Received: 14 April 2020 | Revised: 14 January 2021 | Accepted: 15 February 2021
DOI: 10.1002/mde.3320

RESEARCH ARTICLE

WILEY

The organizational choice of technology transfer mode: Theory and application to the genetically modified plant industry

Samira Rousselière[1] | Shyama V. Ramani[2] | Damien Rousselière[3]

[1]Oniris, LEMNA, Nantes, France
[2]UNU-MERIT, United Nations University, Maastricht, The Netherlands
[3]SMART-LERECO, Institut Agro - AGROCAMPUS OUEST, INRAE, Angers, France

Correspondence
Samira Rousselière, Oniris, LEMNA, Nantes, France.
Email: samira.rousseliere@oniris-nantes.fr

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 genetically modified (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.

JEL CLASSIFICATION
D20; D45; L10; L65

1 | INTRODUCTION

Agbiotechnology has revolutionized the seeds sector with the creation of transgenic seeds with specific properties (Deconinck, 2020). 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 (JV), or subsidiary to facilitate its entry into new markets (Arza & Van Zwanenberg, 2014).

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 develop 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, JV, 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? A common feature of most of the 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 and nanotechnology), where firm growth is conditioned by firm-specific dynamic capabilities (Amaro Rosales & Natera Marín, 2020; Gilding et al., 2020). 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: the 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 & 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, 2000; Ramani et al., 2001). 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 JV 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 downstream firm is not very capable. Finally, an upstream firm initiates a subsidiary if the monopoly corresponding to the innovation is inefficient, and 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. To our knowledge, the full choice between subsidiary, merger, JV, and licensing has not been addressed together, as previous works (e.g. Kim & Vonortas, 2006; Orsi & Belussi, 2015) highlight only the trade-offs between two alternatives.[1] Various authors examined the entry of multinational corporations (MNCs) on developing economies market. They highlight the trade-offs between international JV and a wholly owned subsidiary by the foreign JV partner (Banerjee & Mukherjee, 2010; De Hek & Mukherjee, 2011) and deal with the issue of instability of JVs in the context of international investment.

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. 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) (Lemarié et al., 2017; Shi, 2009; Sobolevsky et al., 2005). 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 next section introduces the model, its outline, and its main assumptions. The model is solved in Section 3, with the bargaining game, the final market equilibrium, and the two main propositions presented in Sections 3.1, 3.2, and 3.2.1. The final section offers discussions and conclusion.

2 | THE MODEL

2.1 | Outline of 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 (see Table 1 for the symbols used in the model and their meanings). There are *n* consumers indexed by a quality preference parameter θ, which, in turn, is uniformly distributed over the interval $[\underline{\theta},\bar{\theta}]$ with $\bar{\theta}-\underline{\theta}=1$ and $\underline{\theta}>0$. The total mass of consumers is therefore normalized to 1.

In the ex post situation, the upstream firm, *u*, developed a quality enhancing product innovation that yields a higher utility to consumers. As shown in Figure 1, the three-stage sequential game starts with the move of the upstream firm, which decides between offering a license to the 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 JV, *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.

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, JV, 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* is 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.

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

TABLE 1 Table of symbols

Symbol	Meaning
α_d	Capability of the downstream firm
α_u	Capability of the upstream firm
s_c	Quality of the conventional product
s_i	Quality of the innovative product
θ	Quality preference parameter uniformly distributed over the interval $[\underline{\theta},\bar{\theta}]$ with $\bar{\theta}-\underline{\theta}=1$ and $\underline{\theta}>0$
CS_i^m	Consumer surplus with innovative product under monopoly
CS_c^m	Consumer surplus with conventional product under monopoly
CS^{df}	Consumer surplus under duopoly with differentiated products
E	Entry costs
L	Value of the license
M	Acquisition price
v	Share in the joint venture
p_c^m	Price of the conventional product under monopoly
p_i^m	Price of the innovative product under monopoly
p_c^{df}	Price of the conventional product under duopoly with differentiated products
p_i^{df}	Price of the innovative product under duopoly with differentiated products
q_c^m	Quantity consumed of the conventional product under monopoly
q_i^m	Quantity consumed of the innovative product under monopoly
q_c^{df}	Quantity consumed of the conventional product under duopoly with differentiated products
q_i^{df}	Quantity consumed of the innovative product under duopoly with differentiated products
u_j	Utility of the consumer j
π_c^m	Profit from selling conventional product under monopoly
π_i^m	Profit from selling innovative product under monopoly
π_c^{df}	Profit from selling conventional product under duopoly with differentiated products
π_i^{df}	Profit from selling innovative product under duopoly with differentiated products
z_d	Outside alternative payoff for the dowstream firm
z_u	Outside alternative payoff for the upstream firm

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 differentiated duopoly with both the new variety and the conventional variety being sold, π_i^{df} indicates the duopoly profit of the upstream firm from selling the new variety, and π_c^{df} is the duopoly profit of the downstream firm from selling the conventional variety. For narrative convenience, a table of symbols is included below.

2.2 | Main assumptions

Five important contextual features and assumptions 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] Note that if applied to GM plant industry, our model also considers 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.

Second, in the ex ante context, before the introduction of the new input, the downstream market is served uniquely by firm with a conventional variety. The situation is therefore a monopoly. The introduction of the innovation may change this situation. The upstream firm 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. When the upstream firm issues a license or forms a JV or merger, the industrial organization of the downstream market does not change and 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.

Third, 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. For example, when the firms form a JV, they share all information (explicit and tacit knowledge), whereas in the case of a license, there is only a transfer of codified knowledge (Dhanaraj et al., 2004).

- ☐ 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 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

[2]For example, product-enhancing nutritional attributes for final consumers (Colson & 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 & Van Zwanenberg, 2014).

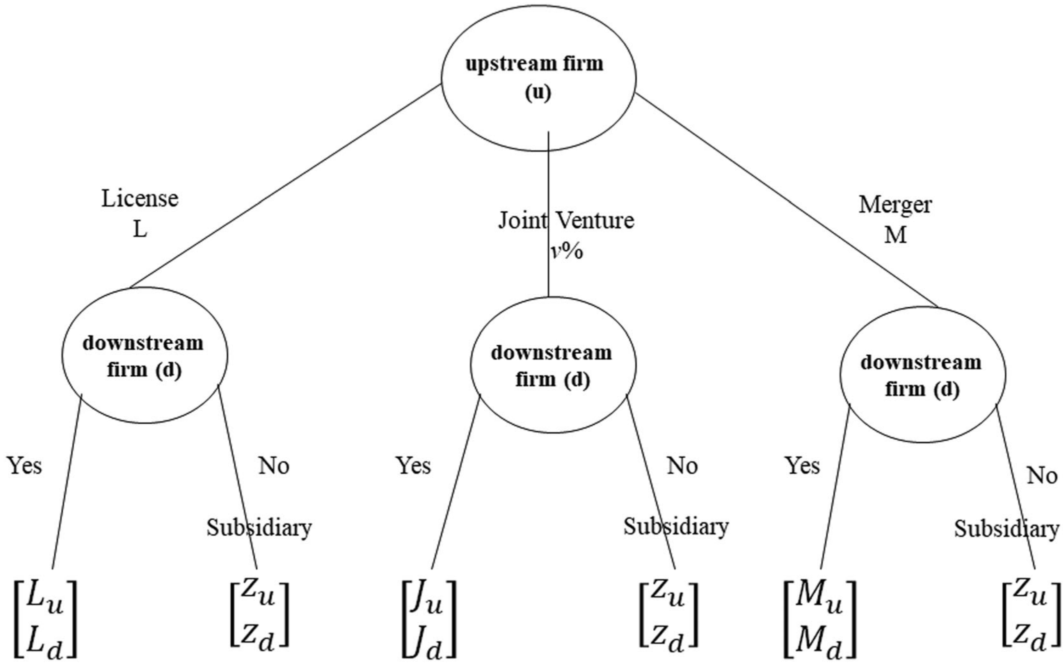

FIGURE 1 Outline of the model

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? As the literature is sparse on this topic, no absolute answer can be given to the above question, and various authors had investigated the instability of JVs (Banerjee & Mukherjee, 2010; De Hek & Mukherjee, 2011; Sinha, 2008). In the case of Italian biotech firms, Orsi and Belussi (2015) show a higher impact of downstream alliance than mergers and acquisitions on innovation. According to Sun (2014), the main motivation of mergers in the Taiwan agbiotech sector is the market access. Usually, a merger is accompanied by a downsizing of personnel, and this may or may not include the research and development (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, especially in the case of vertical integration as this is not a merger between peers (Hussey, 1999). In particular, we consider the extreme case of no information sharing and assume that the probability of successful commercialization of innovation is linked to the technological competence of the bidder or α_u. However, the upstream firm is mainly interested by the marketing competencies of the downstream firm, and there is a capture of the marketing network of the downstream firm as will be detailed later.

Four, 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.

Finally, 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 are not into account. This concerns two factors, the infrastructure and organizational costs of new market entry of the upstream firm 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.

3 | RESOLUTION OF THE MODEL

3.1 | The bargaining game in the third stage

We start the resolution of the game by calculating the values of the alternative payoffs z_u and z_d. This leads us to calculate the values of the acquisition price M, the value of the license L, and the share in the JV v.

When an upstream firm opens a subsidiary, there could be a change in the industrial organization as the downstream firm may or may not be driven out. If coexistence 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 infrastructural entry costs of E. In this case, the downstream firm has an expected profit of $(1-\alpha_u) \cdot \pi_c^m$; that is, 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 coexistence 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, whereas the downstream firm 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 JV*: When a JV 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 costs E. If a new variety is not developed, then the downstream firm rests a monopolist selling the conventional product. 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 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 costs E. Therefore, in a merger, the 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 costs are 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 are 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

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

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

3.2 | Downstream market equilibrium

3.2.1 | Ex ante downstream situation

Before the presentation of the ex post downstream market equilibrium, we begin with an analysis of the ex ante situation before the introduction of the innovation. Let us suppose that the downstream firm, d, which is a monopolist, supplies a conventional variety of quality s_c. 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:

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

This gives the monopoly price, quantity, profit, and consumer surplus (CS) of the the downstream firm d at optimum as

$$p_c^m = \frac{\bar{\theta} \cdot s_c + c}{2}, \tag{6}$$

$$q_c^m = \frac{\bar{\theta} \cdot s_c - c}{2(\bar{\theta} - \underline{\theta}) \cdot s_c} = \frac{\bar{\theta} \cdot s_c - c}{2 \cdot s_c}, \tag{7}$$

$$\pi_c^m = \frac{(\bar{\theta} \cdot s_c - c)^2}{4(\bar{\theta} - \underline{\theta}) \cdot s_c} = \frac{(\bar{\theta} \cdot s_c - c)^2}{4 \cdot s_c}, \tag{8}$$

$$CS_c^m = \frac{(\bar{\theta} \cdot s_c - c)^2}{8 \cdot s_c}, \tag{9}$$

with c a constant marginal cost of production.

Proof. See Appendix A.

From direct derivation, it can be seen that the *CS* 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, that is, $\bar{\theta} \cdot s_c > c > 0$.

3.2.2 | 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 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 $s_i \in [\underline{\theta}, \bar{\theta}]$. 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, on the one hand, and the *CS*, on the other hand, can be obtained as follows:

$$p_i^m = \frac{\bar{\theta} \cdot s_i + c}{2}, \tag{10}$$

$$q_i^m = \frac{\bar{\theta} \cdot s_i - c}{2(\bar{\theta} - \underline{\theta}) \cdot s_i} = \frac{\bar{\theta} \cdot s_i - c}{2 \cdot s_i}, \tag{11}$$

$$\pi_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{4(\bar{\theta} - \underline{\theta}) \cdot s_i} = \frac{(\bar{\theta} \cdot s_i - c)^2}{4 \cdot s_i}, \tag{12}$$

$$CS_i^m = \frac{(\bar{\theta} \cdot s_i - c)^2}{8 \cdot s_i}. \tag{13}$$

This gives us our first result.

Lemma 3.1. In the case of a license, a JV, or a merger, when the downstream market structure remains a monopoly, the price, quantity, profit, and *CS* increase after the introduction of the innovation.

Proof. See Appendix B.

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.

3.2.3 | 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 coexistence of the innovation and conventional variety is possible. If the downstream firm cannot survive the competition, it exits, and the final market remains a monopoly, with only the upstream firm. However, if coexistence is possible, then the upstream firm sells the higher quality innovation while the downstream firm sells the lower quality conventional variety.

When will a downstream firm be driven out with the entry of the upstream firm? Consider the situation of a duopoly with differentiated products.[3] 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,

$$\theta_{ic}^{df} \cdot s_c - p_c^{df} = \theta_{ic}^{df} \cdot s_i - p_i^{df}. \tag{14}$$

This gives

$$\theta_{ic}^{df} = \frac{p_i^{df} - p_c^{df}}{s_i - s_c}. \tag{15}$$

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

$$q_c^{df}(p_c^{df}, p_i^{df}, s_c, s_i) = \frac{\theta_{ic}^{df} - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{p_i^{df} - p_c^{df}}{(s_i - s_c)(\bar{\theta} - \underline{\theta})} - \frac{\underline{\theta}}{\bar{\theta} - \underline{\theta}}, \tag{16}$$

$$q_i^{df}(p_c^{df}, p_i^{df}, s_c, s_i) = 1 - \frac{\theta_{ic}^{df} - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{\bar{\theta}}{\bar{\theta} - \underline{\theta}} - \frac{p_i^{df} - p_c^{df}}{(s_i - s_c)(\bar{\theta} - \underline{\theta})}. \tag{17}$$

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

$$p_i^{df} = c + \frac{(s_i - s_c)(2\bar{\theta} - \underline{\theta})}{3}, \tag{18}$$

$$p_c^{df} = c + \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta})}{3}. \tag{19}$$

The equilibrium quantities and profits can be calculated accordingly as

$$q_i^{df} = \frac{(2\bar{\theta} - \underline{\theta})}{3(\bar{\theta} - \underline{\theta})} = \frac{(2\bar{\theta} - \underline{\theta})}{3}, \tag{20}$$

$$q_c^{df} = \frac{(\bar{\theta} - 2\underline{\theta})}{3(\bar{\theta} - \underline{\theta})} = \frac{(\bar{\theta} - 2\underline{\theta})}{3}, \tag{21}$$

[3]See Singh and Vives (1984) for a seminal paper on price competition in differentiated duopoly.

$$\pi_i^{df} = \frac{(s_i - s_c)(2\bar{\theta} - \underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} = \frac{(s_i - s_c)(2\bar{\theta} - \underline{\theta})^2}{9}, \tag{22}$$

$$\pi_c^{df} = \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta})^2}{9(\bar{\theta} - \underline{\theta})} = \frac{(s_i - s_c)(\bar{\theta} - 2\underline{\theta})^2}{9}. \tag{23}$$

The *CS* becomes

$$CS^{df} = \frac{1}{2}(\theta_{ic}^{df} - \theta_c^{df})(\theta_{ic}^{df} s_c - p_c^{df}) + \frac{1}{2}(\bar{\theta} - \theta_{ic}^{df})(\bar{\theta} s_i - \theta_{ic}^{df} s_i). \tag{24}$$

This brings us to our second result.

Lemma 3.2. 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, that is,

$$(\bar{\theta} - \underline{\theta}) > (\bar{\theta} - 2\underline{\theta}) > 0; \tag{25}$$

- ☐ 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:

$$\underline{\theta} > \frac{3c + \bar{\theta}(s_i) - 2s_c}{2s_i - s_c}. \tag{26}$$

Proof. See Appendix C.

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 2.

3.3 | 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 in the form of two new results.

Proposition 3.1. 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 downstream firm is low, or the quality difference is low, and the entry costs are not too high.

Proof. See Appendix D.

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 JV, or a merger, emerges as the dominant form.

Proposition 3.2. 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 JV if the difference in the quality the innovation and the conventional downstream, $s_i - s_c$, is high and/or the market size for innovation, $\bar{\theta}$, 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 E.

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 JV, for low entry costs, when the market potential of the innovation is high, because the technological competencies of both the upstream firm and the downstream firm are

TABLE 2 The payoffs of the upstream firm *u* and the downstream firm *d*

	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-coexistence)	$\alpha_u \cdot \pi_i^m - E$	$(1-\alpha_u) \cdot \pi_c^m$
Subsidiary (coexistence)	$\alpha_u \cdot \pi_i^{df} - E$	$\alpha_u \cdot \pi_c^{df} + (1-\alpha_u) \cdot \pi_c^m$

Note: With $\pi_i^m = (\bar{\theta} \cdot s_i - c)^2/(4 \cdot s_i)$, $\pi_c^m = (\bar{\theta} \cdot s_c - c)^2/(4 \cdot s_c)$, $\pi_i^{df} = (s_g - s_c)(2\bar{\theta} - \underline{\theta})^2/9$, *and* $\pi_c^{df} = (s_g - s_c)(\bar{\theta} - 2\underline{\theta})^2/9$.

put to use in developing the innovation and 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 JV 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.

4 | DISCUSSION AND CONCLUSION

A game theoretic model of collaboration between an upstream innovator and a downstream producer was developed in this paper. The rationality of the choice between a license, a JV, 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 also to upstream technology providers in other sectors as well.

Third, the model seems to provide a plausible explanation for the behavior of firms 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 (Lee et al., 2017). As shown in Table 3, in the agbiotech industry, Monsanto relies on a diversity of market strategies for the commercialization of Bt cotton (see Arora & Bansal, 2012; Arza & Van Zwanenberg, 2014; Fitt, 2003; Gouse et al., 2004; Huang et al., 2002; Pray et al., 2001; Rei & Ramani, 2012; Traxler & Godoy-Avila, 2004).

TABLE 3 Comparison of market strategy entries of Monsanto and model explanations

Countries	Market strategy	Model explanations
Australia	License	Low technological asymmetry
		Low market size
Argentina, India, China	Joint venture	High quality difference
		High market size
USA	Merger	High technological asymmetry
		Low quality difference
		High market size
Mexico, South Africa	Subsidiary	Low technological asymmetry
		Coexistence with conventional seeds
		Low market size

- ☐ 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 United States, low entry costs have surely played an important role in favoring a JV 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. 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 JV over a license.
- ☐ According to the model, the conditions for coexistence of the GMV along with the conventional seed must be satisfied in the case of a subsidiary. 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 favoring 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 favored the subsidiary option.

Finally, though the present model can been used to explain the international strategies of Monsanto, it can also give some insights on the evolution of the GMO market in the United States, as documented by various authors (Deconinck, 2020; Fulton & Giannakas, 2001a; Oehmke & Naseem, 2016). During the 1980s, licenses and JVs were the most preferred form of collaboration between agrochemical firms, biotech firms, and seed firms. Whereas, during the 1990s and 2000s, agrochemical firms invested in acquiring both biotech firms and seed firms leading to a highly concentrated GMV market. According to the indicators proposed by our model, the licensing period could correspond to a context where the market was perceived to be small, with high quality differences and low technological competencies of partner firms, given that the new technological paradigm was in its infancy. Then, as the market grew and firms became competent, JVs were initiated. Finally, as the product quality differentiation narrowed down even further while the market continued to grow, acquisitions were initiated.

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 (Kranthi & Stone, 2020). 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, the variability of the outcome, and the impact of market and nonmarket 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.

Another limitation is that 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 & 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 Giannakas and Fulton (2005). According to Fulton and Giannakas (2001b), the cooperative is highly competitive on price. Public authorities may therefore want to promote cooperatives and increase their technological competencies.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

ORCID

Samira Rousselière https://orcid.org/0000-0001-9238-6956
Shyama V. Ramani https://orcid.org/0000-0001-8168-4448
Damien Rousselière https://orcid.org/0000-0001-9544-1076

REFERENCES

Amaro Rosales, M., & Natera Marín, J. M. (2020). Technological capabilities accumulation and internationalization strategies of mexican biotech firms: A multi case study from agro-food & pharma industries. *Economics of Innovation and New Technology*, *29*, 720–739.

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

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

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

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

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

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

Deconinck, K. (2020). Concentration in seed and biotech markets: Extent, causes, and impacts. *Annual Review of Resource Economics*, *12*, 129–147.

Dhanaraj, C., Lyles, M. A., Steensma, H. K., & Tihanyi, L. (2004). Managing tacit and explicit knowledge transfer in IJVs: The role of relational embeddedness and the impact on performance. *Journal of International Business Studies*, *35*(5), 428–442.

Fitt, G. P. (2003). Deployment and impact of transgenic Bt cotton in Australia. In Kalaitzandonakes, N. (Ed.), *The Economic and Environmental Impacts of Agbiotech*. London: Springer, pp. 141–164.

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

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

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

Gilding, M., Brennecke, J., Bunton, V., Lusher, D., Molloy, P. L., & Codoreanu, A. (2020). Network failure: Biotechnology firms, clusters and collaborations far from the world superclusters. *Research Policy*, *49*(2), 103902.

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

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

Hussey, D. (1999). Some thoughts on acquisition and merger. *Strategic Change*, *8*(1), 51–60.

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

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

Kranthi, K. R., & Stone, G. D. (2020). Long-term impacts of Bt cotton in india. *Nature Plants*, *6*(3), 188–196.

Lee, D., Kirkpatrick-Husk, K., & Madhavan, R. (2017). Diversity in alliance portfolios and performance outcomes: A meta-analysis. *Journal of Management*, *43*(5), 1472–1497.

Lemarié, S., Baghdasaryan, D., & Campens E. (2017). The Product Line Strategy of a Company Selling Seed with a Licensed GM Trait. *Journal of Agricultural & Food Industrial Organization*, *15*(1). http://doi.org/10.1515/jafio-2016-0030

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

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

Oehmke, J. F., & Naseem, A. (2016). Mergers and acquisitions (M&As), market structure and inventive activity in the agricultural biotechnology industry. *Journal of Agricultural & Food Industrial Organization*, *14*(1), 19–32.

Orsi, L., & Belussi, F. (2015). Management of the collaboration network of italian biotech firms. In Belussi, F., & Orsi, L. (Eds.), *Innovation, Alliances, and Networks in High-Tech Environments*. London: Routledge, pp. 123–138.

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

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

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

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

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

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

Singh, N., & Vives, X. (1984). Price and quantity competition in a differentiated duopoly. *RAND Journal of Economics*, *15*(4), 546–554.

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

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

Sun, C. 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., & Godoy-Avila, S. (2004). Transgenic cotton in Mexico. *AgBioForum*, *7*, 57–62.

How to cite this article: Rousselière S, Ramani SV, Rousselière D. The organizational choice of technology transfer mode: Theory and application to the genetically modified plant industry. *Manage Decis Econ*. 2021;1–11. https://doi.org/10.1002/mde.3320

APPENDIX A

Proof of the outcomes for the ex ante situation

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:

$$u_j = \theta_j \cdot s_c - p. \tag{A1}$$

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,

$$u_c = \theta_c \cdot s_c - p_c \Leftrightarrow \theta_c = \frac{p_c}{s_c}. \tag{A2}$$

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

$$d(p_c,s_c) = q(p_c,s_c) = 1 - F(\theta_c) \Leftrightarrow q(p_c,s_c) = 1 - \frac{\theta_c - \underline{\theta}}{\bar{\theta} - \underline{\theta}} = \frac{\bar{\theta}\cdot s_c - p_c}{(\bar{\theta} - \underline{\theta})\cdot s_c}. \tag{A3}$$

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:

$$\max_{p_c}(p_c - c)\cdot q_c(p_c,s_c). \tag{A4}$$

This gives the monopoly price, quantity, profit, and consumer surplus (CS) at optimum as

$$p_c^m = \frac{\bar{\theta}\cdot s_c + c}{2}, \tag{A5}$$

$$q_c^m = \frac{\bar{\theta}\cdot s_c - c}{2(\bar{\theta} - \underline{\theta})\cdot s_c} = \frac{\bar{\theta}\cdot s_c - c}{2\cdot s_c}, \tag{A6}$$

$$\pi_c^m = \frac{(\bar{\theta}\cdot s_c - c)^2}{4(\bar{\theta} - \underline{\theta})\cdot s_c} = \frac{(\bar{\theta}\cdot s_c - c)^2}{4\cdot s_c}, \tag{A7}$$

$$CS_c^m = \frac{(\bar{\theta}\cdot s_c - c)^2}{8\cdot s_c}. \tag{A8}$$

APPENDIX B

Proof of Lemma 3.1

From direct observation, it can be seen that $p_i^m > p_c^m$, because $s_i > s_c$. 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 $\bar{\theta}\cdot s_c > c$.

APPENDIX C

Proof of Lemma 3.2

Equation (25) follows directly from the price and quantity equilibrium values for the downstream firm given in equation sets (18)–(21) as it is necessary to ensure positive prices and quantities for the downstream firm. In what follows, we assume the same, that is, $(\bar{\theta} - 2\underline{\theta}) > 0$ in order to ensure that all prices and quantities are positive even under a differentiated duopoly.

Equation (26) also follows simply from the fact that the conventional variety must present a price advantage for coexistence. 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 $\tilde{\theta}_i^{df} = p_i^{df}/s_i$ and $\tilde{\theta}_c^{df} = p_c^{df}/s_c$. Then given that $s_i > s_c$ for all $\theta_j > \tilde{\theta}_i^{df}$, we have

$$s_i \cdot \theta_j - p_i^{df} = s_i(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_i^{df}). \tag{C1}$$

Suppose $\tilde{\theta}_i^{df} < \tilde{\theta}_c^{df}$. Then we can expand the right hand side of Equation (C1) further as follows:

$$s_i(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_i^{df}) > s_c(\theta_j - \tilde{\theta}_c^{df}) = s_c\theta_j - p_c^{df}. \tag{C2}$$

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 coexistence, 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 coexist on the market.

By simple substitution of the equilibrium values, it can be shown that

$$\tilde{\theta}_i^{df} > \tilde{\theta}_c^{df} \Leftrightarrow \underline{\theta} > \frac{3c + \bar{\theta}(s_i - 2s_c)}{2s_i - s_c}. \tag{C3}$$

Furthermore, since $(s_i - 2s_c)/(2s_i - s_c)$ 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 (26) and lower the probability of inequality (26) being satisfied. This implies that coexistence requires that the difference in the quality of the innovation and the conventional variety be small and the market size be small.

APPENDIX D

Proof of Proposition 3.1

When coexistence 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

$$z_u - E > \frac{\alpha_u \cdot \pi_i^m + (1-\alpha_u)\cdot \pi_c^m - z_d + z_u}{2} - E \Leftrightarrow \pi_i^{df} + \pi_c^{df} > \pi_i^m. \tag{D1}$$

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

$$\alpha_u \cdot (\pi_i^{df} + \pi_i^{df}) + (1-\alpha_u)\cdot \pi_c^m > \alpha_u \cdot \pi_i^m + \alpha_d \cdot (1-\alpha_u)\cdot \pi_i^m. \tag{D2}$$

Clearly, even if the innovation monopoly is inefficient, either the technological competence of the 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 (D2) to be satisfied. Finally, a subsidiary dominates a license if

$$\alpha_u \cdot (\pi_i^{df} + \pi_c^{df}) + (1-\alpha_u)\cdot \pi_c^m - E > \alpha_d \cdot \pi_i^m. \tag{D3}$$

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

APPENDIX E

Proof of Proposition 3.2

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 $\pi_i^m < 2E/(\alpha_u \cdot (1-\alpha_d))$, 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 $d\pi_i^m/ds_i > 0$ and $d\pi_i^m/d\bar{\theta} > 0$ 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 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 $\alpha_d < \pi_c^m/\pi_i^m$. 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.