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Influence of voluntary GMO-free production standards on the reputation and flexibility of agricultural value chains

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Abstract

We analyze dairies' decisions to invest in voluntary GMO-free certification. Using a real-option model, we find the maximum precautionary investment in a single-firm setting. The model is extended to a non-cooperative game framework where dairies' decisions are linked by their reputation gains and losses from investing and waiting, respectively. We show two main results: (1) smaller firms are more likely to invest; (2) both small and large firms may be worse off when it is optimal for both firm types to invest.

Keywords: Reputation, Private quality standard value chain, Real option, Game theory
JEL codes: C72, D21, Q10

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1 Introduction

1.1 Background to GMO-free production

Different labelling systems are available to show consumers whether the product they purchase does or does not contain GM organisms (GMOs) (Caswell, 1998). In the EU labelling of all food and feed products that contain more than 0.9 % EU approved GM material is mandatory (European Union, 2003). Unapproved GM events are only allowed in feed, up to 0.1 %, while for food products a zero per cent threshold applies. Not included in the scope of the Regulation (EC) 1829/2003 on mandatory labelling are products that are obtained from animals fed with GMO-containing feed or treated with GM medicinal products.

GMO-labelled food products are rare in most EU grocery stores, but EU countries do import large amounts of GMO feed; mainly GM soybeans and soybean meal used as protein feed. Additionally, some European countries plant GM maize. If consumers want to avoid animal products derived from GM feed, they can buy organic food, which additionally to the GM-free characteristic provides some further product standard attributes over conventional products.

To close the gap between conventional unlabeled animal products derived from GM feed and organic products, some EU Member States introduced regulations for voluntary "GMO-free" labelling, which producers may adopt by complying with private production standards. Prices and costs of GMO-free products are expected to lie between prices and costs of conventional and organic products (Giannakas & Yiannaka, 2006). The GMO-free agri-food chain standard is set by a collective organization, which operates within the boundaries of an individual country. As such, GMO-free can be considered as a collective national standard (Henson & Humphrey, 2010).

1.2 National regulations

So far, four countries have introduced GMO-free labelling regimes (Smith, Jarvis, & Marino, 2011): Austria, Germany, France and the Netherlands. The first three countries offer standards with thresholds that were chosen to offer practical adaptability. The Netherlands, in contrast, adopted very strict GM-free production standards that prohibit any GM feed or additives in the animal production. Reasons for the strict standards are, "to avoid claims that could mislead consumers (such as 'GM-free', a claim that suggests 100 per cent absence of GM material). Second, they wanted to avoid confusion among consumers as a result of more labels than they considered necessary." (Smith et al., 2011).

In Germany voluntary GMO-free labelling has been regulated since 1998 (Federal Ministry of Germany, 1998). The former regulation for "novel food products" was similar to the one that is in place in the Netherlands: it did not allow any feed that had been in contact with any kind of genetic engineering, or any drugs or vaccines produced with GMOs to label their products as GMO-free ("Ohne Gentechnik"). Due to the strict requirements, only one German dairy offered GMO-free milk products in 2005. In an interview with the dairy by the Gen-ethisches-Netzwerk (2006), the dairy declared that the whole procedure of changing the milk production process had been very difficult, entailed high costs and was induced with many uncertainties on legal requirements. This was the only GMO-free producing dairy until the German regulation (EG-Gentechnik-Durchführungsgesetz) was revised in 2008.

The new regulation facilitates the use of 'GMO-free' labels. Now, farmers can feed GMOs for an time period before slaughtering (4-12 month), milking (3 month) or laying eggs (6 weeks) that is animal specific (Federal Ministry of Germany, 2004). Genetically modified feed additives like vitamins, amino acids or enzymes are allowed too. Additionally, GM medicinal products or vaccine can be used to treat animals.

1.3 Early adoption phase in Germany

At the beginning, the "new" labelling option was not implemented by many firms due to food producers mistrust in being able to convey reliability to consumers by promising 'GMO-free' products, which actually can be produced with some GMOs (BLL, 2008). After the regulatory revision, some products of some small dairies – here, small refers to dairies with only a few suppliers/farmers - and some milk products of one brand of one larger dairy (with about 1000 GM-free suppliers) were labelled as GMO-free. After the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV) introduced a uniform GMO-free label in 2009 that could be implemented on a voluntary basis, more dairies started to adopt this standard.[1]

[1] Due to Governmental interaction in providing a legal basis for GMO-free production, the standard could also be seen as a voluntary public standard as defined by Henson and Humphrey (2010). In this article, we refer to the GMO-free standard as private standard.

Firms have to get a license from the organization for GMO-free food products (VLOG), if they want to use the uniform label, but they can also use their own private labels as long as these comply with the demands of the uniform label.

GMO-free producing firms include among others egg and chicken producers, noodle producers, meat and sausage producers (VLOG, 2013), whereas most of the production takes place in two sectors: egg and milk production. However, early 2014, the egg production association announced that they can no longer guarantee to produce eggs from non-GMO feed due to an increase in GMO contamination of this feed (News aktuell, 2014). Even though, many egg producers still use non-GMO feed, the dairy sector is probably now the main sector for GMO-free labeled products. Even though GMO-free is (still) a niche market in Germany, two years after the regulatory revision, already twice as many farmers (i.e., 6.6 %) in Germany produced more than twice as much GMO-free raw milk (i.e., 3.4 %) than the organic sector (Venus & Wesseler, 2012). Most of these dairies have only a few suppliers and produce in Southern parts of Germany (ibid.). Dairy products are mainly whole and low fat milk, natural yoghurt, cheese, or other milk products, that do not contain additives like fruits, sugar, cacao, etc. (Krewer, 2011). In February 2012, however, the first dairy announced that it will offer fruit yoghurt as well. Its advertising campaign was heavily criticized in the news, as the dairy claimed to be the first to produce “GMO-free” fruit yoghurt, but dairies had been producing GMO-free products as part of their organic standard before.

1.4 Motives of adoption and objective of the paper

What are the reasons for the adoption of private production standards? And if firm adopt, is it always on a voluntary basis? Much of the literature analyzes reasons with retailers as decision makers, since they can exercise market power and may use the standard as strategic tool (e.g. Von Schlippenbach & Teichmann, 2012). In these cases, producers are modeled as the party that is given the option by the retailer, while producers are assumed to invest in the standard, if it increases their profits or not to invest if unprofitable. Von Schlippenbach and Teichmann (2012) find that the quality standard set by the retailer improves their bargaining power over suppliers, since producers who have made irreversible investments are inflexible and exiting the quality standard may cause additional cost. Vandemoortele and Deconinck (2014) surveyed the existing literature and further found the following motives to adopt private standards: (1) Reduction of consumers’ uncertainty and asymmetric information; (2) Strategic tool for product differentiation; and (3) Preempting government regulation. Literature that analyze companies reasons for adopting voluntary standards mention product differentiation and reputation gains as major reasons (Loader & Hobbs, 1999; Porter & Van der Linde, 1995).

In this paper, we combine the effects of irreversible investment decisions of processors with their potential reputation gains from adopting a private standard. Additionally, processors are modeled to differ in their size and have different cost functions. We develop a formal theoretical model, to first find the maximal level of irreversible costs a dairy can invest by considering uncertainty and flexibility. Second, we derive the optimal level of irreversible costs if they are below the maximum threshold level by considering the positive effect of investments on reducing *ex-ante* and *ex-post* costs. Third, we use the model to test the hypothesis, that dairies with more suppliers need a higher reputation effect to trigger the investment. And fourth, we extend the model to the case of more than one firm, to analyze strategic behavior if reputation effects on the market need to be shared by all firms in that market, using a noncooperative game-theoretic extension analysis to the model.

2 Methods and formal model

The net present value (NPV) rule can be a helpful starting point to analyze investments in a production standard.. It says that the expected future cash flows (or net-benefits) from the implementation of the standard, discounted to the time of investment, V, should be greater than (or equal to) the investment cost, I; i.e., invest if $NPV \equiv -I + V \geq 0$. If, however, future cash flows are uncertain, the investment is irreversible, or can be exited only with high exit cost, and the investment can be delayed to wait for the value to reach a certain level, and only invest, if this level is achieved, than the real option approach can be an auxiliary extension to the NPV rule. It says, that an investment should only be made, if the expected reversible present value exceeds some multiple, $m > 0$, of the irreversible value, i.e., $-mI + V \geq 0$. We will now derive the necessary ingredients for the option valuation rule for the case of investments into the GMO-free value chain. We start with the irreversible cost, continue with the deterministic cash flow, followed by the present value of cash flows including the effect of mislabeling, and then set up the equations for the option value including the uncertainty, irreversibility and flexibility effect.

2.1 Investment cost as precautionary measure

Irreversible costs, I, in the adoption phase are for example investments to segregate conventional and GMO-free production lines by separated transportation, processing and storing systems. Further irreversible costs arise from negotiations with stakeholders such as farmers and retailers, and training of employees. Since it is not possible to test for the GMO-free quality[2], companies have to design and set up contracts with their suppliers (e.g. farmers) to guarantee compliance. Higher investments in efficient systems mean a higher level of care as a precautionary measure.

2.2 Deterministic price and ex-ante measures

If consumers are willing to pay a higher price for GMO-free products compared to conventional products, dairies are able to get a price premium, p, for GMO-free products. Dairies are assumed to be price takers. The received premium depends on the reputation gain, R_i for dairy i.[3] The more dairies that produce GMO-free, the lower is the individual gain from GMO-free production, such that $p_i = p_i(R_{-i}, R_i)$ where R_{-i} denotes the reputation gain of all dairies excluding i, with $\partial p_i / \partial R_i > 0$ and $\partial p_i / \partial R_{-i} < 0$. The latter partial derivative reflects a price reduction for dairy i due to losses in sales compared to dairies $-i$. The deterministic price premium, p, a company can get for GMO-free products are reversible benefits.

To compute the deterministic cash flow, we need to deduct the deterministic costs from the deterministic price premium, p. The implementation of a standard affects the whole agricultural and food value chain of a sector. For example, producing GMO-free milk production affects retailers which market the product, dairies which produce it, farmers who produce the raw material, and national and international feed traders. As a result, firms that decide to implement a quality standard enter a new value chain with bilateral co-ordination between producer and processor through contracts (Weaver & Wesseler, 2004) – a low form of vertical integration. Once firms have entered the value chain, some measures need to be taken to enforce the contract. In the contract, dairies should specify *ex-ante* measures that need to be followed by all parties who participate in the value chain.

The minimum measures that need to be taken are specified in the national regulation (e.g. no GM-feed at least three month before milking). Additionally, the dairies can specify further measures, such as the handling of feed sampling, documentation, control, certification, and auditing of suppliers. On the one hand, very strict measures increase *ex-ante* cost, k^a, but on the other hand reduce the probability of *ex-post* harm (e.g. Kolstad, Ulen, & Johnson, 1990; Shavell, 1984). Postponing the

[2] EFSA states "… that no technique is currently available to enable a valid and reliable tracing of animals products (meat, milk, eggs) when the producer animals have been fed a diet incorporating GM plants." (EFSA, 2007)

[3] Reputation gains can also be considered as marketing advantage of a company for avoiding controversially discussed GMOs (Porter & Van der Linde, 1995).

treatment of *ex-post* harm to the next sub-section, we can now define the deterministic cash-flow, C^d to be $C^d = p - k^a$. *Ex-ante* cost depend on the number of suppliers, s, involved in the contract, and how much the dairy invests into efficient segregation system, i.e., $k^a = k^a(I, s)$. The more the dairy invests into segregation, the lower (with an decreasing effect) are the necessary *ex-ante* cost, but the more suppliers, the higher (with an increasing rate) are the *ex-ante* costs, such that $\frac{\partial k^a}{\partial I} < 0$ with $\frac{\partial^2 k^a}{\partial I^2} < 0$, and $\frac{\partial k^a}{\partial s} > 0$ with $\frac{\partial^2 k^a}{\partial s^2} > 0$.

2.3 Effect of mislabeling

Specifying efficient *ex-ante* measures can reduce the probability of *ex-post* harm. Since the increase of the level of care decreases the deterministic cash-flow, the level of care should be weighted such that it equals the expected *ex-post* harm. *Ex-post* harm can be costs of tort liability, or a loss of sales, due to image or reputation losses from misrepresentation and/or mislabeling of products as GMO-free, if at least one of the parties does not comply with production regulation and is detected. We model *ex-post* harm as a shock, D, that is deducted from the deterministic cash flow in some random time periods, t, such that:

$$C_t^d = C_{t-1}^d - D \cdot x_t \tag{1}$$

where x_t is a iid Poisson distributed random number, $x_t \epsilon \{0,1\}$, and D is a so-called Poisson event; a fixed amount that is lost if a Poisson event occurs, i.e., if $x_t = 1$. Over some time periods, we expect a Poisson event to arrive with probability $\lambda = E(x) = Var(x)$. Hence we can write:

$$C_t^d = C_{t-1}^d - \begin{cases} 0 & with\, probability\ (1-\lambda) \cdot \Delta t \\ D & with\, probability\ \ \lambda \cdot \Delta t \end{cases} \tag{2}$$

Having defined the deterministic cash-flows cost and expected *ex-post* harm, we can now compute the expected present value of future deterministic cash-flows, V^d:

$$V^d = \frac{C^d}{r} - \sum_{t=1}^{\infty} \frac{t \cdot (\lambda \cdot D)}{(1+r)^t} = \frac{p - k^a}{r} - \frac{\lambda \cdot D}{r^2} \tag{3}$$

where r denotes the risk-free interest rate and the sum of future expected damages converges to the last term of equation (3). The mean arrival rate of a Poisson event as well as the size of the damage, D, depend on the size of *ex-ante* costs, and on the level of care through investments, such that a higher precaution, k^a, and I, reduce λ and D. More specifically, the probability and size of *ex-post* harm increase with the number of suppliers, such that $\lambda = \lambda(k^a, I, s)$ with $d\lambda = \frac{\partial\lambda}{\partial k^a} dk^a + \frac{\partial\lambda}{\partial I} dI + \frac{\partial\lambda}{\partial s} ds$, and $D = D(k^a, I, s)$, with $dD = \frac{\partial D}{\partial k^a} dk^a + \frac{\partial D}{\partial I} dI + \frac{\partial D}{\partial s} ds$. Total differentials $d\lambda$ and dD are positive (negative) if the effect of increasing suppliers outweighs (falls behind) the precautionary effects.

2.4 Uncertainty, irreversibility and flexibility effect in stochastic costs

So far, we have computed the expected reversible present value, with a time independent variance. Reversible refers to the fact that the reversible benefits and costs will only arise, as long as the production runs. The investment cost, on the other hand, are sunk costs, and hence will be treated as irreversible cost within the option valuation framework. Irreversibility can be a reason for firms to continue producing below the profit break-even point for some period as shown by Tauer (2006) in the case of dairy farms. Uncertainty comes into the model by including the stochastic costs of raw materials, k_t^s. Since dairies are price-takers, an increase (decrease) in input costs, decreases (increases) the value of production, such that

$$V_t^s = V^d - K_t^s(\gamma_i k_t^s) \tag{4}$$

where $K_t^s(\gamma_i, k_t^s)$ are the future input costs, discounted by a not yet defined interest rate to the time of investment. Coefficient $\gamma_i \epsilon (0,1)$ determines, how much of the stochastic input a dairy i uses. The yearly costs k_t^s are stochastic and uncertain over time, and are assumed to follow a geometric Brownian motion with drift, (GBM)[4]:

$$\frac{dk^s}{k_{t-dt}^s} = \alpha_k \cdot dt + \sigma_k \cdot dz \tag{5}$$

where dk^s / k_{t-dt}^s denotes an infinitesimal percentage change in the stochastic cost. The standard deviation, σ_k, reflects the volatility and $dz = \varepsilon_t \sqrt{dt}$ is a Wiener process with $\varepsilon_t \sim iid\ N(0,1)$. Since

[4] Note that the geometric Brownian motion does not differ if k_t^s was multiplied by γ_i, because changes of k_t^s over time are percentage changes.

absolute change dk^s is assumed to be normally distributed, percentage changes are log-normally distributed and the risk-free drift rate α_k is estimated through (e.g. Mußhoff & Hirschauer, 2003):

$$\alpha_k = \ln\left(\frac{1}{(N-1)\cdot\Delta t}\cdot\sum\nolimits_{t=\Delta t}^{N\cdot\Delta t}\frac{k_t^s}{k_{t-\Delta t}^s}\right) \tag{6}$$

The volatility σ_k is:

$$\sigma_k = \sqrt{\frac{1}{N-1}\cdot\sum_{t=\Delta t}^{N\cdot\Delta t}(\chi_t-\bar{\chi})^2} \tag{7}$$

with $\chi_t = ln\frac{k_t^s}{k_{t-\Delta t}^s}$ and $\bar{\chi}$ is the mean of χ_t. With the assumption of a geometric Brownian motion, we can now define the discount rate, by which the stochastic costs are discounted; that is the convenience yield, $r-\alpha_k$.

$$K_t^s = \frac{\gamma_i k_t^s}{r-\alpha_k} \tag{8}$$

The convenience yield can be interpreted as the opportunity cost of delaying the investment until it is "deep enough in the money" (Dixit & Pindyck, 1994, p. 149). Since the underlying value V_t^s is a function of the stochastic cost, it also follows a GBM (Dixit & Pindyck, 1994, p. 184) and its process can be defined as:

$$\frac{dV^s}{V_{t-dt}^s} = \alpha_V\cdot dt + \sigma_V\cdot dz \tag{9}$$

Since $V^s = V^s(V^d)$, the percentage changes in V^s depend on V^d, and hence, drift-rate $a_V = \alpha_V(V^d)$ and volatility $\sigma_V = \sigma_V(V^d)$, which are both computed the same way as α_k and σ_k in equation (6) and (7). The threshold irreversible cost can be found by using the analytic McDonald-Siegel approach (McDonald & Siegel, 1986). Hence, a firm should invest if the stochastic present value is greater or equal to threshold V^{s*}, or equally, if the irreversible costs are smaller than or equal to the threshold cost I^* [5]:

$$V^s \geq V^{s*} \equiv m \cdot I \qquad \text{or} \qquad I \leq I^* \equiv \frac{1}{m} \cdot V^s \tag{10}$$

with

$$V^s = \frac{p(R_{-i}, R_i) - k^a(I^*, s)}{r} - \frac{\lambda(I^*, k^a, s) \cdot D(I^*, k^a, s)}{r^2} - \frac{\gamma_i k^s}{r - \alpha_k} \tag{11}$$

and $m = \frac{\beta - 1}{\beta}$ and $m \epsilon]0,1[$ is some investment multiple. Hence, I^* is some percentage of V^s, and

$$\beta = \frac{1}{2} - \frac{\alpha_V}{{\sigma_V}^2} + \sqrt{\left(\frac{\alpha_V}{{\sigma_V}^2} - \frac{1}{2}\right)^2 + \frac{2 \cdot r}{{\sigma_V}^2}} > 1 \tag{12}$$

where $\beta = \beta(V^s)$.

The real-option value rule suggests, never to invest, if $V^s_{<I} \epsilon]-\infty, I[$, and to wait, if $V^s_{<I} < V^s < V^{s*}$. In the latter case, the time value of the option to wait is $-F_0 + (V - I)$, where F_0 is:

$$F_0 = (mI - I)\left(\frac{V}{mI}\right)^\beta \tag{13}$$

Using equation (13), we find that $F_0 = (I - V^s)$ holds, iff $V^s \geq V^{s*} \equiv mI$.

[5] For a derivation of β using dynamic optimization or contingent claims analysis, compare e.g. Dixit and Pindyck (1994). Using dynamic optimization, the total time differential dt of the Bellman equation, $rF(V^s)dt = E[dF(V^s)]$, is derived with Ito's Lemma. The derived differential equation, $\frac{1}{2}\sigma_V^2 V^2 F''(V) + \alpha_V V F'(V) - rF(V) \equiv 0$, then needs to satisfy three boundary conditions: (1) the condition that the option of a zero value is and remains zero, $F(0) = 0$; (2); the value-matching condition, $F_0 = V - I$; and (3) the smooth pasting condition, $F' = (V - I)'$.

3 Optimal level of investment and size effect on reputation

3.1 Equilibrium identity of real-option investment rule

To analyze the behavior of the real-option investment rule, we using the implicit-function theorem, and define equations (10) and (11) together as equilibrium identity, $F \equiv 0$, which needs to hold at the trigger point of the option:

$$-I^* + \frac{1}{m(V^d)}\left[\frac{p(R_{-i}, R_i) - k^a(I, s)}{r} - \frac{\lambda(I, k^a, s) \cdot D(I, k^a, s)}{r^2} - \frac{\gamma_i k^s}{r - \alpha_k} - V^s\right] \equiv 0 \qquad (14)$$

with

$$V^{s*} = V^{s*}(I, R_{-i}, R_i, s, r, \gamma_i, k^s, \alpha_k) \qquad (15)$$

$$I^* = I^*(I, R_{-i}, R_i, s, r, \gamma_i, k^s, \alpha_k) \qquad (16)$$

Since $\beta = \beta(V^s)$, we can define $m = m(V^d; I, R_{-i}, R_i, s, r, k^s, \alpha_k)$. However, since β is based on a stochastic process with changing percentage increments over time, we cannot use comparative statics to analyze its behavior with respect to changes in e.g. s and R. However, comparative-statics can be used by first approximating β using simulation of different values of V^d, and then, estimate β as a linear or polynomial function of V^d with $\beta'(V^d) > 0$ and $\beta''(V^d) = 0$, in the linear case. Positive effect of V^d on β leads to a positive effect on m, $m'(V^d) \equiv m_V = \beta'/\beta^2 > 0$.

The partial total derivative of I^* is[6]:

$$\left.\frac{dI^*}{d\delta}\right|_{-\delta\ \text{constant}} \equiv §I^*_\delta = \frac{V^s_\delta m - V^s m_V}{m^2} \qquad \text{for} \quad \delta \epsilon \{I, R_{-i}, R_i, s\} \qquad (17)$$

where $-\delta$ are all exogenous variables not in δ. The $sgn\,(§I^*_\delta)$ depends entirely on $sgn(V^s_\delta)$, such that $sgn\,(§I^*_\delta)$ is negative for subset $\delta_1 \epsilon \{s, R_{-i}\}$, and is assumed to be positive for subset $\delta_2 = \{b | V^s_b m > V^s m_V\} = \{I, R_i\}$.[7]

[6] Subscripts denote partial derivatives.

[7] Higher irreversible costs and reputation would only have a negative effect on I^*, if V^s had a very large effect on m.

3.2 *Level of precautionary investments and reputation depending on dairy size*

Using the implicit function rule on the equilibrium identity, $F \equiv 0$ in equation (14), we can find the effect of quasi-fixed factor, size, $\underline{s}$, on investment, I, and on reputation, R_i:

$$\frac{dI}{d\underline{s}} \equiv -\frac{\partial F/\partial \underline{s}}{\partial F/\partial I} = -\frac{V_{\underline{s}}^{s} m - V^{s} m_{\underline{s}}}{m^{4}(V_{I}^{s} m - V^{s} m_{I})} > 0 \tag{18}$$

$$\frac{dR_i}{d\underline{s}} \equiv -\frac{\partial F/\partial \underline{s}}{\partial F/\partial R_i} = -\frac{V_{\underline{s}}^{s} m - V^{s} m_{\underline{s}}}{m^{4}\left(V_{R_i}^{s} m - V^{s} m_{R_i}\right)} > 0 \tag{19}$$

where

$$V_{\underline{s}}^{s*} = -\frac{\frac{\partial k^{a}}{\partial \underline{s}}}{r} - \frac{\left(\frac{\partial \lambda}{\partial k^{a}}\frac{\partial k^{a}}{\partial \underline{s}} + \frac{\partial \lambda}{\partial \underline{s}}\right) D + \lambda\left(\frac{\partial D}{\partial k^{a}}\frac{\partial k^{a}}{\partial \underline{s}} + \frac{\partial D}{\partial \underline{s}}\right)}{r^{2}} < 0 \tag{20}$$

Equations (18) and (19) show, that larger dairies need to invest more in irreversible precautionary measures, and/or need to get greater reputation gains than smaller dairies. This suggests, that in the case of individual decisions, without including the decisions of other firms, smaller dairies will be more likely to invest earlier in GMO-free production than larger ones.[8]

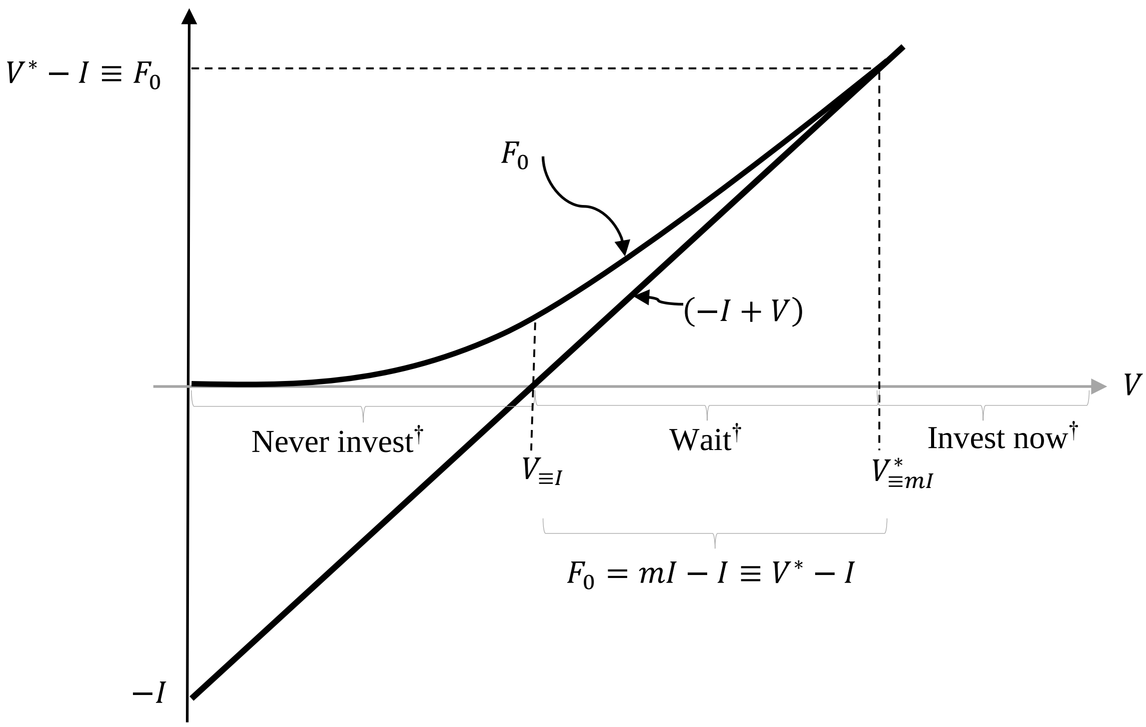
4 Equilibrium investment strategies of dairies in the market

4.1 *Decision of a single dairy and extension to the case of more than one dairy*

In section 2.4, we found that a dairy should apply the following three investment decision strategies, shown graphically in Figure 1: (1) Never invest, if $-I + V < 0$; (2) Wait to invest, if $0 \leq -I + V < F_0$, and (3) to invest now, if $-I + V \equiv F_0$, iff $V \geq V^{*} = mI$. The value of having the option to wait

[8] Earlier does not necessarily mean at an earlier point in time. It rather means at a lower level of reversible benefits.

is called the time value of the option, $F_0 - (-I + V)$. If a dairy invests before the optimal investment point, that is, if $V^S_{\equiv I} < V^{S*}_{\equiv mI}$, it will make economic losses in the size of the time value.



Note: † optimal strategy for a single firm.

Figure 1: Real option value and firm's optimal investment strategies.

In reality, dairy, i, makes its decision to wait, denoted by W, or to invest now, denoted by N, depending on the decision of all other dairies, $-i$. Generally, let the set of dairies be $D = \{1, \dots, n\}$. Then dairy i has two pure strategies, $a_i = \{\text{W}, \text{N}\}$, where a_i denotes the set of actions of i. Further, let the set of all pure strategy profiles of n dairies except dairy i be $a_{-i} = \langle a_1, \dots, a_{i-1}, a_{i+1}, \dots, a_n \rangle$, then by combining actions of i and $-i$, we get the action profile $a = (a_i, a_{-i})$.

4.2 General-form net-payoff functions and best response for competing dairies

Net-payoffs of dairy i, denoted $\pi^i(a_i, a_{-i})$, are described by the following functions:

$$\pi_i(\text{W}, a_{-i}) = V^c_i(R_{-i}) \qquad \forall i \epsilon D \tag{21}$$

$$\pi_i(\text{N}, a_{-i}) = -mI + V^s_i(R_i, R_{-i}, \gamma_i) \qquad \forall i \epsilon D \tag{22}$$

where $V_i^c = p_i^c(R_{-i})/r$ denotes the expected present value of conventional production as a function of the reputation gain of all other dairies, R_{-i}. For both equations (21) and (22), $R_{-i} = 0$, $\forall -i$, iff $a = (a_i, \mathrm{W})$. Further, if all dairies decide to wait, that is, $a = (\mathrm{W}, \mathrm{W})$, reputation gains are for all dairies, $R_{-i} = 0$, and hence, payoff $\pi_i(\mathrm{W}, \mathrm{W}) = \pi_{-i}(\mathrm{W}, \mathrm{W}) = V^c(0) = 0$. This implies, that no dairy in the market would offer GMO-free products, if $\pi_i(\mathrm{N}, a_{-i}) = -mI + V_i^s(R_i, R_{-i}, \gamma_i) < 0$, $\forall i \epsilon D$. But if $-i$ offer GMO-free, $a = (\mathrm{W}, \mathrm{N})$, and payoff $\pi_i(\mathrm{W}, \mathrm{N}) \equiv \pi_i(\mathrm{W}, \mathrm{W}) + \Delta V_i^c / \Delta R_{-i} < \pi_i(\mathrm{W}, \mathrm{W})$, where $\Delta V_i^c / \Delta R_{-i} < 0$ denotes the loss of payoffs for dairy i, due to the effect of other dairies gaining reputation, and hence, having a marketing advantage.[9] Firms may differ with respect to their amount of stochastic input (e.g. GMO-free feed) they use, γ_i.

As benchmark, we investigate the case of full symmetry, where $\gamma_i = \gamma_{-i}$, and $\pi_i = \pi_{-i}, \forall a = (a_i, a_{-i})$. Dairy $i's$ best response is $a_i^* \epsilon BR(a_{-i})$, iff $\forall a_i \epsilon A_i$, $\pi_i(a_i^*, a_{-i}) \geq \pi_i(a_i, a_{-i})$, where $BR(a_{-i})$ is the best-response set, assuming that all the other dairies play strategy a_{-i}. The case, where $\pi_i(\mathrm{N}, a_{-i}) < 0$ was already shown to lead to a situation, where both dairies wait. If dairy i can skim off all reputation gains from the market, and hence, gets an expected present value $V^s(R_i, 0, \gamma_i) > V^{s*} \equiv mI$, its strategy will be to invest now. But the best response for all other dairies in this case will be to also invest, if their losses from waiting are greater than their losses from non-optimal investment (i.e., their time value of the option), i.e., if $\Delta V_i^c / \Delta R_{-i} < -mI + V_i^s(R_i', R_{-i}', \gamma_i) < 0$, where $R_i' = R_{-i}'$ denotes the reputation gains, if shared among dairies. In that case, dairy's i dominant strategy is to invest now, and the pure strategy Nash equilibrium is when $a = (\mathrm{N}, \mathrm{N})$, where all dairies give up their respective time value of the option.

4.3 The non-symmetric case of two dairies and dominant strategy of dairy 1

We will now restrict the number of dairies to two, $i \epsilon (1,2)$.[10] Assumptions on the payoffs, $\pi_i(a_1, a_2)$, for both dairies are shown in Table 1. We assume that dairy 1 has a dominant strategy to invest now, that is, $a_1 =$ "N" strictly dominates $a_1 =$ "W", $\forall a_2$, $\pi_1(\mathrm{N}, a_2) > \pi_1(\mathrm{W}, a_2)$. This implies that first, dairy 1's expected present value $V^s > V^{s*}$, when dairy 2 waits, and second, that the time value of dairy 1 from non-optimal investment if both dairies have to share the reputation gain is lower, than

[9] This reputation loss for dairy i can have a strong effect, if NGO's set non-investors under pressure to immediately invest.

[10] A set with parentheses denotes an ordered pair (not an open interval).

what dairy 1 would lose, if it waits, when only dairy 2 invests. The optimal strategies would not differ, if profit of dairy 1 is positive, $0 < \pi_1(\mathrm{N,N}) < \pi_1(\mathrm{N,W})$. Dairy 2 does not gain from being the only investor, because it needs to substitute a larger amount of GMO-feed than dairy 1, i.e., $\gamma_2 > \gamma_1$.

Table 1: Payoffs $\pi_i(a_1, a_2)$ for dairy i, and strategies $a_i = \{\mathrm{W,N}\}$, (W = Wait, N = Invest Now).

Payoffs	Assumptions for R_i	Assumptions for γ_i
$\pi_1(\mathrm{N,N}) = -mI + V_1^s(R_1', R_2', \gamma_1) \gtreqless 0$	$R_2' = R_1' > 0$	$\gamma_2 > \gamma_1$
$\pi_1(\mathrm{N,W}) = -mI + V_1^s(R_1, 0, \gamma_1) > 0$	$R_1 > 0, R_2 = 0$	$\gamma_2 > \gamma_1$
$\pi_1(\mathrm{W,N}) = 0 + \Delta V_1^c(R_2)/\Delta R_2 < 0$	$\Delta R_2 > 0$	
$\pi_1(\mathrm{W,W}) = V_1^c(0) = 0$	$R_2 = 0$	
$\pi_2(\mathrm{N,N}) = -mI + V_2^s(R_1', R_2', \gamma_2) < 0$	$R_1' = R_2' > 0$	$\gamma_2 > \gamma_1$
$\pi_2(\mathrm{N,W}) = 0 + \Delta V_2^c(R_1)/\Delta R_1 < 0$	$R_1 = 0, R_2 > 0$	
$\pi_2(\mathrm{W,N}) = -mI + V_2^s(0, R_2, \gamma_2) < 0$	$\Delta R_1 > 0$	$\gamma_2 > \gamma_1$
$\pi_2(\mathrm{W,W}) = V_2^c(0) = 0$	$R_1 = 0$	

Table 1 shows, that both firms will get zero payoffs from not investing, if the respective other firm, $-i$, also not invests, i.e., $a = (\mathrm{W,W})$. If both firms decide to invest now, $a = (\mathrm{N,N})$, firm 2 will get negative payoffs and firm 1 either positive or negative payoffs, $-mI + V_i^s(R_i', R_{-i}', \gamma_i)$. Only one of the firms $i\epsilon\{1,2\}$ will get negative payoffs of $\Delta V_i^c/\Delta R_{-i}$ if only the other firm $-i$ invests. And only firm 1 will get positive payoffs, if it is the only firm to invest. This holds for $\gamma_2 > \gamma_1$, $R_1' < R_1$, and $R_2' < R_2$.

4.4 Best response and Nash equilibrium in the non-symmetric two-dairy case

The best response for dairy 2, $a_2^*\epsilon BR(a_1 = \text{"N"})$, depends on whether $\pi_2(\mathrm{N,W}) < 0$ is greater or smaller than $\pi_2(\mathrm{N,N}) < 0$. Therefore, the model has two potential pure strategy Nash equilibria, $\forall i$, $a_i \epsilon BR(a_{-i})$:

1. $a = (\mathrm{N,W})$ $\quad$ π_1 gains $-mI + V_1^s(R_1, 0) > 0$ $\quad$ $\pi_i(\mathrm{N,W}) > \pi_i(\mathrm{N,N})$ $\forall i\epsilon\{1,2\}$
   π_2 loses $\Delta V_2^c/\Delta R_1 < 0$

2. $a = (\mathrm{N,N})$ $\quad$ π_1 has $-mI + V_1^s(R_1', R_2') \gtreqless 0$ $\quad$ $\pi_i(\mathrm{N,N}) > \pi_i(\mathrm{W,N})$ $\forall i\epsilon\{1,2\}$

$$\pi_2 \text{ loses } -mI + V_1^s(R_1', R_2') < 0$$

The first Nash equilibrium with action profile $a = (\text{N}, \text{W})$ implies, that only firm 1 invests, and gains from investing, while firm 2 waits, because its time value of investing when $V^s < V^{s*}$, outweighs the reputation losses from waiting.

The second Nash equilibrium with $a = (\text{N}, \text{N})$ implies, that both firms will invest now, iff firm $i\epsilon\{1,2\}$ loses more reputation payoffs from $-i's$ investment, than what i will lose by sharing the reputation gains, $R_1' = R_2' > 0$.

5 Discussion and conclusion

The derivatives of the option framework identity with respect to reputation in the single-firm investment setting imply that smaller firms invest earlier. This is, because firms with fewer suppliers will more easily reach a high enough reputation gain from investing in the GMO-free standard, than a firm with many suppliers. In the equilibrium analysis with more than one firm, we found that firms with low stochastic input have a dominant strategy to invest. Combining the first and the second result suggests, that firms with low usage of stochastic input, and a small size, will be more likely than firms with many suppliers to achieve an expected present value above the threshold value. This further implies, that it is more likely to get a pure strategy Nash equilibrium, where only small firms invest, while large ones wait and lose some payoffs from reputation losses, than the reverse situation. This model might explain, why GMO-free production in Germany is a niche market for mainly small dairies in Southern parts of Germany, where cows are often fed with grass, and hence do not need to substitute large amounts of GMO-soybean as protein feed. The second equilibrium was found by combining the reputation-size effect with the second Nash equilibrium. In that case also large firms decide to invest because their expected reputation loss – this effect can be intensified when external forces like media reports or NGO attacks are in public - is larger than their losses of non-optimal investment. This could lead to an outcome, where firms invest into GMO-free production, even though they are worse off than before the standard was developed. This might explain, why (almost) all dairies in Austria, where cows are more often fed on grassland areas, produce GMO-free. We generally find that the larger a firm is, and the higher its stochastic costs, the more likely it is for the firm to be worse off than in the situation, where no dairy invested.

References

BLL. (2008, September 19). Pressemitteilung: "Ohne Gentechnik"-Kennzeichnung findet kaum Akzeptanz. *Bund für Lebensmittelrecht und Lebensmittelkunde e.V., BLL.* Retrieved May 18th, 2013, from http://www.bll.de/print/presse/pressemitteilungen/pm_080919_ohne_gentechnik

Caswell, J. A. (1998). Should use of genetically modified organisms be labeled? *AgBioForum, Volume 1, Number 1*, 22-24.

Dixit, A., & Pindyck, R. S. (1994). *Investment Under Uncertainty*. Princeton, New Jersey: Princeton University Press.

EFSA. (2007). Statement on the fate of recombinant DNA or proteins in the meat, milk or eggs of animals fed with GM feed *EFSA Journal*.

European Union. (2003). *Regulation (EC) No 1830/2003 of the European Parliament and of the Council of 22 September 2003 concerning the traceability and labeling of gmo and the traceability of food and feed products produced from gmo and amending Directive 2001/18/EC*.

Federal Ministry of Germany. (1998). *Verordnung zur Durchführung gemeinschaftsrechtlicher Vorschriften über neuartige Lebensmittel und Lebensmittelzutaten*.

Federal Ministry of Germany. (2004). *"EG-Gentechnik-Durchführungsgesetz vom 22. Juni 2004 (BGBl.|S.1244), das zuletzt durch Artikel 2 des Gesetzes vom 9. Dezember 2010 (BGBl.|S.1934) geändert worden ist"*.

Gen-ethisches-Netzwerk (Producer). (2006, June). Milch ohne Gentechnik - geht das? Interview von Christof Potthof. *GeN (Gen-ethisches Netzwerk)*. Retrieved from http://www.gen-ethisches-netzwerk.de/gid/176/milch-ohne-gentechnik-geht

Giannakas, K., & Yiannaka, A. (2006). Agricultural Biotechnology and Organic Agriculture: National Organic Standards and Labeling of GM Products. *AgBioForum, 9*(2), 84-93.

Henson, S., & Humphrey, J. (2010). Understanding the complexities of private standards in global agri-food chains as they impact developing countries. *The journal of development studies, 46*(9), 1628-1646.

Kolstad, C. D., Ulen, T. S., & Johnson, G. V. (1990). Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements? *The American Economic Review, 80*(4), 888-901.

Krewer, G. (Producer). (2011, September 07). Zitat aus Deutschlandfunk-Interview. Milch und Milchprodukte "Ohne Gentechnik". Molkereien setzen auf konventionelles Futter. *Deutschlandfunk Inteview von Susanne Kuhlmann mit Gerd Krewer und Anderen*. Retrieved from http://www.dradio.de/dlf/sendungen/umwelt/1548754/

Loader, R., & Hobbs, J. E. (1999). Strategic responses to food safety legislation. *Food policy, 24*(6), 685-706.

McDonald, R., & Siegel, D. (1986). The Value of Waiting to Invest. *Quarterly Journal of Economics, 101*(4), 707-727.

Mußhoff, O., & Hirschauer, N. (2003). *Bewertung komplexer Optionen*: PD-Verlag.

News aktuell. (2014). Deutsche Eierwirtschaft sieht GVO-Freiheit in Legehennenfutter nicht mehr gewährleistet: Breite Teile der Erzeuger können Zusage GVO-freier Fütterung nicht mehr aufrecht erhalten *Newsroom: Zentralverband der deutschen Geflügelwirtschaft e.V.*, from http://www.presseportal.de/pm/32363/2670443/deutsche-eierwirtschaft-sieht-gvo-freiheit-in-legehennenfutter-nicht-mehr-gewaehrleistet-breite

Porter, M. E., & Van der Linde, C. (1995). Toward a new conception of the environment-competitiveness relationship. *Journal of economic perspectives, 9*, 97-118.

Shavell, S. (1984). A Model of Optimal Use of Liability and Safety Regulation. *The RAND Journal of Economics, 15*(2), 271-280.

Smith, E., Jarvis, A., & Marino, A. (2011). State of play in the EU on GM-free food labelling schemes and assessment of the need for possible harmonisation - A Proposal to DG SANCO: GHK in association with ADAS, Ltd.
Tauer, L. W. (2006). *When to Get In and Out of Dairy Farming: A Real Option Analysis*. Paper presented at the American Agricultural Economics Association Annual Meeting, Long Beach, California, July 24-26, 2006.
Vandemoortele, T., & Deconinck, K. (2014). When are private standards more stringent than public standards? *American Journal of Agricultural Economics*, *96*(1), 154-171.
Venus, T., & Wesseler, J. (2012). Bereits doppelt so viel "ohne Gentechnik"-Milch als Biomilch in Deutschland: Welche Bedeutung hat GVO-freie Milch für unsere Milchwirtschaft? *Deutsche Molkerei Zeitung*, *133*(2), 24-26.
VLOG. (2013, February 21). Lizenznutzer und Mitglieder. Stand: 13.05.2013. from http://www.ohnegentechnik.org/fileadmin/ohne-gentechnik/Dokumente/VLOG_Siegelnutzer_Mitglieder.pdf
Von Schlippenbach, V., & Teichmann, I. (2012). The strategic use of private quality standards in food supply chains. *American Journal of Agricultural Economics, 94*(5), 1189-1201.
Weaver, R. D., & Wesseler, J. (2004). Monopolistic pricing power for transgenic crops when technology adopbers face irreversible benefits and costs. *Applied Economic Letters*, *11*, 969-973.

Appendix

Table 2: Payoffs, $\pi_i(a_1, a_2)$ for dairies $i\epsilon(1,2)$.

		Dairy 2	
		Now	**Wait**
Dairy 1	**Now**	$\pi_1(\mathrm{N,N}) \gtreqless 0$ $\pi_2(\mathrm{N,N}) < 0$	$\pi_1(\mathrm{N,W}) \geq 0$ $\pi_2(\mathrm{N,W}) < 0$
	Wait	$\pi_1(\mathrm{W,N}) < 0$ $\pi_2(\mathrm{W,N}) < 0$	$\pi_1(\mathrm{W,W}) = 0$ $\pi_2(\mathrm{W,W}) = 0$