Innovation Led Alliances: Theory and application to the GM Plant Industry

Samira Rousselière,

ONIRIS, Department of Management, Statistics and Communication, Nantes, France, samira.rousseliere@oniris-nantes.fr

Damien Rousselière,

AGROCAMPUS OUEST, Department of Economics, Management and Society, Angers, France, damien.rousseliere@agrocampus-ouest.fr

Shyama Ramani,

United Nations University, Maastricht, The Netherlands, ramani@merit.unu.edu

Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association Annual Meeting, Boston, MA, July 31 – Aug. 2.

Innovation Led Alliances: Theory and application to the GM Plant Industry

Samira Rousselière*[1], Damien Rousselière†[2], and Shyama Ramani‡[3]

[1]ONIRIS, Department of Management, Statistics and Communication, Nantes, France
[2]AGROCAMPUS OUEST, Department of Economics, Management and Society, Angers, France
[3]United Nations University, Maastricht, The Netherlands

May 24, 2016

Abstract

The objective of the present paper is to identify the determinants of the form of collaboration initiated between an upstream innovator and a downstream producer in order to incorporate a new input and commercialize an innovation consisting of a quality enhanced final product, with an empirical application to the GM plant industry. The choice of upstream firm between license, joint venture, merger or a subsidiary is modeled as a function of three parameters: degree of quality improvement engendered by the new input, the market share of the downstream producer and the capability of the downstream producer to incorporate the new input and commercialize it successfully. We also discuss the case where the downstream firm is a cooperative.

Keywords: biotechnology, cooperative, GMO, innovation, intellectual property, merger, joint venture, license, subsidiary
JEL Classification: D20, D45, L10, L65,Q13

*Corresponding author. Email: samira.rousseliere@oniris-nantes.fr.
†Email: damien.rousseliere@agrocampus-ouest.fr.
‡Email: ramani@merit.unu.edu

1 Introduction

A major difference between innovation creation in knowledge intensive industries like pharmaceuticals fifty years back and today, is that while earlier innovations were mainly created through in-house R&D, today it involves a complex sequence of processes necessitating collaborations with specialty firms at many steps. With increasing vertical division of labor in the innovation creation process, there are increasing instances of an upstream input-supplier firm coming up with an innovation, which has to be transferred to a downstream producer firm, in order to be incorporated into a final product for the market. Such input innovations usually improve the quality of the product. For instance, Intel has been supplying the computers and telecommunications industry with chips, boards, systems and software building blocks since the last three decades. Quintiles is the leading service firm that carries out clinical trials of new drugs for the pharmaceutical industry. Gore-Tex transformed the outdoor clothing industry by commercializing non-crease and specialty fabrics. In the seeds sector, agbiotechnology has revolutionized the seeds sector with the creation of transgenic seeds with specific properties. The objective of the present paper is therefore to contribute to our understanding by identifying the determinants of the form of collaboration initiated between an upstream innovator and a downstream producer to order to incorporate a new input and commercialize an innovation consisting of a quality enhanced final product.

Any upstream innovator of an "input" has essentially three strategies to choose from in order to transfer its technology to a downstream producer: license, joint venture or merger. Of course, the innovator firm can also decide not to "transfer" its technology and instead try to develop the final product incorporating the innovation on its own and enter the market on its own. What will be the best option for the innovator? The answers to the above question have been pondered over extensively in three domains of economics: industrial organization (see Rey and Tirole (2007); Geroski (1995); Beath et al. (1995) for surveys); international economics (see Singh and Marjit (2003); Saggi (2002); Krugman (1995) for surveys) and the economics of innovation (see Sena (2004); Arora et al. (2002) for surveys). These works examine the demand conditions (market size and elasticity of demand), firm characteristics (cost of production, information), product characteristics (quality, complementarities between different inputs or outputs) and market features (degree of competition, entry barriers) that lead to one or the other modes of technology transfer.

A common feature of most of the above theoretical literature on technology transfer is their consideration of symmetric firms. Clearly, the assumption of identical firms is unrealistic, especially in emerging or fast evolving markets shaped by innovation (e.g. biotechnology, nanotechnology), where firm growth is conditioned by firm specific dynamic capabilities. Therefore, starting from the premise that firms are distinct in terms of their capacity to create and commercialize innovations, the present paper examines how the mode of technology transfer between an upstream and a downstream firm is determined, as a function of three parameters that seem important: degree of quality improvement engendered by the new input, the market share of the downstream producer and the dynamic capabilities of the downstream producer to incorporate the new input and commercialize it successfully. Such dynamic capabilities could include technological capabilities or absorptive capacity to integrate the new input into the production process, regulatory capabilities or knowledge of the legal system to get authorization to market the new product, and intimate knowledge of the needs and preferences of targeted consumers.

A game theoretic model of technology transfer between an upstream innovator and a downstream producer is developed in this paper by combining the well known model of competition through quality differentiation (Mussa and Rosen, 1978; Tirole, 1989), with the even more general model of negotiation through bargaining (Nash, 1950) and integrating them into a model of technology transfer based on firm specific competencies (Ramani et al., 2001; Ramani, 2000). Firm specific dynamic capabilities are measured by a probability of success of incorporation of new input into an old product to improve its quality and then selling it in the final market, after clearing regulation. The equilibrium outcomes of the game demonstrate that an upstream firm is likely to choose a license if the difference in the capabilities of the two firms is not significant and the entry costs are high; a joint venture if the value of the innovation is high or if the difference in the qualities is high and the market size is large and the downstream firm is highly capable; and a merger if the difference in the qualities is small and the local firm is not very capable. Finally, an upstream firm initiates a subsidiary, if the monopoly corresponding to the innovation is inefficient, the capability of the downstream firm is low but it cannot be driven out.

The present paper makes two types of contributions to the existing literature. First, it contributes to the theoretical literature by proposing a model that explains the mode of technology transfer on the basis of firm specific capabilities, market size and product qualities. While standard theoretical models have clearly highlighted the influence of market size and quality differences on supplier-producer transactions, the impact of asymmetric firm-specific capabilities on the form of technology transfer has rarely been examined. Furthermore to our knowledge the full choice between subsidiary, merger, joint venture and licensing has not been addressed together, as previous works highlight only the trade-offs between two alternatives [1]. We also show that the legal status of the downstream has huge effects on the mode of technology transfer, that may lead government to promote cooperatives. Second, through an application of the model to worldwide commercialization of Bt cotton by Monsanto, the present paper also attempts to add to the empirical literature on the strategies deployed by agbiotech firms to introduce transgenic plants all over the world. The existing empirical literature has mainly examined the role of asset complementarities, high transactions costs in technology markets, maximization of the first mover's advantage, minimization of the risks of opportunism and access to intellectual property in the evolution of the transgenic plant varieties market. The present paper gives further insight by focusing on the impact of factors such as the demand shifts associated with the enhanced quality of the transgenic variety, the capabilities of downstream seed firms and the upstream agbiotech firm and the size of the market for the transgenic varieties.

The remainder of this article is organized as follows. The first section presents the related

[1] A exception is the recent work of Sun (2014), but the purpose of this author is to provide an expert-based method to analyze the strategic alliances modes.

empirical and theoretical literature on the technology alliance in industrial organization and agricultural economics. The following section introduces the model. The final market equilibrium and the two main propositions are eventually presented in sections 4 and 5. We study the case where the downstream firm is a cooperative. The penultimate section presents an application to the introduction of transgenic plants. The final section offers conclusions and recommendations.

2 Related Literature

The relevant literature is both empirical and theoretical. The literature on the technology alliances (Colombo, 2003; Kim and Vonortas, 2006; Somaya et al., 2010; Ceccagnoli and Hicks, 2013) has highlighted the trade-offs between licensing and joint ventures. For Colombo (2003), equity joint ventures occur 42.7% between two partners with similar (but low) capabilities and only 7.6% between two partners with similar (but high) capabilities. Kim and Vonortas (2006) show that the stock of technological knowledge of the licensor and the strenght of IPR (Intellectual Property Rights) protection are found to be important determinants of the propensity to sell technology through nonexclusive licenses. citeSohn2006 examine the license policy of an innovator in a monopolist position, facing potential entrants. Various authors examined the entry of multinational corporations (MNC) on developing economies market. They highlight the trade-offs between international joint venture and a wholly owned subsidiary by the foreign JV partner (Banerjee and Mukherjee, 2010; De Hek and Mukherjee, 2011; Sinha, 2008) and deal with the issue of instability of joint ventures in the context of international investment. For Banerjee and Mukherjee (2010) or Sinha (2008), there may be a coexistence between an joint venture and subsidiary that can be used as a threat and can stabilize the joint-venture. To our knowledge, no author try to model the whole choice of technology transfer. Baker et al. (2008) model the strategic alliances between two firms which own assets that can be combined together.

In the existing literature on consolidation activities in the biotechnology industry, starting from the seminal work of Fulton and Giannakas (2001a), Spielman et al. (2014) show that Firms use mergers, acquisitions, licensing agreements, and technical collaborations to increase the efficiency of their operations, secure valuable intellectual property (IP), launch new products, break into new markets, or integrate related operations. However the authors note that these strategic behavior are different in various countries. Marco and Rausser (2008) find that large firms with high patent enforceability to buy small diversified firms. In line with our model, authors have already analyzed the impact of the introduction of GM seeds in a framework with explicitly market power of the innovator (upstream agbiotech firm) (Bagdhasaryan et al., 2010; Falck-Zepeda et al., 2000; Shi, 2009; Sobolevsky et al., 2005).

3 The Model

There are two firms, an upstream firm, u, and a downstream firm, d. In the ex-ante context, before the introduction of the new input, the downstream market is served uniquely by firm d

with a conventional variety. The upstream firm, u, armed with a new input has to incorporate it in the conventional variety being sold by the downstream firm. The innovation is then sold on the final market.

Three important contextual features are to be kept in mind. First, we consider a quality enhancing product innovation that yields a higher utility to consumers vis-à-vis an existing variety [2] [3]. Second, for simplicity we assume that the cost of incorporating the new input into the existing product is already included in the fixed sunk costs of creating the new input, which does not influence the negotiations between the upstream firm and the downstream firm. Third, when an upstream firm issues a license or forms a joint venture or merger, the industrial organization of the downstream market does not change and it rests a monopoly. However, if the upstream firm enters the final market without collaboration by creating its subsidiary, either the incumbent downstream firm can guard its niche in the conventional variety or it can be driven out. In the former case, the competition in the downstream market increases and the final market becomes a duopoly offering different quality products.

As may be recalled, the dynamic capability of the downstream firm is represented in terms of a firm-specific probability of incorporating the new input and commercializing the innovation successfully. Each mode of collaboration will impact the capability of the firms differently.

When the upstream firm offers a license to the downstream firm, there is a transfer of "codified knowledge" about the technology leading to an increase in the technological competence of the licensee. Let the probability of a downstream firm to commercialize the innovation after the knowledge transfer be α_d .

When the upstream firm offers to form a joint venture (JV), it shares all its information with the downstream firm. This means that a new variety is created whenever any of the two partners succeed in developing the right variety. Suppose the capability of the upstream firm is given by α_u and the capability of the downstream firm is given by α_d, as in the case of the license after the knowledge transfer. Then the probability of successfully commercializing the innovation is $\bar{\alpha} = 1 - ((1 - \alpha_u)(1 - \alpha_d))$. This increases the technological competence of the downstream firm more than in a license, since $\bar{\alpha} > \alpha_d$ (also note that $\bar{\alpha} > \alpha_u$).

What should be the capability of a merger? Will the information sharing be more or less than in a JV? No absolute answer can be given to the above question and various authors had investigated the instability of such JV (Banerjee and Mukherjee, 2010; De Hek and Mukherjee, 2011; Sinha, 2008). Usually a merger is accompanied by a downsizing of personnel and this may or may not include the R&D staff. For the purposes of this paper, in order that there is a trade-off between a merger and JV assuming equal entry costs, we assume that information sharing is less in a merger than in JV. It is the assumption made in the literature which try to address the "merger paradox" by allowing internal competition (see for example Creane and Davidson (2011)). In particular, we consider the extreme case of no information sharing

[2] For example, product-enhancing nutritional attributes for final consumers (Colson and Huffman, 2011) or Bt cotton which is toxic to some insect pests or BR cotton that combines the insect resistance and the herbicide tolerance traits for farmers (Arza and Van Zwanenberg, 2014).

[3] Note that our model considers also producers/farmers as consumers who maximize utility, although their demand is derived. We assume that product quality above takes the form of productivity increases, risk reductions and convenience gains, in which case a utility maximization assumption for the producer is appropriate. See Fulton and Giannakas (2001b) or Saitone and Sexton (2010, p. 361) for an example of this assumption

and assume that the probability of successful commercialization of innovation is linked to the technological competence of the bidder or α_u . However, there is a capture of the marketing network of the downstream firm as will be detailed later.

The three stage sequential game starts with the move of the upstream firm, which decides between offering a license to the local downstream firm, initiating a JV or a merger, or opening its own subsidiary in the final market. Both firms enter into a second stage if the subsidiary is not chosen. In the second stage, the downstream firm can accept or reject the offer of the upstream firm. If it accepts, the two firms enter into a third stage in which they bargain over the value of the license, L or the share in the joint venture, v, or the acquisition price in the merger, M. If the bargaining fails, then the upstream firm enters the final market anyway by opening a subsidiary. The game is resolved by applying the standard method of backward induction.

3.1 The bargaining game in the third stage

The final values of L , v , and M are obtained by solving for the Nash Bargaining equilibrium, which gives the outcome of a negotiation process between the upstream firm and the downstream firm, where each makes a proposal, which the other can accept or refuse, and in the case of refusal, make a counter offer. In the case of all three options: license, joint venture or merger, the alternative payoffs that can be obtained if the negotiation fails, are the same as the payoffs that can be obtained under a subsidiary. Therefore, the outcome of the negotiations concerning L and v are given by the equilibrium values of a Nash-Bargaining game, with the outside alternative payoffs z_u for the upstream firm and z_d for the downstream firm, where z_u and z_d are the payoffs from a subsidiary for the upstream firm and the downstream firm respectively. For each entry option the Nash bargaining solution is found by maximizing the product of the payoff from collaboration net of the outside alternative payoffs of each player, over the variable being negotiated.

It is to be noted that the bargaining is over the innovation rent generated by the collaboration. In other words, the costs and benefits obtained by each of the players outside of the negotiation process is not into account. This concerns two factors, the infrastructure and organizational costs of new market entry of the upstream firm, $E < \pi_c^m$; and the earnings of the downstream firm from the conventional variety in the absence of collaboration. Again, the entry costs are assumed to be equal for all forms of entries, JV, merger and subsidiary, for simplicity of analysis.

In what follows, the monopoly profit from the conventional variety is given by π_c^m and the monopoly profit from the innovation by π_i^m . In the case when the final market becomes a duopoly, the duopoly profit from selling the innovation is π_i^d . Finally, if there is a differentiated duopoly with both the new variety and the conventional variety being sold, π_i^{df} indicates the duopoly profit to the upstream firm from selling the new variety and π_c^{df} is the duopoly profit to the downstream firm from selling the conventional variety.

We start the resolution of the game by calculating the values of the alternative payoffs z_u and z_d.

When an upstream firm opens a subsidiary there could be a change in the industrial organization as the local downstream firm may or may not be driven out. If co-existence of conventional variety and innovation is not possible, then the subsidiary earns an expected profit of $\alpha_u \cdot \pi_i^m$ from sales of the innovation, while incurring an infrastructural entry cost of E. In this case, the downstream firm has an expected profit of $(1 - \alpha_u) \cdot \pi_c^m$ i.e. it earns monopoly profit from selling conventional variety in the event that the upstream firm fails. If the upstream firm succeeds in commercializing the innovation, and if co-existence is possible, then the downstream firm earns the duopoly profit π_c^{df} (under product differentiation) from selling the conventional variety, the lower-quality product, and the upstream firm earns π_i^{df} from offering the innovation. If the upstream firm fails to commercialize the innovation, then it earns nothing, while the local downstream earns a monopoly profit as usual from selling conventional variety, π_c^m .

- ☐ *Bargaining outcomes in a license*: When the upstream firm and the downstream firm initiate a license they negotiate on the split of the expected payoff, $\alpha_d \cdot \pi_i^m$, into the license fee L for the upstream firm and the rest for the downstream firm. If the downstream firm does not succeed in developing the innovation, it falls back on sales from the conventional variety that it would have in its stocks, but this does not enter into the negotiation, as it is totally unaffected by the license. This leads to a payoff of $\alpha_d \cdot \pi_i^m + (1 - \alpha_d) \cdot \pi_c^m - L$ for the downstream firm and a payoff of L to the upstream firm from licensing.

- ☐ *Bargaining outcomes in a joint venture*: When a joint venture succeeds in commercializing the innovation, the upstream and the downstream firms share the expected monopoly profit, $\bar{\alpha} \cdot \pi_i^m$, in the ratio of $(1 - v)$ and v . In addition, the upstream firm incurs the entry cost E. If a new variety is not developed, then the local downstream firm rests a monopolist selling the conventional downstream. However, this possibility does not affect the negotiation outcome, as it is totally independent of the knowledge transfer. This gives rise to payoffs of $(1-v) \cdot \bar{\alpha} \cdot \pi_i^m - E$ for the upstream firm and $v \cdot \bar{\alpha} \cdot \pi_i^m + (1 - \bar{\alpha}) \cdot \pi_c^m$ for the downstream firm.

- ☐ *Bargaining outcomes in a merger*: By buying out a local downstream firm, the upstream firm captures the latter's marketing network, thereby assuring itself the monopolistic market of the conventional downstream in case it fails to create the innovation. The upstream firm incurs two types of costs, the merger payment M and the entry cost E. Therefore, in a merger, the local downstream firm gets the merger payment of M, while the upstream firm gets $\alpha_u \cdot \pi_i^m + (1 - \alpha_u) \cdot \pi_c^m - M - E$. Now we can understand the reasoning for differential information sharing. If in a merger, the entry cost is the same as in a JV and the information sharing is also the same, then a merger will always dominate a JV because of positive earnings even when the commercialization fails.

The Nash Bargaining equilibrium values is calculated by maximizing the product of the net gain for the two players from the negotiation process over the variable being negotiated. The net gain for each player is the difference between what would be obtained if the negotiation is successful and what would be obtained if the negotiation fails. For instance, when a license is offered, it generates an expected income of $\alpha_d \cdot \pi_i^m$, to be divided into L for the upstream firm and $\alpha_d \cdot \pi_i^m - L$ for the downstream firm. According to the Nash-Bargaining theorem, the value of the license L is obtained by solving the following problem:

$$\max_L \left[(L - z_u) \cdot (\alpha_d \cdot \pi_i^m - L - z_d)\right] \tag{1}$$

This yields the equilibrium license value as:

$$L = \frac{\alpha_d \cdot \pi_i^m - z_d + z_u}{2} \tag{2}$$

It is to be noted that what the downstream firm gets outside of the negotiation context, in case it does not succeed in creating the appropriate innovation and falls back onto the conventional variety, equivalent to $(1 - \alpha_d) \cdot \pi_c^m$ does not enter into the discussion of the negotiation.

Similarly, applying the Nash Bargaining method, the equilibrium values of v and M can be obtained as:

$$v = \frac{\bar{\alpha}\pi_i^m + z_d - z_u}{2 \cdot \bar{\alpha} \cdot \pi_i^m} \tag{3}$$

$$M = \frac{\alpha_q \cdot \pi_i^m + (1 - \alpha_u) \cdot \pi_c^m + z_d - z_u}{2} \tag{4}$$

Now we proceed to solve for the values of π_c^m, π_i^m, π_i^d, π_i^{df} , π_c^{df} , z_u and z_d in order to identify the conditions under which each mode of entry will be chosen by the upstream innovator.

3.2 Outcomes of the second stage

We begin with an analysis of the ex-ante downstream market equilibrium before the introduction of the innovation Let us suppose that the downstream firm, d, which is a local monopolist, supplies a conventional variety of quality s_c . There are n consumers indexed by a quality preference parameter θ , which in turn is uniformly distributed over the interval $\left[\underline{\theta}, \overline{\theta}\right]$ with $s_c \in \left[\underline{\theta}, \overline{\theta}\right]$. A consumer buys one unit of the conventional variety whenever his utility from consumption is positive. Moreover, suppose that when consumer j with a quality index θ_j consumes one unit of the conventional variety, the utility obtained, u_j , is a function of the quality s_c and the price p as shown below:

$$u_j = \theta_j \cdot s_c - p \tag{5}$$

As a point of reference, θ_c is the value of the quality parameter such that the utility per unit consumption at price p_c is zero,

$$u_c = \theta_c \cdot s_c - p_c \Leftrightarrow \theta_c = \frac{p_c}{s_c} \tag{6}$$

Thus, all consumers j with $\theta_j > \theta_c$ buy one unit of the conventional downstream at price p_c . Let the cumulative density function of θ be given by $F(\theta)$. Then the demand at price p_c is:

$$d(p_c, s_c) = q(p_c, s_c) = 1 - F(\theta_c) \Leftrightarrow q(p_c, s_c) = 1 - \frac{\theta_c - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{\bar{\theta} \cdot s_c - p_c}{(\bar{\theta} - \underline{\theta}) \cdot s_c} \tag{7}$$

Let c denote the constant marginal cost of production of the downstream firm. Then the downstream firm, d, decides the quantity to be produced by solving the following problem:

$$\max_{p_c} (p_c - c) \cdot q_c(p_c, s_c) \tag{8}$$

This gives the monopoly price, quantity and profit at optimum as:

$$p_c^m = \frac{\bar{\theta} \cdot s_c + c}{2} \tag{9}$$

$$q_c^m = \frac{\bar{\theta} \cdot s_c - c}{2(\bar{\theta} - \underline{\theta}) \cdot s_c} \tag{10}$$

$$\pi_c^m = \frac{(\bar{\theta} \cdot s_c - c)^2}{4(\bar{\theta} - \underline{\theta}) \cdot s_c} \tag{11}$$

The consumer's surplus under the monopoly case then emerges as:

$$CS_c^m = \frac{(\bar{\theta} \cdot s_c - c)^2}{8 \cdot s_c} \tag{12}$$

From direct derivation it can be seen that the consumer's surplus is an increasing function of the market size, given by $\bar{\theta}$, and the quality of the final product being offered, s_c , while being a decreasing function of the production costs, c. In order to ensure positive quantities and profits, in what follows, it is assumed that the initial market size and the quality of the conventional variety are sufficient to support production costs, i.e. $\bar{\theta} \cdot s_c > c > 0$.

4 Ex-post downstream market equilibrium

Now we proceed to examining the final market equilibrium in the ex-post situation

4.1 Ex-post downstream market equilibrium with innovation under license, JV or merger: the case of the monopoly

If an innovation is introduced in the market through a license, a JV or a merger with the local downstream firm, the final market remains a monopoly with the innovation being the only product sold. Let the quality of the improved final product or innovation be given by s_i where $s_i > s_c$ and $s_i \in \left[\underline{\theta}, \bar{\theta}\right]$. Let the price, quantity and profit associated with an innovation under a monopoly be given by p_i^m, q_i^m and π_i^m respectively. Then following the same chain of reasoning as before, the monopolist's profit maximizing price, profit and quantity can be obtained as follows:

$$p_i^m = \frac{\bar{\theta} \cdot s_i + c}{2} \tag{13}$$

$$q_i^m = \frac{\bar{\theta} \cdot s_i - c}{2(\bar{\theta} - \underline{\theta}) \cdot s_i} \tag{14}$$

$$\pi_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{4(\bar{\theta} - \underline{\theta}) \cdot s_i} \tag{15}$$

$$CS_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{8 \cdot s_i} \tag{16}$$

This gives us our first result.

Lemma 4.1. *In the case of a license, a JV or a merger, when the downstream market structure remains a monopoly, the price, quantity, profit and consumer's surplus increase after the introduction of the innovation.*

Proof. See Appendix A. □

This is not surprising as the innovation is quality enhancing. Therefore, even while price increases, there is a rise in demand and in consumer welfare.

4.2 Ex-post downstream market equilibrium with a subsidiary : the issue of the co-existence

When the upstream firm opens a subsidiary, the impact on the industrial organization of the final market will depend on whether or not the co-existence of the innovation and conventional variety is possible. If the local downstream firm cannot survive the competition, it exits and the final market remains a monopoly, with only the upstream firm. However, if co-existence is possible then the upstream firm sells the higher quality innovation while the downstream firm sells the lower quality conventional variety.

When will a local downstream firm be driven out with the entry of the upstream firm? Consider the situation of a duopoly with differentiated products. Let p_i^{df} be the price charged by the upstream firm for the innovation and let p_c^{df} be the price charged by the downstream firm for the conventional variety.Furthermore, let θ_{ic}^{df} be the quality index such that a representative consumer is indifferent between consuming a unit of the conventional downstream or the innovation downstream. In other words:

$$\theta_{ic}^{df} \cdot s_c - p_c^{df} = \theta_{ic}^{df} \cdot s_i - p_i^{df} \tag{17}$$

This gives:

$$\theta_{ic}^{df} = \frac{p_i^{df} - p_c^{df}}{s_i - s_c} \tag{18}$$

Thus, the demand for the conventional variety and the innovation becomes:

$$q_c^{df}(p_c^{df}, p_i^{df}, s_c, s_i) = \frac{\theta_{ic}^{df} - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{p_i^{df} - p_c^{df}}{(s_i - s_c)(\bar{\theta} - \underline{\theta})} - \frac{\underline{\theta}}{\bar{\theta} - \underline{\theta}} \tag{19}$$

$$q_i^{df}(p_c^{df}, p_i^{df}, s_c, s_i) = 1 - \frac{\theta_{ic}^{df} - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{\bar{\theta}}{\bar{\theta} - \underline{\theta}} - \frac{p_i^{df} - p_c^{df}}{(s_i - s_c)(\bar{\theta} - \underline{\theta})} \tag{20}$$

At Nash equilibrium the two firms maximize their profit with respect to their prices, which gives the equilibrium prices as follows

$$p_i^{df} = c + \frac{(s_i - s_c)(2\bar{\theta} - \underline{\theta})}{3} \tag{21}$$

$$p_c^{df} = c + \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta})}{3} \tag{22}$$

The equilibrium quantities and profits can be calculated accordingly as :

$$q_i^{df} = \frac{(2\bar{\theta} - \underline{\theta})}{3(\bar{\theta} - \underline{\theta})} \tag{23}$$

$$q_c^{df} = \frac{(\bar{\theta} - 2\underline{\theta})}{3(\bar{\theta} - \underline{\theta})} \tag{24}$$

$$\pi_i^{df} = \frac{(s_i - s_c)(2\bar{\theta} - \underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} \tag{25}$$

$$\pi_c^{df} = \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} \tag{26}$$

Given that the innovation is of superior quality, the conventional variety must present a price advantage for co-existence. This implies that the price of the conventional variety must be sufficiently lower than that of the new product so that the quality parameter at which utility from an innovation becomes positive is greater than the quality parameter at which utility from a conventional downstream becomes positive. We show this through a simple proof by contradiction.

Let quality indices $\tilde{\theta}_i^{df}$ and $\tilde{\theta}_c^{df}$ be the qualities at which consumers get positive utility from the innovation and the conventional downstream respectively, so that $\tilde{\theta}_i^{df} = \frac{p_i^{df}}{s_i}$ and $\tilde{\theta}_c^{df} = \frac{p_c^{df}}{s_c}$. Then given that $s_i > s_c$ for all $\theta_j > \tilde{\theta}_i^{df}$ we have:

$$s_g \cdot \theta_j - p_i^{df} = s_i(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_i^{df}) \tag{27}$$

Suppose $\tilde{\theta}_i^{df} < \tilde{\theta}_c^{df}$. Then we can expand the right hand side of equation (27) further as follows:

$$s_g(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_c^{df}) = s_c\theta_j - p_c^{df} \tag{28}$$

The above inequality indicates that if $\tilde{\theta}_i^{df} < \tilde{\theta}_c^{df}$, then the utility from consumption of an innovation will always be greater than from a conventional variety at equilibrium for all $\theta_j > \tilde{\theta}_i^{df}$. Evidently in this case, the conventional variety will be driven out of the market. Therefore for co-existence we need $\tilde{\theta}_i^{df} > \tilde{\theta}_c^{df}$, in which case we will also have $\theta_{ic}^{df} > \tilde{\theta}_i^{df} > \tilde{\theta}_c^{df}$. In other words, whenever the innovation is not much costlier than a conventional downstream, it becomes attractive on both the quality and the price front driving out the conventional downstream segment. However, if the innovation is substantially costlier than a conventional downstream then both products will be able to co-exist on the market.

This brings us to our second result.

Lemma 4.2. *When the upstream firm opens a subsidiary, the conventional variety will be able to coexist if:*

- ☐ *there is a sufficient divergence in the quality preferences of consumers, i.e.*

$$(\bar{\theta} - \underline{\theta}) > (\bar{\theta} - 2\underline{\theta}) > 0 \tag{29}$$

- ☐ *the quality difference between the innovation and the conventional variety $s_i - s_c$, and the market size for the innovation, $\bar{\theta}$, are sufficiently small such that the following condition is satisfied:*

$$\underline{\theta} > \frac{3c + \bar{\theta}(s_i) - 2s_c}{2s_i - s_c} \tag{30}$$

Proof. See Appendix B. ☐

Compiling the results obtained so far, the payoffs of the upstream firm and the downstream firm from the different entry options can be summarized as in table 1.

Table 1: The payoffs of the upstream firm and the downstream firm

	Firm u	Firm d
License	$(\alpha_d \cdot \pi_i^m - z_d + z_u)/2$	$(\alpha_d \cdot \pi_i^m - z_d + z_u)/2 + (1-\alpha_d) \cdot \pi_c^m$
Joint-Venture	$(\bar{\alpha} \cdot \pi_i^m - z_d + z_u)/2 - E$	$(\bar{\alpha} \cdot \pi_i^m - z_d + z_u)/2 + (1-\bar{\alpha}) \cdot \pi_c^m$
Merger	$(\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m - z_d + z_u)/2 - E$	$(\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m - z_d + z_u)/2$
Subsidiary (non co-existence)	$\alpha_u \cdot \pi_i^m - E$	$(1-\alpha_u) \cdot \pi_c^m$
Subsidiary (co-existence)	$\alpha_u \cdot \pi_i^{df} - E$	$\alpha_u \cdot \pi_c^{df} + (1-\alpha_u) \cdot \pi_c^m$

with $\pi_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{4(\bar{\theta}-\underline{\theta})s_i}, \pi_c^m = \frac{(\bar{\theta} \cdot s_c - c)^2}{4(\bar{\theta}-\underline{\theta})s_c}$, $\pi_i^{df} = \frac{(s_g - s_c)(2\bar{\theta}-\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}$ *and* $\pi_c^{df} = \frac{(s_g - s_c)(\bar{\theta}-2\underline{\theta})^2}{9(\bar{\theta}-\underline{\theta})}$

5 Two propositions about new market entry strategies

Now we can turn to the main problem of the paper. How should an upstream innovator transfer technology downstream? For this, we examine the subgame perfect equilibrium of the game on the basis of the payoff structure defined in table 1 in the form of two results.

Proposition 5.1. *A subsidiary will be dominated by at least one other form of entry if the monopoly generated by the innovation is efficient vis-à-vis a duopoly with differentiated products. A subsidiary can emerge as a dominant form if the monopoly created by the innovation is inefficient, the competence of the local downstream firm is low or the quality difference is low and the entry costs are not too high.*

Proof. See Appendix C. □

In what follows, let us suppose that the monopoly generated by the innovation is efficient so that a subsidiary is always dominated by a merger. Then we can compare the conditions under which one of the three other possibilities, a license, a joint venture or a merger emerges as the dominant form.

Proposition 5.2. *An upstream firm is likely to choose:*

- □ *A license if the entry costs E is high and/or the difference in the capability of the upstream firm and the downstream firm, $\alpha_u - \alpha_d$, is low.*

- ☐ *A joint venture if the difference in the quality the innovation and the conventional downstream,*$s_i - s_c$ *, is high and/or the market size,* $\bar{\theta} - \underline{\theta}$ *, is large and the entry costs* E *are low.*
- ☐ *A merger if the difference in the quality of the innovation and the conventional variety,* $s_i - s_c$ *, is low and/or the difference in the capability of the upstream firm and the downstream firm,* $\alpha_u - \alpha_d$ *, is high and the entry costs* E *are low.*

Proof. See Appendix D. ☐

The intuition behind these arguments can be understood as follows. Under a license, the entire risk of developing an innovation is borne by the downstream firm and thus if the capability of the downstream firm is high, the prospects are good. The other advantage of a license is that the upstream firm does not pay an entry fee, and so whenever entry fees are high, a license is preferred. However, a license is always dominated by a joint venture, for low entry costs, when the market potential of the innovation is high, since the technological competencies of both the upstream firm and the downstream firm are put to use to develop the innovation, increasing the probability of its development. A merger also dominates a license, if in the case of failure, there is a large market for the conventional variety as a fall back option. However, a joint venture dominates a merger if the downstream firm has a high capability, as this is the input that does not figure in a merger. On the other hand, if the gain from the introduction of the innovation is low because of small quality difference between the innovation and the conventional variety, then a merger presents a low opportunity cost, because in case an appropriate innovation is not developed, the merger can fall back on the conventional downstream market.

6 Discussion: The case where the downstream firm is a cooperative

6.1 The new situation

In the seed industry, most of the local seed dealers are cooperatives supplying inputs to their members. In Argentina, the cooperatives generally received a subsidy from the Provincial government to purchase seeds from Monsanto (Arza and Van Zwanenberg, 2014). But plant breeders can also be cooperatives. For example, two well-known global seed companies are Limagrain (Joly, 2001) and Land O'Lakes (Boland et al., 2004). In other industries, the role of cooperative in providing quality-enhancing innovation to their members has been studied by Drivas and Giannakas (2010); Giannakas and Fulton (2005). Borgen and Aarset (2016) show also that breeding cooperatives have successfully increased their competitiveness in breeding by means of collectively organized efforts, here referred to as "Participatory Innovation". Taking into account this legal status may lead to two major changes:

- ☐ *the objective of the firm.* There is no consensus in the literature on what the cooperative maximize. It can be for example the utility or welfare of the members (as in Fulton and Giannakas (2001b) or Giannakas and Fulton (2005)) or its profit with a patronage refunded to its members (as in Agbo et al. (2015)). See Soboh et al. (2009) for a more complete review on the objective functions of cooperatives. We choose to follow Fulton and Giannakas (2001b) as there is only slightly change if we model the cooperative as a profit-maximizing enterprise.

- *the alternatives.* A merger with a cooperative is impossible under some regulations (e.g. France), but can occur in other countries (U.S.A. or Canada) although it is not common in agriculture (Chaddad and Cook, 2007). Lamprinakis and Fulton (2011) describe a takeover of a cooperative by an investor-owned firm. A recent example is the acquisition of *Cooperativa Central de Pesquisa Agricola* by Dow Agrosciences in Brazil (August 2014). We assume here that the merger is possible and that the members can liquidate the cooperative by distributing the equity to their members (as in Cross et al. (2009)).

On the downstream market, the cooperative' problem becomes a maximization of the utility of member with a constraint of covering the marginal cost c.

$$\max_{p_c}(u_j) = \theta_j \cdot s_c - p_c \tag{31}$$

$$s.t.\ p_c \geq c$$

We assume a free entry consumer cooperative(Drivas and Giannakas, 2010). As in Fulton and Giannakas (2001b), the optimality conditions for a maximum are satisfied when the coop prices its product at marginal cost i.e. CS is maximized when $p_c = c$. The ex-ante situation on the local market (with conventional product) is such as :

$$p_c^{mcoop} = c \tag{32}$$

$$q_c^{mcoop} = \frac{\bar{\theta} \cdot s_c - c}{(\bar{\theta} - \underline{\theta}) \cdot s_c} \tag{33}$$

$$\pi_c^{mcoop} = 0 \tag{34}$$

$$CS_c^{mcoop} = \frac{(\bar{\theta} \cdot s_c - c)^2}{2 \cdot s_c} \tag{35}$$

We can summarize the main change in the game. There is no change in the case of a merger with the previous situation. The upstream firm will takeover the cooperative and the final market remains a monopoly with a maximization of profit. The acquisition price M will be distributed to the members. There is a change if a subsidiary compete with the cooperative : the co-existence of a cooperative and a IOF is a mixed duopoly (Giannakas and Fulton, 2005; Saitone and Sexton, 2009; Fulton and Giannakas, 2013). A major difference with previous papers is that in our case the cooperative did not have an access to the high quality (innovation) and can only supply the low quality (conventional product). The case of the joint-venture between a IOF and a cooperative is ambiguous. We can reasonably assume that the new enterprise will maximize a joint function of the profit of the upstream firm and the consumer surplus (Soboh et al., 2009, p. 453). This is a non-weighted sum as the joint-venture places the same importance on both the joint-venture profit and the consumer surplus.

$$\max_{p_i}(p_i - c) \cdot q_i(p_i, s_i) + \frac{(\bar{\theta} - \theta_c)(\bar{\theta} \cdot s_i - p_i)}{2} \tag{36}$$

which is equivalent to

$$\max_{p_i}(p_i - c) \cdot \frac{\bar{\theta} \cdot s_i - p_i}{(\bar{\theta} - \underline{\theta}) \cdot s_i} + \frac{1}{2} \cdot (\frac{\bar{\theta} \cdot s_i - p_i}{s_i})(\bar{\theta} \cdot s_i - p_i) \tag{37}$$

Therefore the three bargaining situations are modified as follow:

- ☐ *Bargaining outcomes in a license.* When a license is offered to the cooperative, it generates an expected incomes of $\alpha_d \cdot \pi_i^{mcoop} = 0$ but an expected $\alpha_d \cdot CS_i^{mcoop}$ to be divided into L for the upstream firm and $\alpha_d \cdot CS_i^{mcoop} - L$ for the cooperative. The equilibrium value of L is $L = \frac{\alpha_d \cdot CS_i^{mcoop} - z_d - z_u}{2}$.

- ☐ *Bargaining outcomes in a Merger.* When a takeover of the cooperative is proposed to the members by the upstream firm. M for the cooperative to be refunded to the members, who have also a consumer surplus CS_i^m that will be lower than the consumer surplus under the cooperative CS_c^{mcoop}. The upstream firm is monopolistic profit-maximizing firm even if it fails to create the innovation: its payoff is still $\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m - M - E$. The equilibrium value of M is $M = \frac{\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m - z_u - CS_i^m + z_d}{2}$

- ☐ *Bargaining outcomes in a joint-venture.* If the new variety is not developed the cooperative rests a consumer surplus maximizing enterprise selling the conventional product. If the joint venture succeeds in commercializing the innovation, it maximizes the joint function of the profit of the upstream firm and the consumer surplus π_i^{jv}. The two firms share π_i^{jvcoop} in the ratio of $(1 - v)$ for the upstream firm (which still incurs the entry cost E) and v for the cooperative. The equilibrium value of v is $v = \frac{\bar{\alpha}\pi_i^{jvcoop} + z_d - z_u}{2 \cdot \bar{\alpha} \cdot \pi_i^{jvcoop}}$

6.2 The new ex-post downstream equilibria

We now need to define the four ex-post downstream equilibria.

- ☐ *Ex-post downstream equilibrium with a innovation under a License* The downstream enterprise is a cooperative.

$$p_i^{mcoop} = c \tag{38}$$

$$q_i^{mcoop} = \frac{\bar{\theta} \cdot s_i - c}{(\bar{\theta} - \underline{\theta}) \cdot s_i} \tag{39}$$

$$\pi_i^{mcoop} = 0 \tag{40}$$

$$CS_i^{mcoop} = \frac{(\bar{\theta} \cdot s_i - c)^2}{2 \cdot s_i} \tag{41}$$

☐ Ex-post downstream equilibrium with innovation under a JV
The maximization of π_i^{jvcoop} leads to the following values.

$$\max_{p_i}(p_i - c) \cdot \frac{\bar{\theta} \cdot s_i - p_i}{(\bar{\theta} - \underline{\theta}) \cdot s_i} + \frac{1}{2} \cdot (\frac{\bar{\theta} \cdot s_i - p_i}{s_i})(\bar{\theta} \cdot s_i - p_i) \tag{42}$$

$$p_i^{jvcoop} = \frac{\bar{\theta} \cdot s_i(\bar{\theta} - \underline{\theta} - 1) - c}{\bar{\theta} - \underline{\theta} - 2} \tag{43}$$

$$q_i^{jvcoop} = \frac{c - \bar{\theta} \cdot s_i}{(\bar{\theta} - \underline{\theta})s_i(\bar{\theta} - \underline{\theta} - 2)} \tag{44}$$

we know that $c - \bar{\theta} \cdot s_i < 0$, therefore for q_i^m to be positive, we need $\bar{\theta} < \underline{\theta} + 2$ i.e. a relative small market.

$$\pi_i^{jvcoop} = \frac{2(\bar{\theta} - \underline{\theta} - 2)(\bar{\theta} - \underline{\theta} - 1)(-c^2 - \bar{\theta}^2 \cdot s_i^2) + s_i(c - \bar{\theta}s_i)^2(\bar{\theta} - \underline{\theta})^2}{(\bar{\theta} - \underline{\theta} - 2)(\bar{\theta} - \underline{\theta})^2 \cdot s_i^2} \tag{45}$$

$$CS_i^{jvcoop} = \frac{(c - \bar{\theta}s_i)^2}{2s_i(\bar{\theta} - \underline{\theta} - 2)^2} \tag{46}$$

☐ Ex-post downstream equilibrium with innovation under a Merger

$$p_i^m = \frac{\bar{\theta} \cdot s_i + c}{2} \tag{47}$$

$$q_i^m = \frac{\bar{\theta} \cdot s_i - c}{2(\bar{\theta} - \underline{\theta}) \cdot s_i} \tag{48}$$

$$\pi_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{4(\bar{\theta} - \underline{\theta}) \cdot s_i} \tag{49}$$

$$CS_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{8 \cdot s_i} \tag{50}$$

☐ *Ex-post downstream equilibrium with a subsidiary and a cooperative*

The demand for the conventional product and the innovation becomes:

$$p_c = c \tag{51}$$

$$p_i = \frac{\bar{\theta}(s_i - s_c)}{2} \tag{52}$$

$$q_c = \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta}) - c}{2(s_i - s_c)(\bar{\theta} - \underline{\theta})} \tag{53}$$

$$q_i = \frac{c + \bar{\theta}(s_i - s_c)}{2(\bar{\theta} - \underline{\theta})(s_i - s_c)} \tag{54}$$

$$\pi_c = 0 \tag{55}$$

$$CS_c^{df} = \frac{(\bar{\theta} - c)^2}{2s_c} \tag{56}$$

$$\pi_i^{df} = \frac{(\bar{\theta}(s_i - s_c))^2 - c^2}{4(\bar{\theta} - \underline{\theta})(s_i - s_c)} \tag{57}$$

The new coexistence condition is now as follows.

Lemma 6.1. *When the upstream firm opens a subsidiary and if the downstream firm is a cooperative, the conventional variety will be able to coexist if the quality difference between the innovation and the conventional variety $s_i - s_c$ and the marginal cost c are sufficiently small , and the market size for the innovation, $\bar{\theta}$ is sufficiently large, such that the following condition is satisfied:*

$$\bar{\theta} > \frac{c(2s_i - s_c)}{s_c(s_i - s_c)} \tag{58}$$

Proof. See Appendix E. □

There is a significant change in the coexistence condition because of change in the objective function of the downstream firm.

6.3 New market entry strategies with a cooperative in the downstream market

Compiling the results obtained so far, the payoffs of the upstream firm (profit maximizing) and the downstream firm (cooperative) from the different entry options can be summarized as in table 2. Therefore the new market entry strategies for the upstream firm are as follow (see table 2)

Table 2: The payoffs of the upstream firm and the downstream firm

	Firm u	Firm d
License	$(\alpha_d \cdot CS_i^{mcoop} - z_d - z_u)/(2)$	$(\alpha_d \cdot CS_i^{mcoop} - z_d - z_u)/(2) + (1 - \alpha_d) \cdot CS_c^{mcoop}$
Joint-Venture	$(\bar{\alpha} \cdot \pi_i^{jvcoop} - z_d + z_u)/2 - E$	$(\bar{\alpha} \cdot \pi_i^{jvcoop} - z_d + z_u)/2 + (1 - \bar{\alpha}) \cdot CS_c^{mcoop}$
Merger	$(\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m + z_u + CS_i^m - z_d)/(2) - E$	$(\alpha_u \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m - z_u + CS_i^m + z_d)/(2)$
Subsidiary (non co-existence)	$\alpha_u \cdot \pi_i^m - E$	$(1 - \alpha_u) \cdot CS_c^m$
Subsidiary (co-existence)	$\alpha_u \cdot \pi_i^{df} - E$	$\alpha_u \cdot CS_c^{df} + (1 - \alpha_u) \cdot CS_c^m$

7 Empirical Application: New market entry strategies in the Agbiotech

7.1 Empirical Evidence

A transgenic plant is a typical example of an upstream innovation that requires collaboration between the innovator and a downstream producer for successful commercialization. An upstream firm creates a genetically modified plant variety, or GMV, with a particular trait, through artificial insemination of a gene or genes in a host plant. However, it cannot sell the seeds produced from the GMV directly to a farmer, because such seeds would be too fragile and inapt for all terrains. Instead the upstream firm seeks a seed firm to transfer the desired trait from the GMV prototype to elite, robust varieties, specifically developed for targeted regions in accordance with their agronomic and climatic features. Monsanto, the leader among upstream firms, has commercialized GMV in many countries of the world, using different strategies such as license, joint venture or subsidiary to facilitate its entry into new markets (Arza and Van Zwanenberg, 2014). The purpose of the present paper is to give insight on the rationality behind the variety of collaborative strategies deployed by Monsanto to commercialize genetically modified cotton (or Bt cotton), through the development of a game theoretic model designed to capture the main features of the context under study.

Conventional methods of breeding that have been developed over the centuries start with an initial selection of desired plants, followed by a sequence of cross-breeding, involving sexual and asexual reproduction processes. On the other hand, agbiotechnology uses genetic engineering techniques to create new plant varieties by first inserting specific genetic material into a selected plant and then following it up with cross-breeding. Agbiotechnology increases the precision of new plant variety creation exponentially by enabling the transfer of a desired gene set rather than permitting a random transfer of genes. It also cuts down the costs of producing new plant varieties, as plants can be "designed" to exhibit desired traits in a much shorter time. At present, the most popular traits that have been genetically transferred are insect resistance, pest resistance, herbicide tolerance and blockage of the functioning of certain genes (e.g. the gene that causes ripening).

A number of studies have also examined the rationality of alliances between upstream agbiotech innovators and downstream seed producers in the context of GMV commercialization. Kalaitzandonakes and Bjornson (1997) analyze 1600 collaborative agreements initiated during the 1980's in the sectors affected by agro-biotechnology, including R&D contracts, equity and licensing agreements, joint ventures and mergers and acquisitions, to show that the dominant strategies adopted during the 1980's were contractual relations rather than firm acquisitions. The predominance of R&D collaborations seems to have been due to the fact that this period represented the beginning of the life cycle of the agbiotechnology revolution with a high degree of technology and market uncertainty.

Several explanations have also been proposed for the waves of consolidation between agbiotech multinationals (same as the agrochemical incumbents) and seed firms during the 1990's. According to Kalaitzandonakes (1998) the acquisitions of seed firms by agbiotech firms in the USA were due to the high complementarities of assets owned by the agbiotech firms and the seed firms and the high transaction costs in technology markets to acquire the assets of the seed firms. This is also confirmed in a game theoretic model proposed by Johnson and Melkonyan (2003) to explain the restructuring of the crop seed sector. Their main result indicates that when the substitutability or complementarities of the investments of two firms are small, then transactions on the technology market without consolidation is optimal. However, when the substitutability or complementarities of the investments of two firms are high, then it is better for the firm with a higher stake in the innovation rent, to acquire the other. Graff et al. (2003) suggest that the purchases of seed firms were motivated by the need to acquire intellectual property, which otherwise could not be bought or could only be bought at higher prices in the markets for technology. They confirm their hypothesis by showing that the patent stocks of a group of agrochemical firms exhibit greater diversification rather than specialization over time, from 1975 to 1998. In their survey of mergers and acquisitions in the crop seed sector, Rausser et al. (1999) propose that mergers with seed firms served to minimize risks of opportunism associated with contracts. They note that it is impossible to write complete, contingent contracts in environments characterized by uncertainty and infrequent contract negotiations and very costly even to write incomplete, reasonably comprehensive, contingent contracts under such circumstances.

In 1911 in the province of Thuringia, in Germany, a scientist named Ernst Berliner discovered that a commonly occurring bacterium of the region could act as an insecticide against the local "flour moth" and he named it Bacillus Thuringensis (BT) after the region. An insecticide using these bacteria was commercialized in France in 1938 and thereafter in the USA during the 1950's. The Bt bacteria is a veritable reservoir of genes resistant to insects. Its different layers contain several proteins that act as poison for specific insects according to different modes of action. Each of these proteins is coded by a single gene, which makes it easy to transfer the trait to plants. By 1996, Monsanto had developed and bought to the market cotton containing Bt genes. Bt cotton contains its own insecticide against attacks of the bollworm, a major pest of cotton. When a bolloworm feeds on the leaves of a Bt cotton plant, its intestines get damaged so that the bollworm eats much less of the plant. Therefore, with Bt cotton, farmers do not need to spray pesticides as frequently as in the case of non-Bt cotton. Their costs go down and the damage to the plant and the environment is much less.

By 2001, Monsanto's Bt cotton technology, first commercialized in 1996 in the USA, was being sold commercially in seven countries: the United States, China, Mexico, Australia, Argentina, South Africa and Indonesia. The different strategies of Monsanto to commercialize Bt cotton world wide are now briefly presented. The case of Indonesia is left out as the government stopped the Bt cotton program in 2003 following years of controversy over the tactics deployed by Monsanto in Indonesia. Columbia is also left out as the adoption there is in its infancy stage.

- ☐ *Bt cotton in the USA through a joint venture* In 1993, Delta & Pineland (DPL) signed an exclusive agreement with Monsanto to commercialize the transgenic varieties created through their collaboration all over the world except in Australia and India (Pray et al., 2001). Monsanto and DPL developed Bt cotton varieties for the USA which were approved for commercial use in 1996. Given the intense cooperation between Monsanto and DPL, we consider their collaboration as a joint venture at the time it occurred, for the purpose of evaluating the predictions of the model developed in this paper. Though overruled by the US anti-trust authorities in 1998, Monsanto was permitted to acquire DPL in 2006.

- ☐ *Bt cotton in Mexico through a subsidiary* Transgenic cotton was introduced in Mexico in the same year as in the United States, due to its geographical proximity. It was the same strain as the one created for the US market and it was distributed by a subsidiary of DPL in Mexico (Traxler and Godoy-Avila, 2004). Since we consider DPL-Monsanto as one entity, we take the distribution of Bt cotton seeds by DPL in Mexico as being equivalent to the entry of the Mexican market through the creation of a subsidiary.

- ☐ *Bt cotton in Australia through a license* The national laboratory CSIRO (Commonwealth Scientific and Industrial Research Organization) of Australia licensed the genetic trait corresponding to the Bt cotton from Monsanto and created its own variety of Bt cotton for the Australian farmers called INGARD. Since 1997, Bt cotton seeds are distributed in Australia both by CSIRO and the Australian subsidiary of DPL (Fitt, 2003).

- ☐ *Bt cotton in China through a joint venture* In 1995, DPL started a research collaboration on cotton with the Chinese Academy of Agricultural Sciences (CAAS). In 1996, Monsanto, DPL and Singapore Economic Development Authority developed a joint venture, Ji Dai. In 1997, the Chinese Bio-safety Committee (CBC) approved the marketing of Bt cotton created by this venture in the province of Hebei and in 1999, two other varieties of Bt cotton were authorized to be marketed in the provinces of Anhui (Pray, 2001; Pray et al., 2001). In 1997, CAAS also obtained the authorization of the Chinese Bio-safety Committee to market the varieties of its transgenic cotton in nine provinces. In 2000, Monsanto and DPL formed a joint venture, An Dai, with the seed company of the province of Anhui. Within the framework of these joint ventures, Monsanto provides the Bt gene, and DPL the cotton varieties, while the Chinese companies undertake the evaluation of the varieties and the multiplication of the seeds and their distribution (Huang et al., 2002).

□ *Bt cotton in South Africa through a subsidiary* In South Africa, international seed companies such as DPL supply domestic companies with seeds and chemicals, and these firms are often local monopolies as well. For instance, a special variety of Bt cotton has been developed by the Monsanto-DPL team for South Africa and in the region of Makhathini, where it has been adopted, it is distributed by the local monopolist Vunisia cotton since 1997 (Ismael et al., 2002; Gouse et al., 2004).

□ *Bt cotton in Argentina through a joint venture and eventually a subsidiary* Monsanto created a joint venture, Genética Mandiyù with DPL and a local Argentian company called Ciagro. Farmers buying transgenic cotton seeds have to sign a contract promising not to use the seed for a second period as in Mexico. The adoption of Bt cotton in Argentina has been limited at first to a small set of large-scale farmers. Two plausible reasons have been offered for this mediocre response to Bt cotton. First, there is no government subsidy for cotton production in Argentina, unlike most other cotton growing countries. Second, the heavy price premium charged by the joint venture for the Bt cotton seeds could be a deterrent to adoption by the small scale poor farmers, who form the majority of the farming population (Qaim and De Janvry, 2003; Qaim et al., 2003). A change occurred in 2008 with the agreement between Monsanto, Provincial Governments and the actors of the cotton chain. The agreement led to a decrease in price, with a subsidy provided by the goverment to the cooperatives in order to purchase the seeds. In 2011, Monsanto Argentina acquired the whole ownership of Genética Mandiyù. Mandiyù GM seed varieties account for 100% since 2011(Arza and Van Zwanenberg, 2014).

□ *Bt cotton in India through a joint venture and eventually a license* In 1998, Monsanto formed a joint venture with Maharashtra Hybrid Seeds Company Ltd or Mahyco, the seed firm with the highest market share in India for cotton. Bt cotton seeds were imported from the USA and then crossed with the local varieties. By 2002, authorization was granted by the Indian authorities for the commercialization of Bt cotton seeds on Indian markets (Qaim, 2003). Since June 2006, each state of India imposed a ceiling seeds prices (including technology fee) for Bt Cotton (Arora and Bansal, 2012). Almost

90% of cotton area is planted to Bt cotton (Kalambar, 2013). Evidence from Reid and Ramani (2012) and specially (Spielman et al., 2014, p.95) suggests that in the trend of the consolidation of the industry most of firms have "relied largely on licensing agreements to integrate upstream technology development activities with downstream seed production and marketing, most significantly in the Bt cotton segment of the market".

The above facts can be further substantiated with figures on area under coverage of cotton, both GMV and conventional, which are an indicator of market size and patent applications related to cotton issuing from these countries, which are an indicator of their technological prowess. It is more difficult to get information on the prices of conventional cotton and Bt cotton, which can be taken as indicators of quality and only partial information is freely available. The compilation of the available information is given in table A2 in the appendix. Here, in table 3, we compare the predictions of the model with real facts to see to what extent reality is corroborated by theory. As the table indicates, the model seems to provide plausible explanations for the behaviour of Monsanto, though some caveats must be noted.

☐ With respect to Australia "low technological asymmetry" is likely to have been the key determinant rather than "small market size" in the choice of license as an entry strategy. As may be recalled, the public research system in Australia is strong and has already developed a number of GM cotton varieties.

☐ In the US, low entry costs have surely played an important role in favouring a joint venture over licensing once the market potential was established at the time of the first commercialization of Bt cotton.

☐ The technological asymmetry between the agbiotech firm and the local seed firm was probably greater in Argentina, India and China than in North America, but the difference in product quality seems to have been even more important. It can also be noted that these cases do not correspond to any of our simulations. This could be because regulation does not permit 100% equity holdings by a foreign company in the seeds sector in China and India, thereby barring mergers or subsidiaries as entry options for Monsanto in these countries. However, the present model still serves to explain the choice favoring a joint venture over a license. This is also validated by simulations 1-3, where the license often leads to a lower payoff for the agbiotech firm than a joint venture, especially when the technological asymmetries are high and the product quality difference is high.

☐ According to the model, in order to open a subsidiary the conditions for co-existence of the GMV along with the conventional seed must be satisfied. This implies that the size of the market is perceived to be low or/and the quality of the GMV is not deemed to be much greater than that of the conventional seed. It is not clear to what extent these perceptions hold true for the South African and Mexican markets. Furthermore, it is likely that the other factor favouring a subsidiary, namely low technological competencies of local seed firms, has played a role. Finally, with respect to Mexico, the geographical proximity and the concomitant low costs of entry could have also favoured the subsidiary option.

8 Conclusion

The phenomenon of upstream innovation led collaborations is not unique to the GMV industry. It is increasing in all high-tech sectors, where the division of labor in the creation of innovations is on the rise. In the above context, the present paper addresses two general questions. What kind of a collaborative strategy will an upstream innovator initiate with a downstream producer in order to incorporate its innovation into a final product and maximize its own profits? What are the consequences for the downstream firm and for consumer welfare? A game theoretic model is formulated to answer the above questions and the predictions of the model are tested against the case study of the commercialization of Bt cotton by Monsanto.

The main purpose of the present paper has been to try to explain the rationality of the strategies employed by a firm to commercialize an innovative product worldwide, through the initiation of licenses, joint ventures, mergers with local seed firms or subsidiaries in foreign markets. In order to respond to this query a game theoretic model of collaboration between an upstream innovator and a downstream producer was formulated. The rationality of the choice between a license, a joint venture, a merger or a subsidiary was then identified as a function of the market size, the asymmetry in technological competencies and the differences in product quality between the GMV and the existing conventional variety. The game theoretical model yielded three main results.

First, as long as the degree of market competition in the downstream seeds market does not change, the introduction of a GMV increases the price, quantity sold and consumer welfare in spite of any change in the composition of the players in the downstream market.

Second, the resolution of the game provided some simple indicators for the choice of entry strategy of an upstream innovator wanting to transfer its technology to a downstream producer. These are applicable not only to agbiotech firms, but to upstream technology providers in other sectors as well.

Third, the model seems to provide a plausible explanation for the behavior of Monsanto without taking recourse to transaction costs, informational constraints, complementary assets or intellectual property acquisitions, which are the factors most evoked in the present literature to explain the evolution of the GMV market or the technology alliance (e.g. (Colombo, 2003)). On the other hand, a comparison with reality makes it clear that all the explanatory variables proposed in this paper, market size, quality differences between GMV and conventional seeds and asymmetry in technological competencies between the agbiotech multinational and the local seed firm, do not apply in equal degree to the corresponding situations.

A limitation of the present model and most other theoretical models examining the welfare implications of the introduction of GMV is their unique focus on the short term market impact of GMV. A number of consumer associations and NGOs have highlighted the existence of market and non-market externalities. This calls for the formulation of more elaborate theoretical models, perhaps as extensions of the present paper, to take into account the resource constraints of farmers in the downstream crop seed market and examine the implications of the adoption of GMV with respect to the financial risk incurred and the impact of market and non-market externalities. Another possible extension is to test the present model against a larger dataset as a variety of GMV have been introduced in many countries.

References

Agbo, M., D. Rousselière, and J. Salanié (2015). Agricultural Marketing Cooperatives with Direct Selling: A Cooperative Non Cooperative Game. *Journal of Economic Behavior and Organization 109*, 56–71.

Arora, A. and S. Bansal (2012). Diffusion of bt cotton in india: Impact of seed prices and varietal approval. *Applied Economic Perspectives and Policy 34*(1), 102–118.

Arora, A., A. Fosfuri, and A. Gambardella (2002). *Markets for Technology. The Economics of Innovation and Corporate Strategy.* Cambridge: MIT Press.

Arza, V. and P. Van Zwanenberg (2014). The politics of technological upgrading: International transfer to and adaptation of gm cotton in argentina. *World Development 59*, 521–534.

Bagdhasaryan, D., E. Campens, and S. Lemarié (2010). The product line strategy of a seed company in a context with a licensed gm trait. GAEL, INRA-Université Pierre Mendès-France, Grenoble.

Baker, G., R. Gibbons, and K. Murphy (2008). Strategic alliances: Bridges between "islands of conscious power". *Journal of the Japanese and International Economies 22*, 146–163.

Banerjee, S. and A. Mukherjee (2010). Joint venture instability in developing countries under entry. *International Review of Economics and Finance 19*, 603–614.

Beath, J., Y. Katsoulacos, and D. Ulph (1995). Game-theoretic approaches to the modelling of technological change. In P. Stoneman (Ed.), *Handbook of the Economics of Innovation and Technological Change*, pp. 132–181. Blackwell Publishers.

Boland, M., V. Amanor-Boadu, and D. Barton (2004). Land o'lakes. *International Food and Agribusiness Management Review 7*(2), 63–75.

Borgen, S. and B. Aarset (2016). Participatory Innovation: Lessons from breeding cooperatives. *Agricultural Systems 145*, 99–105.

Ceccagnoli, M. and D. Hicks (2013). Complementary assets and the choice of organizational governance: Empirical evidence from a large sample of u.s. technology-based firms. *IEEE Transactions on Engineering Management 60*(1), 99–112.

Chaddad, F. and M. Cook (2007). Conversions and other forms of exit in U.S. Agricultural Cooperatives. In K. Karantininis and J. Nilsson (Eds.), *Vertical Markets and Cooperative Hierarchies*, pp. 61–72. London: Springer.

Colombo, M. (2003). Alliance form: A test of the contractual and competence perspectives. *Strategic Management Journal 24*, 1209–1229.

Colson, G. and W. E. Huffman (2011). Consumers' willingness to pay for genetically modified foods with product-enhancing nutrional attributes. *American Journal of Agricultural Economics 93*(2), 358–363.

Creane, A. and C. Davidson (2011). Multidivisional firms, internal competition and the merger paradox. *Canadian Journal of Economics 37*(4), 951–977.

Cross, R., S. Buccola, and E. Thomann (2009). Cooperative liquidation under competitive stress. *European Review of Agricultural Economics 36*(3), 369–393.

De Hek, P. and A. Mukherjee (2011). Joint venture buy-outs under uncertainty. *Journal of Industrial Economics 54*(1), 155–176.

Drivas, K. and K. Giannakas (2010). The effect of cooperatives on quality-enhanicng innovation. *Journal of Agricultural Economics 61*(2), 295–317.

Falck-Zepeda, J., G. Traxler, and R. Nelson (2000). Surplus distribution from the introduction of a biotechnology innovation. *American Journal of Agricultural Economics 82*, 360–369.

Fitt, G. (2003). Deployment and impact of transgenic bt cotton in australia. In N. Kalaitzandonakes (Ed.), *The economic and environmental impacts of Agbiotech*, pp. 141–164. London: Springer.

Fulton, M. and K. Giannakas (2001a). Agricultural biotechnology and industry structure. *Agbioforum 4*(2), 137–151.

Fulton, M. and K. Giannakas (2001b). Organizational commitment in a mixed oligopoly: agricultural cooperatives and investor-owned firms. *American Journal of Agricultural Economics 83*, 1258–1265.

Fulton, M. and K. Giannakas (2013). The future of agricultural cooperatives. *Annual Review of Resource Economics 5*, 61–91.

Geroski, P. (1995). Markets for technology: Knowledge, innovation and appropriability. In P. Stoneman (Ed.), *Handbook of the Economics of Innovation and Technological Change*, pp. 90–131. Blackwell Publishers.

Giannakas, K. and M. Fulton (2005). Process innovation activity in mixed oligopoly: The role of cooperatives. *American Journal of Agricultural Economics 87*(2), 406–422.

Gouse, M., C. Pray, and D. Schimmelpfennig (2004). The distribution of benefits from bt cotton adoption in south africa. *AgBioForum 7*, 187–194.

Graff, G., G. Rausser, and A. Small (2003). Agricultural biotechnology's complementary intellectual assets. *Review of Economics and Statistics 85*, 349–363.

Huang, J., R. Hu, C. Fan, C. Pray, and S. Rozelle (2002). Bt cotton benefits, costs and impacts in china. *AgBioForum 5*, 153–166.

Ismael, Y., R. Bennett, and S. Morse (2002). Benefits from bt cotton use smallholder farmers in south africa. *AgBioForum 5*, 1–5.

Johnson, S. and T. Melkonyan (2003). Strategic behavior and consolidation in the agricultural biotechnology industry. *American Journal of Agricultural Economics 85*, 216–233.

Joly, P. (2001). Limagrain: A cooperative spirit among the world's seed leaders. *AgBioForum 4*(1), 52–57.

Kalaitzandonakes, N. (1998). Biotechnology and the restructuring of the agricultural supply chain. *Agbioforum 1*, 40–42.

Kalaitzandonakes, N. and B. Bjornson (1997). Vertical and horizontal coordination in the agro-biotechnology industry: evidence and implications. *Journal of Agricultural and Applied Economics 29*, 129–139.

Kalambar, S. (2013). Biotechnology in indian agriculture: Review of adoption and performance of bt cotton. *Millennial Asia 4*(2), 211–236.

Kim, Y. and N. Vonortas (2006). Determinants of technology licensing: The case of licensors. *Managerial and Decision Economics 27*, 237–249.

Krugman, P. (1995). Technological change in international trade. In P. Stoneman (Ed.), *Handbook of the Economics of Innovation and Technological Change*, pp. 342–365. Blackwell Publishers.

Lamprinakis, L. and M. Fulton (2011). Does acquisition of a cooperative generate profits for the buyer? the dairyworld case. *Agricultural Economics 42*, 89–100.

Marco, A. and G. Rausser (2008). The role of patent rights in mergers: Consolidation in plant biotechnology. *American Journal of Agricultural Economics 90*(1), 133–151.

Mussa, M. and S. Rosen (1978). Monopoly and product quality. *Journal of Economic Theory 18*, 201–317.

Nash, J. F. (1950). The Bargaining Problem. *Econometrica 18*(2), 155–162.

Pray, C. (2001). Public-private sector linkages in research and development: biotechnology and the seed industry in brazil, china and india. *American Journal of Agricultural Economics 83*, 742–747.

Pray, C., D. Ma, J. Huang, and F. Qiao (2001). Impact of bt cotton in china. *World Development 29*, 813–825.

Qaim, M. (2003). Bt cotton in india: field trial results and economic projections. *World Development 31*, 2115–2127.

Qaim, M., E. Cap, and A. De Janvry (2003). Agronomics and sustainability of transgenic cotton in argentina. *AgBioForum 6*, 41–47.

Qaim, M. and A. De Janvry (2003). Genetically modified crops, corporate pricing strategies, and farmers' adoption: the case of bt cotton in argentina. *American Journal of Agricultural Economics 85*, 814–828.

Ramani, S. (2000). Technology cooperation between firms of developed and less-developed countries. *Economics Letters 68*, 203–209.

Ramani, S., M. El Aroui, and P. Audinet (2001). Technology transfer: partner selection and contract design with foreign firms in the indian biotechnology sectors. *Developing Economies 39*, 85–111.

Rausser, G., S. Scotchmer, and L. Simon (1999). Intellectual property and market structure in agriculture. Technical report, Department of Agricultural and Resource Economics, University of California at Berkeley, Working Paper 880.

Reid, S. and S. Ramani (2012). The harnessing of biotechnology in india: Which roads to travel? *Technological Forecasting and Social Change 79*, 668–664.

Rey, P. and J. Tirole (2007). A primer on foreclosure. In M. Armstrong and R. Porter (Eds.), *Handbook of Industrial Organization, Volume 3*, pp. 2145–2220. Amsterdam: North Holland, Elsevier.

Saggi, K. (2002). Trade, foreign direct investment, and international technology transfer: A survey. *The World Bank Research Observer 17*, 191–235.

Saitone, T. and R. Sexton (2009). Optimal cooperative pooling in a quality differentiated market. *American Journal of Agricultural Economics 92*, 164–180.

Saitone, T. and R. Sexton (2010). Product differentiation and quality in food markets: Industrial organization implications. *Annual Review of Resource Economics 2*, 341–368.

Sena, V. (2004). The return of the prince of denmark: A survey on recent developments in the economics of innovation. *Economic Journal 114*, 312–332.

Shi, G. (2009). Bundling and licensing of genes in agricultural biotechnology. *American Journal of Agricultural Economics 91*(1), 264–274.

Singh, N. and S. Marjit (2003). *Joint ventures, international investment and technology transfer.* Oxford: Oxford University Press.

Sinha, U. (2008). International joint venture: Buy-out and subsidiary. *Journal of Economic Behavior and Organization 65*, 734–756.

Soboh, R. A. M. E., A. O. Lansink, G. Giesen, and G. van Dijk (2009). Performance Measurement of the Agricultural Marketing Cooperatives: The Gap between Theory and Practice. *Review of Agricultural Economics 31*(3), 446–469.

Sobolevsky, A., G. Moschini, and H. Lapan (2005). Genetically modified crops and product differentiation: Trade and welfare effects in the soybean complex. *American Journal of Agricultural Economics 82*, 360–369.

Somaya, D., Y. Kim, and N. Vonortas (2010). Exclusivity in licensing alliances: using hostages to support technology commercialization. *Strategic Management Journal 32*, 159–186.

Spielman, D., D. Kolady, A. Cavalieri, and N. Rao (2014). The seed and agricultural biotechnology industries in india: An analysis of industry structure, competition and policy options. *Food Policy 45*, 88–100.

Sun, C. (2014). A conceptual framework for R&D strategic alliance assessment for Taiwan's biotechnology industry. *Quality and Quantity 48*, 259–279.

Tirole, J. (1989). *The theory of Industrial Organization*. Cambridge: MIT Press.

Traxler, G. and S. Godoy-Avila (2004). Transgenic cotton in mexico. *AgBioForum 7*, 57–62.

A Proof of Lemma 4.1

From direct observation it can be seen that $p_i^m > p_c^m$, since $s_i > s_c$. Similarly, simple calculations yield that $q_i^m > q_c^m$ if $s_i > s_c$. In the case of profit and consumer's surplus, there is an increase if $\bar{\theta}^2 \cdot s_i \cdot s_c > c^2$ which is always true since by assumption $\bar{\theta} \cdot s_i > c$ and $\bar{\theta} \cdot s_c > c$.

B Proof of Lemma 4.2

Equation (29) follows directly from the price and quantity equilibrium values for the local downstream firm given in equation sets (21),(22),(23) and (24) as it is necessary to ensure positive prices and quantities for the downstream firm. In what follows, we assume the same, i.e.$(\bar{\theta} - 2\underline{\theta}) > 0$ in order to ensure that all prices and quantities are positive even under a differentiated duopoly. Equation (30) also follows simply from the fact that that we need $\tilde{\theta}_i^{df} > \tilde{\theta}_c^{df}$ for co-existence. By simple substitution of the equilibrium values it can shown that :

$$\tilde{\theta}_i^{df} > \tilde{\theta}_c^{df} \iff \underline{\theta} > \frac{3c + \bar{\theta}(s_i - 2s_c)}{2s_i - s_c} \tag{59}$$

. Furthermore, since $\frac{s_i - 2s_c}{2s_i - s_c}$ is an increasing function in s_i and a decreasing function in s_c , larger the difference in qualities and/or larger the market size,$\bar{\theta}$, greater the value of the right hand side of equation (30) and lower the probability of inequality (30) being satisfied. This implies that co-existence requires that the difference in the quality of the innovation and the conventional variety be small and the market size be small.

C Proof of Proposition 5.1

When co-existence is not possible, it can be easily shown that a merger and a subsidiary yield the same payoff such that the upstream firm is indifferent between the two options.
When coexistence of the innovation and conventional variety is possible, the upstream can expect to earn more from a subsidiary than from a merger if:

$$z_a - E > \frac{\alpha_u \cdot \pi_i^m + (1 - \alpha_u) \cdot \pi_c^m - z_d + z_u}{2} - E \iff \pi_i^{df} + \pi_c^{df} > \pi_i^m \tag{60}$$

Thus, if the monopoly revenue from an innovation is greater than the sum of the profit generated under a differentiated duopoly market, a merger will dominate a subsidiary.
Similarly, the payoffs corresponding to a joint venture and a subsidiary can be compared. A subsidiary will dominate a joint venture if:

$$\alpha_u \cdot (\pi_i^{df} + \pi_i^{df}) + (1 - \alpha_u) \cdot \pi_c^m > \alpha_u \cdot \pi_i^m + \alpha_d \cdot (1 - \alpha_u) \cdot \pi_i^m \tag{61}$$

Clearly, even if the innovation monopoly is inefficient, either the technological competence of the local downstream firm, α_d has to be very low or the difference $\pi_i^m - \pi_c^m$ or $s_i - s_c$ has to be very low for equation (61) to be satisfied. Finally, a subsidiary dominates a license if:

$$\alpha_u \cdot (\pi_i^{df} + \pi_c^{df}) + (1 - \alpha_u) \cdot \pi_c^m - E > \alpha_d \cdot \pi_i^m \tag{62}$$

According to the above equation, even if the innovation monopoly is inefficient, and the technological competence of the local downstream firm, α_d , is very low, for a high enough entry cost, E, a license will dominate a subsidiary. Therefore, a combination of an inefficient innovation monopoly, low technological competency of local downstream firm and low entry costs are needed for the opening of a subsidiary.

D Proof of Proposition 5.2

The necessary conditions are easily derived from the payoffs associated with the different entry options for the upstream firm as presented in table 1. A license is preferred to a joint venture if $\pi_i^m < \frac{2E}{\alpha_u \cdot (1-\alpha_d)}$ and it is preferred to a merger if $(\alpha_u - \alpha_d) \cdot \pi_i^m + (1-\alpha_u) \cdot \pi_c^m < 2E$. Clearly for any given parameter configuration, we can always find a high enough value of E such that the above inequalities hold. Furthermore, higher the capability α_d , lower the upper bound of the entry costs E at which the license becomes the most attractive option.
A joint venture is preferred to a license if $\alpha_u \cdot (1-\alpha_d) \cdot \pi_i^m > 2E$ and to a merger if $\alpha_d \pi_i^m > \pi_c^m$. Given that $\frac{d\pi_i^m}{ds_i} > 0$ and $\frac{d\pi_i^m}{d\theta} > 0$ if $\bar{\theta} > 2\underline{\theta}$, which we have assumed to be the case, for any given configuration of parameters we can find an innovation quality, s_i , high enough, and a quality upper bound $\bar{\theta}$ high enough, such that the value of the innovation π_i^m is high enough to satisfy both the inequalities. It can also be noted that the capability of the local downstream firm makes a joint venture attractive vis-à-vis a merger but not a license. However a higher quality difference, $s_i - s_c$, increases $\pi_i^m - \pi_c^m$, which pushes an upstream firm towards a joint venture.
By symmetry, we can deduce similar arguments for a merger. A merger is preferred to a license if $2E < (\alpha_u - \alpha_d) \cdot \pi_i^m + (1 - \alpha_u) \cdot \pi_c^m$ and to a joint venture if $\alpha_d < \frac{\pi_c^m}{\pi_i^m}$. Clearly the above inequalities will both hold if $\alpha_u - \alpha_d = 1$ or $\pi_i^m = \pi_c^m$ and both π_i^m and π_c^m are high enough to compensate for the entry costs E. Therefore, for any given configuration there exists a difference in capabilities, $\alpha_u - \alpha_d$, large enough and/or a difference in product qualities $s_i - s_c$ small enough, such that the merger emerges as the most preferred option.

E Proof of Lemma 6.1

The proof is a straightforward extension of the proof Lemma 4.2, using the new utility functions.