinising the output or production operations of some randomly chosen firms that profess to be green, in order to verify their environment friendliness. If a brown firm is caught pretending to be green, it faces a penalty which acts as the deterrence.[11]

This paper investigates optimal labelling rules both when the labelling process is reliable (Section 3), as well as when the labelling process can be misused by dishonest firms (Section 4). Our results show that the optimal labelling policy depends on relative magnitude of the costs of production, labelling, and monitoring (if required). If all firms act honestly, monitoring is not required, and the optimal third party labelling policy then depends on the production and labelling costs alone. Specifically, third party labelling requirement should be imposed on brown firms if and only if the market share of the brown good is less than a threshold value that depends on labelling costs. Of course, honest self-labelling would costlessly solve the information asymmetry problem, and trivially lead to the first-best outcome.

In contrast, when dishonest firms can misuse third party labels, monitoring becomes necessary to deter brown firms from cheating. Consequently, monitoring costs need to be additionally considered while designing optimal labelling rules. The optimal third party labelling policy then depends on a new threshold market share, which can be higher or lower than the corresponding threshold in the absence of monitoring, depending on the relative strength of the "market-share effect" and "incentive-to-cheat effect". Moreover, comparing the respective levels of social welfare, we find that a self-labelling scheme generally dominates third party labelling by either brown or green firms. The only exception to this occurs when the "market-share effect" greatly exceeds the "incentive-to-cheat effect", whence third party labelling by green firms becomes the most preferred option. We provide a numerical example (Section 5) to illustrate our conclusions.

Kirchhoff and Zago (2001) have analysed the optimality of costly third-party labelling policies for GM and non-GM food. They too find that third party labelling by non-GM firms (or what they term "voluntary labelling") is preferable to third party labelling by GM firms (or their "mandatory labelling") when the number of green consumers is less than a threshold, and vice versa. There is, however, an asymmetry in the financing of the two alternative labelling schemes in Kirchhoff and Zago's paper: when the non-GM firms label, they pay the cost of third party labelling; but when the GM firms label, the cost of third party labelling is borne by the government. This cost advantage to GM firms makes more consumers choose the GM variety than would be the case if GM firms had to bear their own labelling cost. We ignore such discriminatory behaviour on part of the government favouring the GM (or brown) firms, and assume that each type of firms pay the third party labelling cost when they do such labelling. Only the monitoring cost is borne by the government, for all methods of labelling, in our paper. Unlike us, Kirchhoff and Zago do not focus on enforcement problems, and hence do not distinguish between third party labelling cost and monitoring cost. Another difference between our paper and Kirchhoff and Zago (2001) is that they do not consider the self-labelling option, which involves a monitoring but no labelling cost. Including this option in our analysis, we find that the self-labelling option generally dominates third party labelling, and should be preferred by the policymaker in most cases.

Mason (2006) has analysed the welfare implications of third party eco-labelling as an imperfect and costly signal of quality. His random labelling process allows for both Type I (a green firm is mistakenly certified as brown) and Type II (brown firm certified as green) errors, and the rational expectation prices are determined in equilibrium using Bayes' rule. Mason shows that introduction of the eco-labelling option can increase or reduce social welfare, depending upon parameter values and whether firms have the option of choosing their production technology. One major difference of our paper with Mason's is that we do not consider unintentional errors in the labelling process. Instead we take into consideration incentives for firms to deliberately misuse the labelling process by taking recourse to dishonest means.

In the next section, we outline the model and solve for the full information equilibrium when consumers can observe the product type and no labelling is required. This is the benchmark case for our subsequent analysis of hidden information (in Sections 3 and 4).

2. First Best Outcome: Complete Information

Consider a good that is vertically differentiated into two types – brown (type 1) and green (type 2) – with all consumers preferring the latter to the former. Each type of the good is produced by a large number of identical firms under perfect competition with free entry and exit. The total cost of producing q_i units of type i good ($i = 1,2$) consists of the fixed cost K_i, and the variable cost $\frac{1}{2}c_i q_i^2$. We assume $K_2 > K_1$ and $c_2 > c_1$ to represent a higher cost of producing the green variety. With p_i denoting the price of type i good, the profit of a representative type i firm producing q_i units of type i good is

$$\pi_i = p_i q_i - K_i - \frac{1}{2} c_i q_i^2. \tag{1}$$

Each firm maximises profit with respect to quantity by taking price as given. Due to free entry/exit, the equilibrium profit of each firm is zero. This zero-profit condition, together with the first order condition (FOC) for profit maximisation, yields the equilibrium price and quantity as

$$p_i^* = \sqrt{2c_i K_i}, \quad q_i^* = \sqrt{2K_i/c_i}. \tag{2}$$

Note that q_i^* is also the output that minimizes the average cost $1/2c_i q_i + K_i/q_i$. Thus, in equilibrium, each firm produces at its *minimum efficient scale*.

With complete information, consumers can observe the good's type.[12] It is assumed that each consumer inelastically demands one unit of the good, and is willing to pay $(M - \theta)$ dollars for the type 1 good, and M dollars for the type 2 good. θ is a parameter that represents a consumer's measure of "distaste" for the brown good and is assumed to be uniformly distributed with support [0,1]. A consumer is indifferent between buying good of either type when $M - \theta - p_1^* = M - p_2^*$. Thus the indifferent consumer has a threshold value of θ given by

$$\theta^* = p_2^* - p_1^* = \sqrt{2c_2K_2} - \sqrt{2c_1K_1}. \tag{3}$$

The consumers with distaste parameter less (more) than θ^* will buy the brown (green) good under complete information, and can be interpreted as "brown (green) consumers". We assume that the parameters of our model are such that both types of the good are produced in equilibrium, i.e.

Assumption A1. *Costs are such that* $0 < \sqrt{2c_2K_2} - \sqrt{2c_1K_1} < 1$.[13]

Since each type i firm produces q_i^* units of the good, the equilibrium number of type i firms, n_i^*, is

$$n_1^* = \theta^*/\sqrt{2K_1/c_1} = \sqrt{c_1c_2K_2/K_1} - c_1, \tag{4a}$$

$$n_2^* = (1-\theta^*)/\sqrt{2K_2/c_2} = \sqrt{c_1c_2K_1/K_2} + \sqrt{c_2/2K_2} - c_2. \tag{4b}$$

The market equilibrium under full information as derived above can be shown to be socially optimal or first best. The social welfare is represented by

$$\begin{aligned} W &= \int_0^\theta (M-\theta)d\theta + \int_\theta^1 Md\theta - (K_1 + \frac{1}{2}c_1q_1^2)\theta/q_1 \\ &\quad - (K_2 + \frac{1}{2}c_2q_2^2)(1-\theta)/q_2 \\ &= M - \frac{1}{2}\theta^2 - (K_1 + \frac{1}{2}c_1q_1^2)\theta/q_1 - (K_2 + \frac{1}{2}c_2q_2^2)(1-\theta)/q_2. \end{aligned} \tag{5}$$

The first two terms on the R.H.S. of (5) represents the consumer surplus from the two types of the good, while the third and fourth terms represent the total industry costs of producing each type (aggregated across firms of the same type). Note that $n_1 = \theta/q_1$, while $n_2 = (1-\theta)/q_2$. Hence, W represents the difference between consumer surplus and production costs in the economy. The government maximises W with respect to θ and q_i. The FOCs are

$$-\theta - (K_1 + \frac{1}{2}c_1q_1^2)/q_1 + (K_2 + \frac{1}{2}c_2q_2^2)/q_2 = 0, \tag{6a}$$

$$-\frac{1}{2}c_i + (K_i/q_i^2) = 0. \tag{6b}$$

From (6b), we have $K_i = 1/2c_iq_i^2$, when (6a) becomes

$$-\theta - c_1q_1 + c_2q_2 = 0 \tag{6a'}$$

or,

$$(M - \theta) - c_1q_1 = M - c_2q_2 \tag{6a''}$$

The expressions on each side of the above equation represent the difference between the surplus of the indifferent consumer and the marginal cost of production of the respective type of the good. In other words, the first-order conditions for welfare maximization represent the fact that the social planner decides the optimal allocation by equating the net marginal benefit across the two types. Solving (6a) and (6b) we get the socially optimal levels of outputs and market share as

$$q_i^W = \sqrt{2K_i/c_i}, \tag{7}$$

$$\theta^W = \sqrt{2c_2K_2} - \sqrt{2c_1K_1}. \tag{8}$$

Comparing equations (2), (3), (7) and (8) we see that under full information the market outcome is socially optimal. This is the familiar result that, in the absence of imperfect competition and incomplete information (and externalities), markets are efficient. Substituting (2) and (3) into (5), gives the social welfare under full information as

$$W^* = M + \frac{1}{2}(\theta^*)^2 - \sqrt{2c_2K_2}. \tag{9}$$

3. Incomplete Information with Truthful Labelling

Now suppose that consumers cannot observe the good's type. No firm would have an incentive to produce the green good if it sold at a price equal to or lower than that of the brown. If the green good sold at a higher price than the brown, all brown firms would want to pretend to be green. Thus, there cannot be an equilibrium where differences in price signal the different types. Consequently, no firm would find it profitable to produce the green good at a higher cost. In such a situation, eco-labelling serves as a mechanism for the disclosure of information that enables the green firms to differentiate themselves, and the consumers to exercise their preferences for the hidden attribute. If there were no labelling, only the brown good would be sold in the associated uninformative equilibrium.[14]

In this section, we assume that all labelling is done by a third party, and that this process results in accurate revelation of the type of good produced by any firm. If costless self-labelling is done truthfully, the outcome will be identical to that analysed in the previous section. Therefore, we focus on costly third party labelling, and ignore, for the time being, dishonest practices (such as use of spurious labels) by firms: all labels are genuine and issued by the third party as the certifying agency. Suppose that a type i firm has to pay the labelling agency a fee l_i for each unit of output that carries the label.[15] We assume that l_i represents the entire (social) cost of producing and affixing the third-party label on each unit of the type i good.[16] This could be either because (i) the labelling agency is a non-profit organisation making zero profit (i.e. its revenue from labelling fees exactly covers its total cost of verification/certification), or because (ii) the labelling agency is foreign owned.[17] Either way, the labelling agency's profit (if any) does not enter social welfare. Since there are only two types of firms, labels can be used by either the brown or the green firms. Each case is analysed below separately to determine the socially optimal alternative.

3.1. CASE A: LABELLING BY BROWN FIRMS

Suppose third party labelling is made mandatory for the brown firms. The profit of each brown firm then is $p_1q_1 - K_1 - 1/2c_1q_1^2 - l_1q_1$. The FOC for profit maximisation and the zero-profit condition together give the new equilibrium price and quantity for brown firms as[18]

$$p_1^A = \sqrt{2c_1K_1} + l_1 = p_1^* + l_1, \quad q_1^A = \sqrt{2K_1/c_1} = q_1^*. \tag{10}$$

Since the green firms do not label, their equilibrium price-quantity combination remains unchanged. The market share of the brown good therefore decreases to

$$\theta^A = p_2^* - p_1^A = \theta^* - l_1, \tag{11}$$

where θ^* is given by (3). To rule out corner solutions, where only one type of the good is produced, we make the following assumption:

Assumption A2. *The labelling cost are such that* $l_1 < \sqrt{2c_2K_2} - \sqrt{2c_1K_1} < 1 - l_2$ *holds.*[19]

Remark. *For all* $l_i \in [0,1)$, *if A2 is satisfied, then A1 is satisfied as well. Also, A2 implies that* $l_1 + l_2 < 1$.

Since each brown firm continues to produce the previously optimal level of output $(q_1^A = q_1^*)$, l_1/q_1^* brown firms have to exit the market when eco-labelling is made mandatory for them. Their place is taken up by l_1/q_2^* new green firms entering the market. Social welfare in case A is

$$W^A = \int_0^{\theta^A} (M-\theta)d\theta + \int_{\theta^A}^1 Md\theta - \left(K_1 + \frac{1}{2}c_1(q_1^*)^2 + l_1 q_1^*\right)\frac{\theta^A}{q_1^*} - \left(K_2 + \frac{1}{2}c_2(q_2^*)^2\right)\frac{1-\theta^A}{q_2^*} = M + \frac{1}{2}(\theta^A)^2 - \sqrt{2c_2K_2}. \tag{12}$$

Thus incomplete information imposes a welfare loss on society which, when brown firms label, equals $W^* - W^A = l_1(\theta^* - \frac{1}{2}l_1) > 0$. Since $\partial(W^* - W^A)/\partial\theta^* = l_1 > 0$, this welfare loss increases as θ^* rises.

3.2. CASE B: LABELLING BY GREEN FIRMS

Suppose third party labelling is done by the green firms instead. Proceeding as in case A, it can be shown that equilibrium price and quantity, when green firms label, are

$$p_2^B = p_2^* + l_2, \quad q_2^B = q_2^*. \tag{13}$$

Increase in price of the green good, raises the market share of the brown good to

$$\theta^B = p_2^B - p_1^* = \theta^* + l_2. \tag{14}$$

l_2/q_2^* green firms exit the market and are replaced by l_2/q_1^* brown firms. Moreover, social welfare when green firms label is

$$W^B = \int_0^{\theta^B} (M-\theta)d\theta + \int_{\theta^B}^1 Md\theta - \left(K_1 + \frac{1}{2}c_1(q_1^*)^2\right)\frac{\theta^B}{q_1^*} - \left(K_2 + \frac{1}{2}c_2(q_2^*)^2 + l_2 q_2^*\right)\frac{1-\theta^B}{q_2^*} = M + \frac{1}{2}(\theta^B)^2 - \sqrt{2c_2K_2} - l_2. \tag{15}$$

Again, $W^* - W^B = l_2(1 - \frac{1}{2}l_2 - \theta^*) > 0$ and $\partial(W^* - W^B)/\partial\theta^* = -l_2 < 0$. Thus, welfare loss, when green firms label, decreases as θ^* rises.

From (11), (12), (14) and (15), it is easy to derive that $W^B \geq W^A$ if and only if $\theta^* \geq \frac{l_1^2 - l_2^2 + 2l_2}{2(l_1+l_2)} \equiv \hat{\theta}$. Thus, we have

Proposition 1. *Provided labelling is done truthfully, third party labelling under incomplete information should be undertaken by green firms if and only if market share of the brown good in the first best case,* θ^*, *exceeds the threshold value* $\hat{\theta}$, *as defined above.*

When all firms are honest, there is no need for monitoring, and the only social cost involved is the labelling cost. Since self-labelling solves the information asymmetry problem costlessly, truthful self-labelling will trivially lead to first best outcome. Between third party labelling by browns (case A) and third party labelling by greens (case B), the more efficient policy is the one which involves a lower labelling cost. Total labelling cost under either policy depends upon two factors: (i) the amount of goods to be labelled, which is determined by the equilibrium market split θ^A or θ^B, and (ii) the unit cost of labelling the goods, l_1 or l_2. In fact, if labelling costs are the same for both brown and green types (i.e. $l_1 = l_2$), then $\hat{\theta} = \frac{1}{2}$, i.e. third party labelling should be done by producers of the type that has the smaller market share in the first best case.

4. Incomplete Information with Cheating and Monitoring

In the previous section we assumed that all labelling is done truthfully. However, in reality, labelling may be subject to corruption. Specifically, brown firms have an incentive to pretend to be green in order to benefit from the higher price of the green good. In this section we allow for the possibility that firms can cheat with respect to their labels, i.e., make false claims or affix spurious labels to their product that are not the authentic ones provided by the certifying agency.[20]

When brown firms can cheat and pretend to be green, the government has to monitor the "green" firms in order to ensure that labelling is done truthfully or by the proper agent. We assume that the government is able to pre-commit to its monitoring frequency. This allows the government to move first, and set the level of inspections, before the firms take their decisions.[21] Suppose the government decides to randomly inspect m "green" firms for the accuracy of their labels, and imposes a fine of an amount F on any brown firm caught pretending to be green. F is assumed to be an exogenous parameter, perhaps set by the judiciary, but outside government control. To achieve complete deterrence at minimum cost, the government has to choose a sufficiently high m such that the expected penalty offsets the extra profit from cheating. We assume that if its expected net profit from cheating is zero, then a firm does not cheat. If n_2 is the total number of green firms in the industry, then the detection probability of a brown firm that cheats is m/n_2, and its expected fine is mF/n_2. Clearly, if the fine can be made arbitrarily large, the number of firms the government needs to inspect will go to zero.

However, social conventions (such as ''penalty should be commensurate with crime'') inhibit the setting of extreme penalties in our paper. The remainder of this section sets out three alternative labelling-policy options available to the government, and then goes on to compare their welfare implications.

4.1. EQUILIBRIUM UNDER THREE LABELLING OPTIONS

When brown firms can cheat, and the government has to randomly monitor the ''green'' firms, it has three options with respect to its labelling policy: (i) it can impose third party labelling on the brown firms, or (ii) it can ask the green firms to undertake third party labelling, or (iii) it can ask the green and/or the brown firms to self-label their own products. For each of the three cases, we shall now analyse the equilibrium under optimal deterrence activity by the government.

When the government makes third party labelling mandatory for the brown firms (as in Section 3, Case A), the price of the brown good rises by the amount of the labelling cost to p_1^A, and the brown good's market share falls to θ^A. With mandatory labelling, a brown firm can pretend to be green by simply not obtaining a label from the labelling agency. The profit that a brown firm can get by not obtaining a label is $\tilde{\pi}_1^A = p_2^A q_1 - K_1 - \frac{1}{2}c_1 q_1^2$ (a tilde over a variable denotes its value in the cheating case). The corrupt brown firm maximises this profit by producing quantity $\tilde{q}_1^A = p_2^A/c_1$. Since $p_2^A = p_2^* = \sqrt{2c_2K_2}$, the maximised cheating profit is $\tilde{\pi}_1^A = (c_2K_2 - c_1K_1)/c_1 > 0$. With optimal inspections, no brown firm will have the incentive to cheat. Thus, total number of green firms in equilibrium, when brown firms have to label, is $n_2^A = (1 - \theta^A)/q_2^*$.

On the other hand, when green firms obtain a label from the labelling agency (as in Section 3, Case B), the price of the green good rises to p_2^B, and its market share falls to $(1 - \theta^B)$. With labelling being done by green firms, a brown firm can pretend to be green by carrying a fake label. We assume that this spurious label – perhaps an imitation of the label or certificate issued by the labelling agency to green firms – is costless to the firms.[22] The profit that a brown firm can get by using a fake label is $\tilde{\pi}_1^B = p_2^B q_1 - K_1 - \frac{1}{2}c_1 q_1^2$, or maximised $\tilde{\pi}_1^B = \tilde{\pi}_1^A + l_2\left(\sqrt{2c_2K_2} + \frac{1}{2}l_2\right)/c_1$. With optimal monitoring, the total number of green firms, when green firms bear the labelling cost, falls to $n_2^B = (1 - \theta^B)/q_2^*$.

A third option for the government is to require the brown and/or green firms to self-label their product. Unlike third party labelling, self-labelling is costless. Hence, under self-labelling, the price of the type i good remains unchanged at p_i^*, and the market share of the brown good stays at θ^*. The cheating profit of a brown firm, which self-labels itself as green, then is $\tilde{\pi}_1^S = p_2^* q_1 - K_1 - \frac{1}{2}c_1 q_1^2$, or maximised $\tilde{\pi}_1^S = (c_2K_2 - c_1K_1)/c_1 = \tilde{\pi}_1^A$.[23] The equilibrium number of green firms under self-labelling is $n_2^* = (1 - \theta^*)/q_2^*$, with $n_2^B < n_2^* < n_2^A$.

As mentioned earlier, the government chooses the number of green firms it randomly monitors, m, such that the amount of fine any brown firm considering cheating expects to pay ($= mF/n_2$) equals the extra profit this firm expects to get from such cheating ($\tilde{\pi}_1^A$, or $\tilde{\pi}_1^B$, or $\tilde{\pi}_1^S$, depending on the labelling policy adopted by the government). Thus, when it imposes third party labelling on brown firms, the optimal number of firms that the government has to inspect in order to ensure an expected fine of $\tilde{\pi}_1^A$ is

$$m^A = \frac{\tilde{\pi}_1^A(1 - \theta^A)}{\tilde{\pi}_1^A + F}\sqrt{\frac{c_2}{2K_2}}, \tag{16}$$

where $\tilde{\pi}_1^A \equiv (c_2K_2 - c_1K_1)/c_1 > 0$. If monitoring each firm costs the government an amount h,[24] social welfare under third party labelling by brown firms would be

$$\tilde{W}^A = M + \frac{1}{2}\left(\theta^A\right)^2 - \sqrt{2c_2K_2} - hm^A \tag{17}$$

On the other hand, the number of firms that the government has to monitor, when third party labelling is done by green firms, is

$$m^B = \frac{\tilde{\pi}_1^B(1 - \theta^B)}{\tilde{\pi}_1^B + F}\sqrt{\frac{c_2}{2K_2}}, \tag{18}$$

where $\tilde{\pi}_1^B \equiv \tilde{\pi}_1^A + l_2\left(\sqrt{2c_2K_2} + \frac{1}{2}l_2\right)/c_1$. The associated social welfare is

$$\tilde{W}^B = M + \frac{1}{2}\left(\theta^B\right)^2 - \sqrt{2c_2K_2} - l_2 - hm^B \tag{19}$$

Finally, under self-labelling, the government has to inspect m^S firms in order to deter brown firms from cheating, where

$$m^S = \frac{\tilde{\pi}_1^A(1 - \theta^*)}{\tilde{\pi}_1^A + F}\sqrt{\frac{c_2}{2K_2}}. \tag{20}$$

Social welfare under self-labelling is given by

$$\tilde{W}^S = M + \frac{1}{2}(\theta^*)^2 - \sqrt{2c_2K_2} - hm^S \tag{21}$$

4.2. THIRD PARTY LABELLING BY GREEN VS. BROWN FIRMS

Costly third party labelling by green rather than brown firms leads to a higher price of the green good. This has two opposing effects on the number of firms the government has to inspect. First, it increases the incentive of a brown firm to cheat, as it can get a higher profit from cheating ("incentive-to-cheat effect"). This implies that the government will have to increase the detection probability by inspecting more firms, so as to deter brown firms from cheating. Secondly, however, an increase in price of the green good decreases its market share, and results in fewer numbers of green firms, as some green firms exit the market ("market share effect"). The lower total number of green firms implies that the government has to inspect fewer firms in order to attain the probability of detection that deters brown firms from cheating. When the "incentive-to-cheat effect" dominates the "market share effect", m^B exceeds m^A, i.e. the government has to inspect more firms when it imposes third party labelling requirement on green firms rather than on brown firms (and vice versa).

Comparing (17) and (19), we find that welfare under third party labelling by green firms exceeds that under third party labelling by brown firms (i.e. $\tilde{W}^B \geq \tilde{W}^A$) if and only if $\theta^* \geq \hat{\theta} + h(m^B - m^A)/(l_1 + l_2) \equiv \hat{\hat{\theta}}$. Thus, we have the following result:

Proposition 2. *When the government has to monitor in order to prevent brown firms from cheating, third party labelling should be done by green firms* (*i.e.* $\tilde{W}^B \geq \tilde{W}^A$) *if and only if* $\theta^* \geq \hat{\hat{\theta}}$ (*as defined above*).

When firms can cheat, there are two sources of social welfare loss: the third party labelling cost, and the monitoring cost. Proposition 1 showed that, in the absence of cheating, the third party labelling cost involved is lower with green firms labelling as long as $\theta^* \geq \hat{\theta}$. However, once monitoring costs are included, we get a new threshold market share , which can be higher or lower than $\hat{\theta}$ depending on the relative strengths of the "incentive to cheat" and "market share" effects. For instance, if the "incentive to cheat effect" exceeds the "market share effect", the government has to monitor more firms when the green firms label (i.e. $m^B > m^A$), and we have $\hat{\theta} < \hat{\hat{\theta}}$. Then, even if $\theta^* > \hat{\theta}$, the green firms should not undertake third party labelling as long as $\theta^* < \hat{\hat{\theta}}$, as the additional monitoring cost dominates the lower labelling cost.

4.3. SELF-LABELLING VS. THIRD PARTY LABELLING BY BROWN FIRMS

Since self-labelling is costless to firms, it does not increase the price of either good. Costly third party labelling by brown firms, on the other hand, increases the price of the brown good but leaves the price of the green good unchanged. The incentive of a brown firm to cheat is, therefore, the same irrespective of whether the government imposes self-labelling or third party labelling on brown firms (cheating profit equals $\tilde{\pi}_1^A = \tilde{\pi}_1^S$ in either case).

However, third party labelling by brown firms increases the market share of the green good. This implies that the government has to inspect more firms under third party labelling than under self-labelling. Moreover, third party labelling imposes a labelling cost on society, which self-labelling does not impose. Thus, we have

Proposition 3. *When firms can cheat and monitoring is required for enforcement of labelling rules, self-labelling is better than third party labelling by brown firms, as it imposes less (labelling and monitoring) costs on society.*

Using (17) and (21), the difference in welfare between self-labelling vs. third party labelling by brown firms can be solved as

$$\tilde{W}^S - \tilde{W}^A = l_1\left(\theta^* - \frac{1}{2}l_1\right) + hl_1\frac{\tilde{\pi}_1^A}{\tilde{\pi}_1^A + F}\sqrt{\frac{c_2}{2K_2}} > 0. \tag{22}$$

Note that the first term on the R.H.S. of (22) represents the savings in labelling cost from the self-labelling option, and is strictly positive given Assumption A2. Proposition 3 justifies why all existing third party labels are 'positive' (green), and not 'negative' (brown), in character. Negative labels, in practice, tend to be mandatory self-labels that brown manufacturers are required to attach to their product (for example, pesticide labelling under FIFRA in the US).[25,26]

4.4. SELF-LABELLING VS. THIRD PARTY LABELLING BY GREEN FIRMS

Compared to self-labelling by brown and/or green firms, third party labelling by green firms, which raises the price of the green good, has three effects on welfare. For one, brown firms have a higher incentive to cheat, which implies that the government has to inspect more firms. For another, as the market share of the green good falls, the government has to inspect fewer firms. Thirdly, third party labelling reduces welfare by imposing the labelling cost on society.[27] The first ("incentive to cheat") and the third effects favour self-labelling, whereas the second ("market share") effect favours third party labelling by greens. The relative strengths of these three effects determine whether the government should opt for self-labelling or third party labelling by green firms. Using (17) and (19), the welfare difference between these two labelling options can be expressed as

$$\tilde{W}^S - \tilde{W}^B = l_2\left(1 - \theta^* - \frac{1}{2}l_2\right) + h(m^B - m^S) \tag{23}$$

The first term on the R.H.S. of (21) represents the savings in labelling cost from the self-labelling option, and is positive by Assumption A2. The second term on the R.H.S. represents the differences in the monitoring cost required to enforce the two labelling policies; it is negative if and only if the "market share effect" exceeds the "incentive to cheat effect". Thus we have the following result:

Proposition 4. *If the government has to inspect more firms when it imposes third party labelling on the green firms than when it imposes self-labelling (i.e.* $m^B > m^S$*), then the government should choose the self-labelling option. Self-labelling is also optimal if* m^S *slightly exceeds* m^B*. Only if* m^S *is sufficiently larger than* m^B*,*[28] *so that the lower monitoring cost compensates the additional labelling cost, should the government opt for third party labelling by green firms rather than self-labelling.*

Thus, self-labelling emerges as the best labelling method in most cases. The only exception to this occurs when fewer firms have to be monitored under third party labelling by green firms (i.e. "market share effect" exceeds "incentive to cheat effect"), and the monitoring cost is very high. Under such exceptional circumstances, third party labelling by green firms becomes the most socially desirable option. This is because the monitoring cost savings associated with third party labelling by green firms exceeds the savings in labelling cost associated with self-labelling.

5. Numerical Analysis

This section provides a numerical example to support our analytical results. Suppose the various parameters in our model take the following values:

$$c_1 = 1.9, c_2 = 2, K_1 = 99, K_2 = 100, M = 25, l_1 = 0.01, l_2 = 0.1, F = 50.$$

Then the first-best market share of the brown good is $\theta^* = 0.6$. When all firms act honestly (and, therefore, without any monitoring), the threshold market share, as defined in Proposition 1, is $\hat{\theta} = 0.86$. Since $\theta^* < \hat{\theta}$, third party labelling should be imposed on brown firms, as the associated social welfare ($W^A = 5.18$) is greater than that when green firms do such labelling ($W^B = 5.15$).

When the firms are dishonest, and monitoring is necessary for enforcement, suppose the monitoring cost is $h = 5$. Then the new threshold market share, as given by Proposition 2, is $\hat{\hat{\theta}} = 0.83$. Since $\theta^* < \hat{\hat{\theta}}$, third party labelling should still be imposed on the brown rather than green firms, as the former policy gives higher welfare ($\tilde{W}^A = 5.15$) than the latter ($\tilde{W}^B = 5.13$). Self-labelling, however, gives the highest level of welfare, $\tilde{W}^S = 5.16$.

Alternatively, suppose the monitoring cost is much higher, say $h = 55$. In this case $\hat{\hat{\theta}} = 0.49$, and third party labelling by green firms becomes the most preferred option, yielding welfare of $\tilde{W}^B = 4.945$. The welfare levels associated with third party labelling by brown firms and self-labelling are, respectively, $\tilde{W}^A = 4.93$ and $\tilde{W}^S = 4.94$.

In both cases (i.e. when $h = 5$ and $h = 55$) self-labelling is always better than third party labelling by brown firms, as suggested by Proposition 3. However, the best policy differs in the two case: self labelling is optimal when the monitoring cost is low; otherwise, third party labelling by green firms is superior, as indicated by Proposition 4.

6. Conclusion

This paper has analysed the optimality of different labelling policies for credence goods when firms can cheat with respect to the labels they affix on their products. Labelling is an information disclosure mechanism that enables consumers to make informed choices when they care about a hidden attribute of a product, and can be potentially welfare enhancing. We show that, if firms correctly implement the labelling policy, then the government should impose costly third party labelling requirement on the brown firms if and only if the brown good's market share under complete information (θ^*) is below a threshold ($\hat{\theta}$). Of course, when firms always label honestly, the self-labelling policy would trivially lead to the first best outcome, and would be most preferable.

More realistically, when dishonest firms can circumvent the public labelling process, the government will have to undertake costly monitoring of firms in order to deter brown firms from cheating and pretending to be green. In such a situation, we show that costly third party labelling may have to be imposed on the brown firms even if the brown good's complete information market share exceeded $\hat{\theta}$. As well, we find that self-labelling by brown and/or green firms is always preferable to third party labelling by brown firms, and mostly preferable to third party labelling by green firms. The latter is preferable to self-labelling only when the "market share effect" exceeds the "incentive-to-cheat effect", so that the government has to monitor more firms under self-labelling.

Although we specify the efficient labelling policies in terms of the market share of either type of good relative to threshold values, these policies can be equivalently specified in terms of the various costs involved. This is because, in our perfect competition setting, market share of the brown or green firms depends on their production costs, while the threshold values turn out to be functions of production, labelling, and monitoring costs.[29] Self-labelling has been assumed to be a costless activity for firms in this paper. Even if self-labelling were costly (for example, if it involved running additional advertisements), our results would remain qualitatively unchanged as long as this cost was less than the cost of third party labelling. Finally, this paper has simplistically assumed that the fee charged by the labelling agency represents the social cost of labelling. In future work we intend to explicitly model the labelling agency's incentives and costs.

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Notes

1. Scepticism about GM food is more widespread in the EU as compared to North America (*Economist*, 19 May 2004).
2. For example, using 1997–2001 data for Denmark, Bjorner et al. (2004) found that Danish consumers were willing to pay a 13–18% price premium on different brands of toilet paper carrying the *Nordic Swan* eco-label.
3. Note that once its hidden attribute has been revealed to consumers by an information disclosure mechanism such as eco-labelling, an ex-ante credence good will no longer remain so ex-post.
4. For an evaluation of eco-labelling programmes in different countries see OECD (1997) and US EPA (1998).
5. Shaked and Sutton (1982) showed that such quality competition could be used to relax price competition.
6. Thus, we are ignoring situations where the greenness of the product is a continuous variable. Heyes and Maxwell (2003) and Tian (2003), for example, model environment friendliness as a continuous variable.
7. Examples of such mandatory 'negative' labelling include the state of California's Proposition 65 (which requires manufacturers to warn the public about the hazards or adverse health impacts associated with their product), and the statutory warning that appears on cigarettes. In fact, some consumer groups have suggested that producers of genetically modified food should be legally required to label their products as such.
8. A third type (ISO 14025) of environmental claim requires the manufacturer to present quantified product information that consumers can use in making purchase decisions. The information is presented in a form that facilitates comparison among similar products. An example is the US FDA's nutrition label. However, sometimes such detailed technical information may be difficult for consumers to interpret. Because the logos (e.g. *Nordic Swan*) they carry, or claims they make (e.g. "biodegradable"), summarise the relevant information, Type I and Type II labels are easier for consumers to follow.

9. For example, Nordic Council's website (http://www.svanen.nu/Eng/producer/ansoka.asp) states "companies can obtain the right to use the Swan label on their product via a licensing process."
10. Detecting fake labels without monitoring will be especially difficult when the brown and green goods appear identical, there are many producers for each, and brand name distinction is absent or weak.
11. These issues are further dealt with in Section 4. In this paper only the firms, and not the labelling agency, can be dishonest. The latter is a matter for further exploration that will require the attention and space of a separate paper.
12. The first best outcome also results if the brown and/or green firms truthfully self-labelled their goods, and self-labelling is costless.
13. Note that the higher fixed and unit costs of producing the green type ensures that θ^* is strictly positive.
14. Since we are concerned with a comparison of the different labelling methods, throughout this paper we assume that the labelling costs (introduced in this section) and monitoring costs (introduced in Section 4) are sufficiently small such that the social planner always prefers the informative equilibrium (with labelling) to the uninformative outcome (without labelling). This will usually be the case, more so when the production or consumption of the brown good results in a convexly increasing negative externality: then there will be an additional social benefit of choosing the informative equilibrium (where both brown and green goods are present) rather than the uninformative equilibrium (where the entire market is served by the brown good). However, for expositional simplicity, we do not model externality in this paper.
15. Although our model uses a unit labelling fee for computational convenience, an advalorem labelling fee will not qualitatively alter our results (see footnote 18).
16. Labelling costs are likely to be lower for brown firms. For genetically modified crops, however, the labelling agency might have to perform the same test to determine whether a crop is brown (genetic modification present) or green (genetic modification absent), in which case l_1 could be equal to l_2. Note that the results of our analysis remain qualitatively unchanged even if $l_1 = 0$.
17. For example, the Nordic Council countries allow foreign manufacturers to use the *Nordic Swan* label in the manufacturers' own country.
18. To see why an advalorem labelling fee would not alter our results qualitatively, suppose the labelling agency charges a type i firm a fraction s_i of its sales as labelling fee. When brown firms label, the profit of a brown firm is $(1 - s_1)p_1q_1 - K_1 - \frac{1}{2}c_1q_1^2$. Then the brown good's price rises to $p_1^A = p_1^*/(1 - s_1)$, but each brown firm's output remains unchanged ($q_1^A = q_1^*$).
19. $\theta^* < 1 - l_2$ is necessary to ensure $\theta^B < 1$ in case B.
20. Recall that we are ignoring the case where the labelling agency itself is corruptible.
21. The literature on monitoring and enforcement of regulation models monitoring both with, and without, pre-commitment. The prominent papers that introduced the regulator as a first-mover who pre-commits to a monitoring strategy are, among others, Becker (1968) and Polinsky and Shavell (1979). Grieson and Singh (1990) provide the pioneering analysis of a monitoring game without pre-commitment. They examine a regulator and an agent making inspecting and compliance decisions in a simultaneous move game that has a mixed strategy outcome. We choose the former approach for simplicity of exposition.
22. We are referring only to the direct cost of obtaining fake labels here. Indirect cost of using fake labels will include the expected fine. A green firm will never use a fake label to save on its labelling cost, as the expected fine will exceed its extra profit. We are assuming that brown firms and green firms are fined the same amount, F, for using fake labels.

23. Superscript S stands for "self-labelling".
24. For simplicity, we are assuming that the cost of scrutinising a firm, to verify its greenness, remains the same across the various policy scenarios examined in this paper. Considering different monitoring costs for different policy scenarios will only complicate the algebraic formulation of the conditions derived in this paper without affecting the qualitative nature of our conclusions.
25. Manufacturers may also voluntarily attach hazard/warning labels on their products for liability purposes (US EPA 1998).
26. An exception to Proposition 3 could exist if production or consumption of brown goods created a negative externality. In such a case, the reduction in the negative externality due to imposition of costly third party labelling on brown firms would have to be incorporated into the social welfare as well. The labelling fee would then act like a Pigouvian tax on the brown firms.
27. Note that this is dependent on the assumption that third party labelling is costlier than self-labelling (a zero cost activity in this paper). This assumption, however, is quite realistic given that third party labelling is likely to involve tests and verifications.
28. Specifically, if $m^S > m^B + l_2(1 - \theta^* - \frac{1}{2}l_2)/h$. Note that higher the monitoring cost (h), lower will be the amount by which m^S has to exceed m^B.
29. Recall that the first-best market share of the brown good $\theta^* = \sqrt{2c_2K_2} - \sqrt{2c_1K_1}$ reflects the difference in production cost of the green and brown firms. The threshold values $\hat{\theta} = (l_1^2 - l_2^2 + 2l_2)/(2(l_1 + l_2))$ and $\hat{\hat{\theta}} = \hat{\theta} + h(m^B - m^A)/(l_1 + l_2)$, on the other hand, depend on labelling, production and monitoring costs, with m^A and m^B being given by equations (16) and (18). We chose to specify the efficient labelling rules in terms of market shares rather than the various costs for expositional elegance.

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