Managing animal health status information in the cattle market

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Abstract— **The paper analyses the problem of information in the cattle market, particularly as it relates to the status of animal health, and discusses ways to limit it with the view to improving social surplus. Against this background, it aims to achieve three major objectives. Firstly, it describes the ways of improving the level of information through such schemes as Conventional Warranties and Third Party Certification and the different choices made by sellers and buyers in the presence of these schemes. Secondly, it studies the various ways by which these schemes make an impact on equilibria in different markets (i.e., the pooling market and the premium market), and, consequently, on the social surplus. Thirdly, it identifies the necessary conditions for a third party/public decision-maker to increase social surplus and reduce the negative externality caused by disease by managing and supporting Third Party Certification. The paper shows that product certification and product warranty cannot coexist because product warranty is suboptimal. It also shows that certification, and a possible supporting of certification or animal testing does not necessarily improve the safety of the trade.**

Keywords— **Asymmetric information – Third-party certification —Disease Externalities**

I. INTRODUCTION

Since Akerlof (1970) introduced the world to his "market for lemons", there has been a wide recognition of the importance of incomplete information in different markets. As a result of this recognition, a number of papers have been written which purport to discuss incomplete information, particularly information asymmetry, and point out possible ways of limiting it. Notable papers in this respect include Spence (1973), Rothschild and Stiglitz (1976), Stiglitz and Weiss (1981) and Allen (1993), to name just a few. In the cattle market, which forms the focus of our paper, the problem of information is quite prominent; even though the health status of the animals is important information for the buyer, this information is rarely directly observable. A number of papers have investigated the nature of the problem in this market from different angles. Allen (1993) looks at the phenomenon of Holstein veal calves dominating live beef auctions in British Columbia as a reflection of the problem of asymmetric information in the market. Carriquiry and Babcock (2004), however, argue that the information problem prevalent in the market should not necessarily be one of asymmetry. In fact, they argue that given that delivered quality can only be imperfectly learned and affected stochastically by producers, the problem of information can be both symmetric and asymmetric.

For contagious diseases, farm infection often arises either through contact with the environment or through contact with neighbouring farms and with wild animals. However, such an infection can also sometimes arise through trade involving infected animals. If they know that the environment is the source of infection, farmers can take biosecurity measures to separate their herd from the environment. However, if the source of infection is known to be trade involving infected animals, it is not easy for them to take any particular measure as the sources of such an infection are varied and difficult to identify. To protect their herd from the impact of disease introduced to their farms some farmers decide not to buy any animals and work as closed herds (Ezanno et al, 2006). Other farmers sometimes revaccinate their cattle after purchase, but cannot be efficient for all pathogens (Chymis et al., 2007). In the face of uncertainty regarding the source of infection in the market place it is not surprising that they resort to these measures.

Infection through purchase of an infected animal is known to reduce the productivity and increase the mortality rate among herds. Furthermore, disease spread triggered by the purchase of infected animals can at times have direct impact on human health or on the farm system. In order to promote social welfare, diseases that have nationwide implications are often regulated with the community assuming the risk. But diseases whose impact is limited to the farm are not so regulated and, consequently, farmers are left to bear the cost of containing disease spread. In practice this distinction is not clear cut. In Great Britain, policy makers are often concerned that stakeholders pay for improvements in animal health in proportion to their benefit (Defra et al, 2004). This makes it particularly important to understand the market mechanisms involved.

For some such diseases as BVDV[1], the status of the animal purchased is not well known at the time of trading because there is no apparent disease symptom. In this particular instance, buyers have two choices: either to take a major risk of infection by not testing the animal purchased or to test the animal after purchase. There are different tests for verifying the disease-free status of the animal. However, results are not always perfect. Even though testing of the animal after purchase might limit the spread of the disease, contact of purchased animals with the herd often occurs before the test result is received by the farmer. Given the limited effectiveness of testing in dealing with the problem of infection through trade, therefore, the buyer settles for acquiring information regarding the health status of the animal traded.

Knowledge of an attribute reflecting the health status of an animal allows the buyer to reduce the risk of introducing the disease to their own farm. Sellers can provide this knowledge by supplying animals whose disease status is known at a premium price. They can make this attribute known to the buyer via, among others, Conventional Warranty (CW) and Third Party Certification (TPC), contractual terms, repeat purchases, brand names and share contracts (Centner and Wetzstein., 1987). If the buyer knows the seller, he can place trust in the latter[2]. But when the buyer does not know the seller, it is often the case that he is ignorant of the status of the farm from which the animal purchased originated.

There are a number of instances which give rise to CW and TPC. Taking the French cattle market as an instance, for regulated diseases, buyers are protected by latent defect warranties, and the introduction of testing of animals is obligatory for diseases like brucellosis, tuberculosis and IBR[3]. For BVDV, a not so regulated disease, there is, in Brittany, a plan of certification of the animals managed by the GDS (*Groupements de Défense Sanitaire*). These are voluntary producers' associations working on managing farm animal diseases. Indirect methods, such as testing bulk tank milk, allow the identification of farm status without testing all the animals, and deductive methods identify the status of animals. In the case of BVDV, the "*Référentiel non IPI*" (FNGDS, 2005), which is a protocol of certification of farms and animals, is used. Herd certification is also used in the case of paratuberculosis as the quality of the test is not sufficient to certify animals disease-free individually. When there is no latent defect warranty in place for diseases that are not so regulated, the seller and the buyer can also vote for a "Conventional Warranty". Such a warranty gives buyers a cashback guarantee when they return the animal to the original seller if the animal is found to be infected within a short period after purchase. This warranty applies to diseases like paratuberculosis and BVDV but is limited by the quality of the tests. By ensuring the safety of the transaction, this kind of market can have an impact on the level of disease prevalence. The prevalence of the disease can, in turn, have an impact on the potential supply and demand for animals with a known disease status.

Against this background, this paper sets out to analyse the problem of information in the cattle market, particularly as it relates to animal health status, and discusses ways of limiting it with the view to improving social surplus. In this respect, it aims to achieve three major objectives. Firstly, it describes the ways of improving the level of information through such schemes as CW and TPC and the different choices made by sellers and buyers in the presence of these schemes. Secondly, it studies the various ways by which these schemes make an impact on the market equilibrium, and, consequently, on the social surplus. Thirdly, it identifies the necessary conditions for a third party/public decision-maker to increase social

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[1] bovine viral diarrhea virus

[2] With imperfect information for the seller, the extent of repeat purchase or trust is limited. But it can be possible because even if the information is incomplete for the seller, there is asymmetric information.

[3] Infectious Bovine Rhinotracheitis

surplus and reduce the negative externality caused by disease by managing and supporting TPC.

II. MODELING ACTORS DECISION

The information problem analysed is characterised by (1) the availability of limited information regarding the status of the animal for the buyer and for the seller and (2) an asymmetry of information whereby the seller has full information about the health status of their cattle, but the buyer has imperfect information regarding the health status of animals traded (i.e., he/she has a perception of the average level of the health status of animals in the market). In this context, we describe three types of transaction; one without either warranties or third party certification (WW), another one with TPC and a third one with punctual contract, (CW). Following Chymis et al. (2007), we define for each type of transaction the benefit B for seller and the cost C for the buyer. These cost and benefit are a function of the level of disease incidence (or level of prevalence), π_b for the buyer's farm and π_s for the seller's farm[4]. The average value of the prevalence, $\bar{\pi}$, is also the average risk to buy an infected animal. Regardless of the type of exchange that prevails in the market, we assume that farmers are risk neutral and honest in their dealings and that either they maximise expected benefit or minimise expected cost once involved in trade. Given these assumptions, the seller maximises the expected benefit *B* of selling an animal consisting of the price of the animal minus expected cost due to disease risk whereas the buyer minimises *C*, the expected cost of buying an animal consisting of the price of the animal plus expected cost due to disease risk.

A. Trade without disease information (WW)

Firstly, consider trade without disease information, where there is only one price which rules in the market, i.e., the price in the pooling market. In the absence of full information regarding the health status of the animal purchased, the buyer has two decision options; either to buy the animal without testing or test the animal after purchase. If the decision is to buy the animal without testing, then the buyer's expected cost of purchase is:

$$C_{WW} = P_{WW} + \bar{\pi} \cdot c_b, \qquad (1)$$

where P_{WW} is the price in the pooling market, and c_b is the cost of infection when the buyer *b* purchases an infected animal, with a probability $\bar{\pi}$. We assume that c_b is a continuous function of π_b, $c(\pi_b)$, which satisfies $c(\pi_b) \geq 0$ and *c'*, the first derivative of c satisfies $c'(\pi_b) \leq 0$. This states that the impact of the introduction of an infected animal is more important in the naive farm than in an infected farm because the risk of infection on such a farm is higher than on one whose herds are more resistant to infection. Beyond the individual cost of the introduction of an infected animal, purchase without testing causes a negative externality as it increases infection risk for the neighbourhood and the buyers by raising the level of disease prevalence. This effect, in essence, is not considered by the buyer.

If the decision is to buy an animal and test it after purchase, then the buyer keeps on purchasing to the extent that the animal is not infected and that animals infected are culled. Thus the cost to the buyer is:

$$C_{WW} = \frac{P_{WW} + Ct - \bar{\pi} \cdot (Pc - Co)}{1 - \bar{\pi}} \qquad (2)$$

where *Ct* is the cost of the test, *Pc* is the benefit of culling the animal, and *Co* is the opportunity cost of keeping the animal on farm. To simplify the model, we assume that the test is perfect (i.e., there is neither a false positive nor a false negative case), and that there is no longer any risk of infection once the infected animal is culled. See *Annex 1* for the derivation of this equation.

When animals are not differentiated by their health status, then, in the absence of full information regarding their health status, there is an apparent homogeneity of the rate of prevalence among different farms. In this context, the seller has no choice but to sell at the pooling price with an expected benefit,

$$B_{WW} = P_{WW} \qquad (3)$$

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[4] because of lack of information π_b and π_s can be a perceived prevalence of the disease.

B. Trade with Third Party Certification (TPC)

Now consider the choices of the buyer and of the seller when the market involves TPC. In such a market, the cost of buying an animal is specified as:

$$C_{TPC} = P_{TPC} \tag{4}$$

where P_{TPC} denotes the premium price paid for a certified animal. To simplify the model, we assume that the TPC is so perfect as a test that all animals sold under the scheme are uninfected. The benefit to the seller of selling a certified animal is given by

$$B_{TPC} = (1-\pi_s)\cdot P_{TPC} + \pi_s \cdot Pc - Cc \tag{5}$$

where Cc is a predetermined cost of certification[5]. We assume that the animal is culled once it is infected (i.e., once it fails the certification stage); so seller sells at price P_{TPC} with a probability $1-\pi_s$ and culls the animal with a probability π_s.

C. Trade with Conventional Warranty

Finally, consider the choices of the buyer and of the seller when the market involves CW. Assume that, given this exchange regime, the buyer tests every traded animal and keeps on purchasing to the extent that such an animal is not infected[6]. The expected cost to the buyer can then be represented as:

$$C_{CW} = \frac{P_{CW} + Ct - \overline{\pi_{CW}} \cdot (Cr - Co')}{1-\overline{\pi_{CW}}} \tag{6}$$

The derivation of (6) is the same as of (2), except that $Pc - Co$ is replaced by $Cr - Co'$. Cr denotes the cashback whose components are the price of the animal bought with CW, P_{CW}, and a part of Co'[7], the cost of purchase and of return plus the opportunity cost of doing so. Here, $\overline{\pi_{CW}}$ is the perceived average risk to buy an animal infected in the case of the Conventional Warranty, this average risk must be less than $\overline{\pi}$, because farms with a high level of disease do not trade with Conventional Warranty. When $Cr = P_{CW} + Co' + Ct$, we have a perfect warranty for the buyer with $C_{CW} = P_{CW} + Ct$.

The expected benefit to the seller of selling an animal with CW is given by:

$$B_{CW} = P_{CW} - \pi_s \cdot (Cr - Pc) \tag{7}$$

The assumption here is that the seller culls the animal if returned by the buyer. In this case, the benefit of the seller is composed of the price of the animal P_{CW} minus the cost when the animal is returned, composed of the cashback Cr minus the benefit of culling the animal Pc, balanced by π_s.

D. Coexistence of Conventional Warranty and Third Party Certification

To this stage, the implicit assumption has been that CW and TPC coexist. We can assume that Cr, the cash back for the buyer when he returns an animal with Conventional Warranty is greater than the direct costs of the trade, composed of the cost of the animal and the cost of the test on farm, and lower than the total cost of the trade, composed of the direct cost and the opportunity cost. So, Cr satisfies:

$$P_{CW} + C_t \leq C_r \leq P_{CW} + Ct + Co' \tag{8}$$

Given this assumption, seller s trading in a market with CW requires that :

$$\pi_s \cdot (P_{CW} + Ct - Cr) > Ct - Cc \tag{9}$$

For proof, see *Annex 2*. The logic goes as follows. Since the test guarantees no infection (this is in accordance with the hypothesis of perfect test and perfect certification), we have $Cc < Ct$. So, when the cashback Cr is greater than the cost of buying, P_{CW},

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[5] We could also assume that Cc depends on the level of prevalence in the seller farm.

[6] Therefore we ignore the case where the buyer does not test the animal because he assumes that animals sold with CW are less likely to be infected. But even this case can be studied using the theory of games.

[7] Note that the possibility to test the animal on the seller's farm can reduce Co', but here, we assume that the buyer trades in a pooled market where there is no possibility for testing the animal before trade.

plus the cost of testing *Ct,* TPC drives out CW from the market. Thus, in the following, we discuss market equilibrium with TPC only.

III. DERIVATION OF SUPPLY AND DEMAND FUNCTIONS OF ANIMAL HEALTH STATUS

In this section, we identify the conditions under which equilibrium exists in a cattle market where TPC operates.

To help identify these conditions, consider a hypothetical market where the price of animals trade without warranty P_{WW} and the risk of buying an infected animal without certification are given. This assumption holds when the market for cattle operates at a global level whereas the market for certified animals operates at the local level, because in such a market, animal without certification are bought on the global market and local actors do not impact the global market and the global epidemiology. Consider also that the number of animals traded is given, because the surplus given to buyers and sellers by the TPC do not impact their supply or demand.

In this market, the following assumptions hold: firstly, the buyer does not choose the seller; secondly, he buys at an equilibrium price because the product (i.e., cattle) being traded in the two markets is homogeneous; and, thirdly, neither the seller nor the buyer has market power. Assume that sellers and buyers are characterised only by the level of disease prevalence among their cattle, which is linearly distributed in the population, and that they have perfect knowledge of market price, of cost and of risk. Furthermore, assume that all buyers (respectively sellers) buy (respectively sell) the same number of animals. Since for each buyer (respectively seller), the maximum (respectively minimum) price premium at which he buys (respectively sells) an animal with TPC is a function of π_b (respectively π_s), we can derive partial supply and demand functions for the certified animal and, define the resulting equilibrium in the market.

Let θ_s (respectively θ_b) be the proportion of sellers (respectively buyers) who verify $\pi_s \leq \pi_{\theta s}$ (respectively $\pi_b \leq \pi_{\theta b}$). With the same uniform distribution for buyers and sellers, the following hold:

$$\theta_s = \frac{\pi_{\theta s}}{2\bar{\pi}}; \qquad \theta_b = \frac{\pi_{\theta b}}{2\bar{\pi}} \tag{10}$$

We used here a uniform distribution and the same distribution for sellers and buyers, but the same results follow any other continuous distributions.

As mentioned earlier, the seller chooses TPC if and only if $B_{WW} > B_{TPC}$ whereas the buyer chooses TPC if and only if $C_{WW} < C_{TPC}$. Given these choices, we can derive the prices *prefs* and *prefb* at which θ_s sellers and θ_b buyers choose to trade with TPC as:

$$prefs(\theta_s) = \frac{P_{WW} + Cc - 2\bar{\pi}\theta_s \cdot Pc}{1 - 2\bar{\pi}\theta_s} \tag{11a}$$

$$\begin{aligned} &prefb(\theta_b) = \min\left(prefb_1(\theta_b), prefb_2(\theta_b)\right) \\ &\text{with } prefb_1(\theta_b) = P_{WW} + \bar{\pi} \cdot C\left(2\bar{\pi} \cdot \theta_s\right); \\ &\text{and } prefb_2(\theta_b) = \frac{\bar{\pi} \cdot (Co - Pc) + P_{WW} + Ct}{1 - \bar{\pi}} \end{aligned} \tag{11b}$$

For $prefb_1(\theta_0) = prefb_2$, θ_0 represents the proportion of buyers who buy and test in a market where there is no TPC.

Consider Φ to be the proportion of animals traded with TPC. Assume that all the buyers and sellers trade the same number of animals, then we have $\Phi = \theta_b$. Due to culling of infected animals prior to trade, we have $\Phi = \theta_s \cdot (1 - \bar{\pi} \cdot \theta_s)$. We can derive the equilibrium conditions as:

$$P_{TPC} = prefb(\Phi) \tag{12a}$$

and

$$\begin{aligned} P_{TPC} &= prefs\left(\frac{1 - \sqrt{1 - 4 \cdot \bar{\pi} \cdot \Phi}}{2\bar{\pi}}\right) \\ &= \frac{P_{WW} + Cc - Pc}{\sqrt{1 - 4\bar{\pi} \cdot \Phi}} + Pc \end{aligned} \tag{12b}$$

Equation (12*a*) represents the supply condition *S* whereas (12*b*) represents the demand condition *D*. They are used to derive equilibrium in *Figures 1 & 2* below yielding the proportion, Φ^*, of certified animals traded at the premium price, P_{TPC}^*. We represent also the preference curve *prefs*. The area between the *prefs* curve and P_{TPC}^* represents the surplus to sellers offered by TPC whereas the area between the Demand curve *D* (ie the *prefb* curve) and P_{TPC}^*, represents the surplus to buyers offered by TPC.

The maximum value between Φ^* and θ_0 give the proportion of safe trade, so the proportion of animals exchanged are either certified or tested after purchase. In the following, we consider three scenarios under which we determine the gain from trade with certification. The first applies for $\Phi^* > \theta_0$, the second when $\Phi^* < \theta_0$ holds and the third when the supply curve does not cross the demand curve.

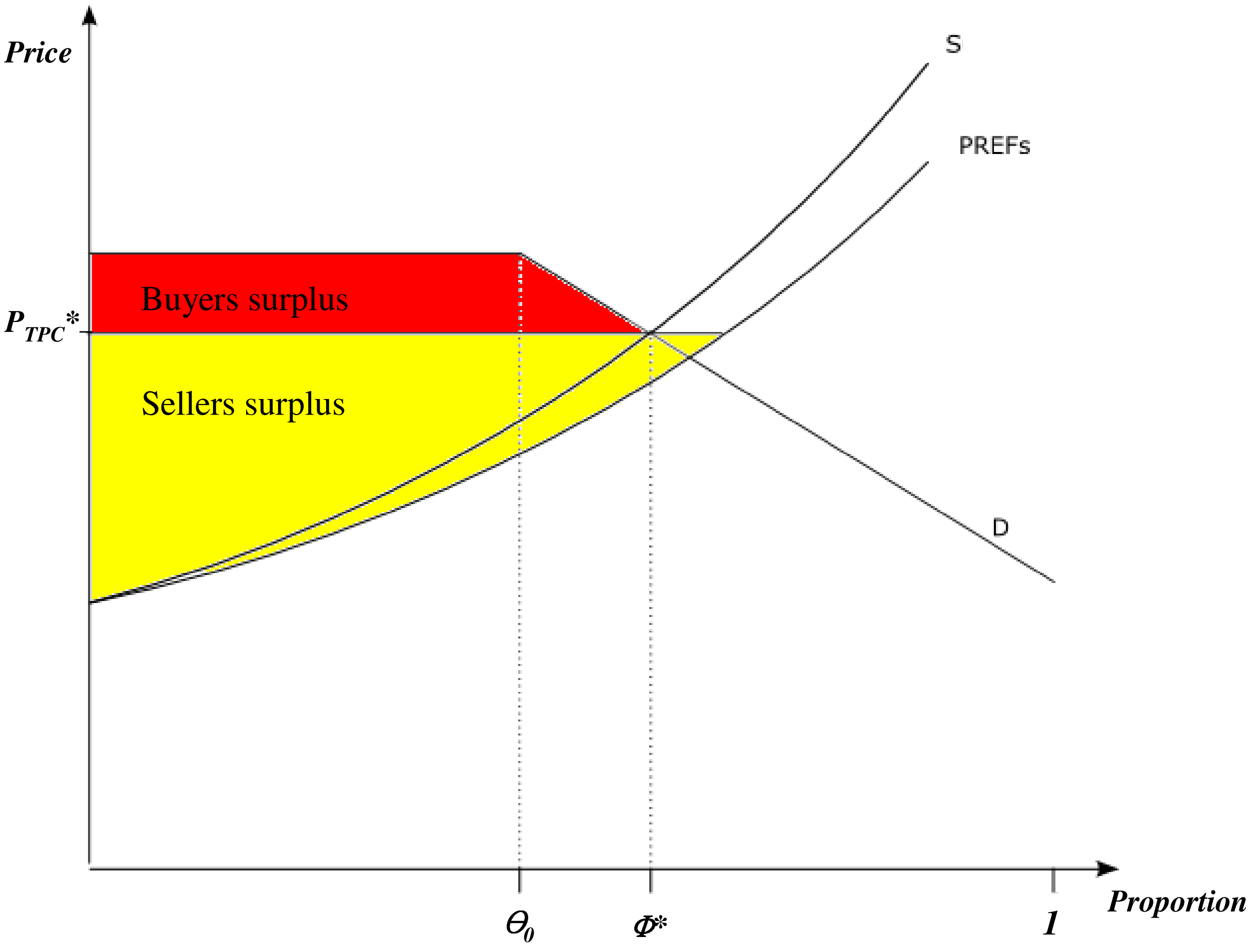

Figure 1. Improvement of trade safety (Scenario 1)

A. Scénario 1: Improvement of trade safety

When $\Phi^* > \theta_0$, both the seller and the buyer gain a positive economic surplus. The test after purchase is suboptimal and is driven out by certification. The supply and demand in such a scenario are represented in *Figure 1*. Under this scenario, a proportion, Φ^*, of buyers buy with certification whereas a proportion, $1 - \Phi^*$, of buyers buy without certification and do not test their purchased animals. With the introduction of TPC, the proportion of animals exchanged with the maximum level of safety increases by $\theta_0 - \Phi^*$. Consequently, the negative externality caused by the trade of infected animals is reduced.

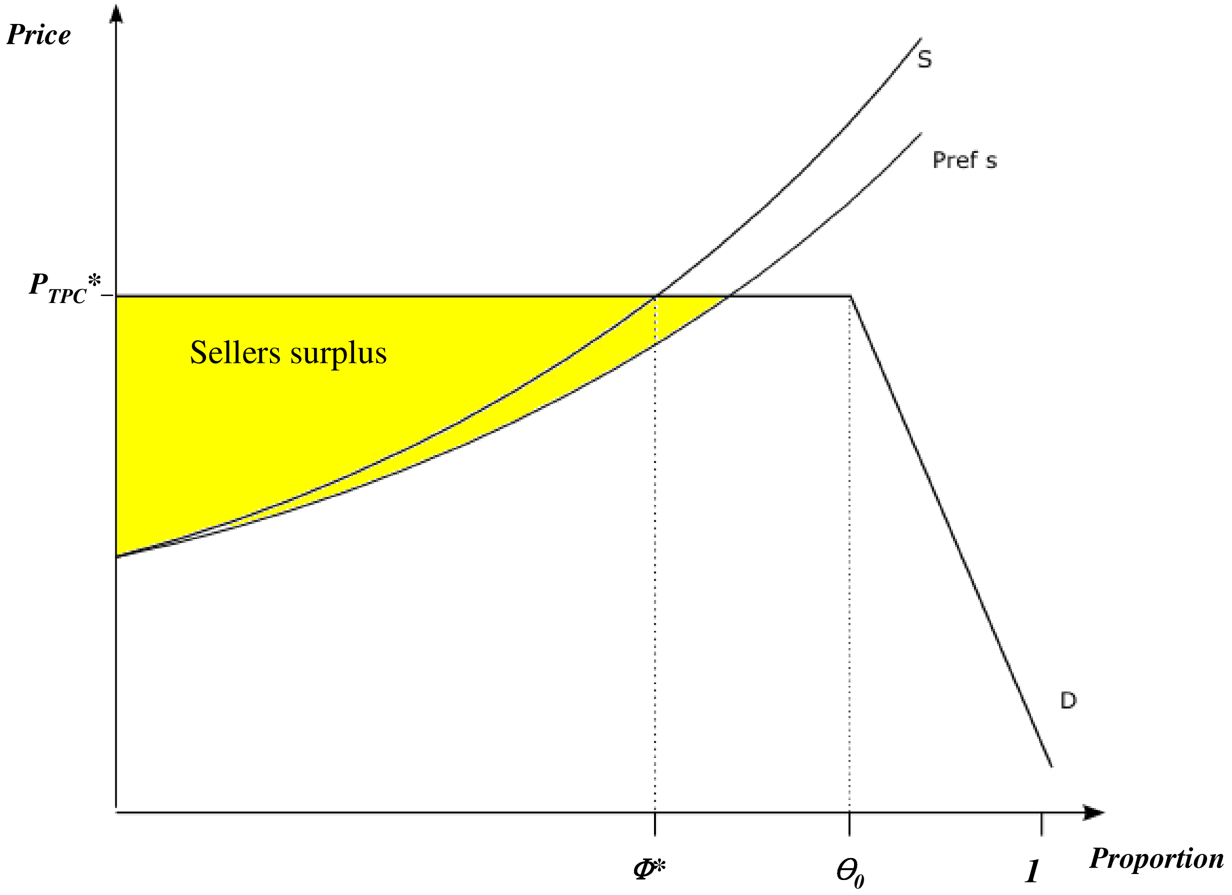

Figure 2. :Transfer of responsibility from buyer to seller (Scenario 2)

B. Scenario 2: Transfer of responsibility from buyer to seller

When $\Phi^* < \theta_0$, the seller gains economic surplus from trading in the certified market but the buyer does not. The supply and demand in such a scenario are represented in *Figure 2*. In the certified market, the price is given by $prefb_2$. There is a proportion θ_0 of buyers who do not choose between testing the animal and buying a certified animal. This leaves a proportion Φ^* of buyers who buy with certification. The outcome of this scenario is that a proportion, $\theta_0 - \Phi^*$, test the animals after purchase and a proportion, $(1 - \theta_0)$, do not. Here, certification serves as a way for the seller to signal the "disease free" status of his animal. In this particular case, certification does not reduce the negative externality that arises due to trade involving infected animals. What takes place in practice here is, therefore, a transfer of responsibility for animal testing from the buyer to the seller with the result that there is a proportion of buyers, who, rather than testing, buy with certification.

C. Scenario 3. The Inefficacy of Certification

When $prefs$ is superior to $prefb_2$, $\Phi^* = 0$ and the supply curve does not cross the demand curve. In this case, certification is inefficient, and, consequently, neither the buyer nor the seller gains a surplus, and the proportion of safe trade does not increase.

IV. A POSSIBLE OPTIMISATION BY THE DECISION-MAKER

In the preceding section, we described market equilibrium and identified the different scenarios under which certification enhances the level of farmers' surplus and the level of positive externality which arises therein. In this section, we consider the possible interventions available to the decision-maker, i.e., the public-choice maker or such producers' associations as GDS interested in reducing negative externality and increasing farmers' surplus.

In the context of our model, it is socially beneficial to introduce TPC when the sum of buyers' and sellers' surpluses derived from certification is greater than the cost of management of the TPC supported by the decision-maker. However, considering Scenario 1, even if the cost of management is higher than the sum of buyers' and sellers' surpluses, the decision-maker might find the introduction of certification in the interest of society since doing so reduces the negative externality resulting from infection.

Our model also allows the decision-maker to support the testing on farm of traded animals and bear the cost of certification in order to reduce negative externality. In both cases, support leads to a sub-optimum equilibrium whereby the net social surplus, composed of farmers' surplus minus decision-maker's cost, is reduced. But such a support can improve the level of trade safety as it improves farmers' welfare by reducing the risk of infection and, consequently, the level of disease prevalence among farms. Considering Scenario 1 again, the provision of support for certification increases the value of Φ^*, so decreases externality due to the trade by increasing the proportion of safe trade. But provision of support for testing of animals after purchase is of no value because no farmer tests his animal. In Scenario 2 and Scenario 3, support for the test at the point of purchase is always efficient and decreases the externality due to the trade. But support for certification increases the sellers' surplus at the expense of the social surplus.

Given our assumptions, we show that it is never efficient for the decision-maker to support both the certification and the test at introduction, the choice to support either one must be made taking account of the scenario observed.

V. DISCUSSION

The theoretical framework developed in this paper should be seen as a first attempt towards analysing the full impact of animal health status on equilibrium in the cattle market. It serves as a starting point for a rigorous study of the negative externality resulting from the exchange of infected animals and as a guide for the management of information regarding animal diseases. By determining the choice of actors in the market in the face of incomplete information, we have shown that Third Party Certification and Conventional Warranty cannot coexist because all actors in the market find the former more efficient than the latter. This seems to be consistent with findings from other markets (Dewally and Ederington, 2006). Furthermore, we have shown that, with Third Party Certification, sellers' surplus increases and that for such a scheme to increase buyers' surplus and reduce the negative externality associated with infection, it must first drive out the practice of testing after purchase from the market. In this respect, we offer a rough guide for decision-makers to reduce the negative externality by supporting either the "testing after purchase" or "certification" schemes. We find that the decision-maker has to select to support either mechanism but never both of them.

Given the simplified assumptions used in the model, however, the results should be treated with caution. We assume in our model that the price of an animal without certification and the number of animals sold are given. However, in practice, the benefits to the seller and to the buyer, which are higher with certification, might modify the global supply and demand conditions. Furthermore, we assume that the global demand and supply are fixed and, as such, we do not describe supply and demand curves for animals. Nevertheless, the aforementioned theoretical framework can be further extended to show how the global quantity supplied and demanded and the price can change over time. Also, price without certification can change because premium price has a direct impact on the disease prevalence of uncertified animals. In effect, animals free of the disease are preferentially sold with the premium price. So there are more infected animals sold without certification.

In our model, the disease prevalence and the risk in the market without certification are assumed to be known by farmers. But in practice, farmers have just a limited perception of the risk and its evolution. The study of this perceived risk, and of how producers cope with this risk can provide an avenue for a useful collaboration with sociologist. In our conceptual framework, limited perception can be modelled by assuming a perceived prevalence and a perceived risk different from the actual risk. The existence of a gap between perceived risk and actual risk results in a suboptimal equilibrium. A principal-agent approach can be developed to determine the maximum such benefit as done in a previous work on food labelling (See, for instance, Marette, 2005). By describing the principal as the decision-maker and buyers and sellers as agents, we can describe the rationale for testing, for certification and for advertising the risk through different signals. Our modelling framework can also describe regulatory means such as the warranty of latent defect and the testing after purchase.

We assume in our model that disease prevalence is given exogenously. But we have shown that, following certification, disease prevalence can change because of the lessening of the effect of externality. Furthermore, the model considers the choice of certification just as a trade choice. But the process of certification can also be motivated with the view to protecting farm objectives as the farmer controls his animals to manage the disease in his herd. As an extension of this framework, we envisage to undertake a dynamic model that has economic and epidemiological components with a particular focus on a disease like BVDV or paratuberculosis and that is empirically testable.

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Annex 1: Derivation of equation 2

Let α=P+Ct, the cost of buying an animal, and β=(P+Ct-Pc+Co), the cost of culling and of buying another animal when the first one is infected. Because the probability of buying an infected animal is $\overline{\pi}$, the probability of buying an infected animal n times is $\overline{\pi}^{\mathrm{n}}$.

So,

$$\begin{aligned} C_{WW} &= \lim_{n\to+\infty} \alpha + \overline{\pi}\cdot\beta + \overline{\pi}^{2}\cdot\beta + \ldots + \overline{\pi}^{n}\cdot\beta \\ &= \lim_{n\to+\infty} \alpha + \beta\cdot\sum_{a=1}^{n}\overline{\pi}^{a} \end{aligned} \qquad \text{(A1a)}$$

Since for all $\overline{\pi} \in [0,1[$

$$\lim_{n\to+\infty}\sum_{a=1}^{n}\overline{\pi}^{a} = \overline{\pi}\Big/1-\overline{\pi}, \qquad \text{(A1b)}$$

We have

$$\begin{aligned} C_{WW} &= \alpha + \beta\cdot\frac{\overline{\pi}}{1-\overline{\pi}} \\ \Leftrightarrow C_{WW} &= \frac{P_{WW} + Ct - \overline{\pi}\cdot(Ac - Co)}{1-\overline{\pi}} \end{aligned} \qquad \text{(A1c)}$$

Annex 2: The incompatibility of Conventional Warranty and Third Party Certification

We assume that C_r, the cash back for the buyer when he returns an animal with Conventional Warranty satisfies:

$$P_{CW} + Ct \leqslant Cr \leqslant P_{CW} + Ct + Co' . \tag{A2a}$$

So, the cost for the buyer is higher than or equal to the cost with a perfect warranty, and

$$C_{CW} \geqslant P_{CW} + Ct \tag{A2b}$$

A buyer who trades in a market with Conventional Warranty requires that

$$\begin{aligned} & C_{TPC} > C_{CW} \; (\geqslant P_{CW} + Ct) \\ \Rightarrow & P_{TPC} > P_{CW} + Ct \end{aligned} \tag{A2c}$$

A seller who trades in a market with Conventional Warranty requires that

$$\begin{aligned} & B_{CW} > B_{TPC} \\ \Leftrightarrow & P_{CW} - \pi_s \cdot Cr > P_{TPC} \cdot (1 - \pi_s) - Cc \\ \Leftrightarrow & P_{CW} \cdot (1 - \pi_s) - \pi_s \cdot (Cr - P_{CW}) > P_{TPC} \cdot (1 - \pi_s) - Cc \qquad \text{Because of (A2c)} \\ \Rightarrow & (P_{TPC} - Ct) \cdot (1 - \pi_s) - \pi_s \cdot (Cr - P_{CW}) > P_{TPC} \cdot (1 - \pi_s) - Cc \\ \Rightarrow & \pi_s \cdot (P_{CW} + Ct - Cr) > Ct - Cc \end{aligned} \tag{A2d}$$