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Abstract

An analytical model is developed to study the problem of designing stable joint ventures aimed at jointly developing and supplying a new technology. The analysis focuses on the extent to which traditional motives for joint ventures like cost sharing, synergy effects or technological spillovers may shape the incentives for firms to cheat on the arrangement and hence despite larger cooperative benefits, endanger the formation of a stable agreement. The cheating firm, although supplying the contractually specified inputs to the venture, manages to keep its know-how proprietary while benefiting from the loyal partner's know-how through spillovers from the venture

Only if know-how can be kept sufficiently proprietary within the venture, will synergy effects stimulate the formation of a stable joint venture, increasing the profitability of cooperation while at the same time stifling the incentives to cheat. But if know-how becomes difficult to appropriate, synergy effects may increase the incentives to cheat, resulting in no agreement when both parties have perfect foresight.

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1. INTRODUCTION

Companies in high-tech industries are increasingly confronted with the need to accumulate and apply new knowledge at a fast pace. In this innovation race, firms tend to revert to cooperative mechanisms motivated by the possibilities to exchange and share technologies, to exploit possible synergies in the creation and implementation of know-how, to share risks and costs, as well as the possibility to control the competitive environment. The following table illustrates the empirical importance of each of these motives:

Motivation of parent company	% agreements
Transfer of technology	29
Complementarity of technology	41
Scale economies in production/distribution	16
Risk reduction	14
Marketing agreements	21
<u>Source:</u> Mariti and Smiley (1983)	

Whereas recent analytical models have detailed the various motives for firms to engage in partnering (Katz (1986), Choi (1989), Sinha & Cusumano (1991), De Bondt, Slaets & Cassiman (1992), Veugelers & De Bondt (1992), Kesteloot & De Bondt (1992), Kamien, Müller & Zang (1992), among others) relatively little attention has been devoted to the costs or potential pitfalls of these cooperative modes (Baumol (1991), De Bondt, Wu and Lievens (1992) and Kesteloot & Veugelers (1992)). Although scarce empirical evidence suggests that cooperative ventures

are highly unstable (Kogut (1989)) little is known on an analytical level about the causes of failure of these ventures.

The analytical framework that will be developed here models the problem of designing stable cooperation, able to prevent failure due to deliberate non-compliance of the partners. Whereas cooperative mechanisms can take various forms, ranging from alliances without any equity commitment over cross-equity investments between the partners, the model focuses on a joint venture setting that involves a separate entity whose equity is shared by the parent companies. Whereas a 'tight' form of coordination such as a joint venture structure may involve larger set-up costs, it also allows for bigger returns as embodied in larger synergy effects as compared to more 'loose' forms of coordination.

The analysis is concentrated on the extent to which traditionally considered motives for joint ventures like

- the sharing of R&D and setup costs;
- efficiency gains in R&D and/or production from sharing complementary know-how;
- enhanced know-how for the partners through spillovers from the venture;

may not only determine the profitability of the venture, but may also be of relevance for the design of stable joint ventures through shaping the incentives for firms to cheat on the venture arrangement. The envisaged joint venture is engaged in development activities focused on obtaining the necessary cost conditions to operate profitably in a market which is completely new to the parent companies.

Given that joint ventures are typically organized in a contractual framework, the analysis should be embedded in a cooperative setting. However, the perfect enforceability of these contracts may be

a problem certainly with respect to the specificities of the contract regarding the prevention of cheating, if only because the detection of this cheating is imperfect. To incorporate these cheating incentives with imperfect detection, the model is set up to combine elements from cooperative and non-cooperative game theory to allow for strategic considerations and all this in a static setting.

Section II details the theoretical framework, after which, the analytical results are presented.

II. THE THEORETICAL FRAMEWORK

A simple setting is used to highlight the structure of incentives that is required for successful, stable joint ventures. The market is composed of two symmetrical firms (denoted by subscripts $i=1,2$). These firms have the option to develop and implement a new technology or a new product that is independent from the products they are currently producing. R&D expenditures will result in cost reductions that are necessary for production to take place. If they reach a cooperative agreement, a separate entity is set up (denoted by subscript v) which will take account of the R&D as well as the production and marketing of a new good. When the parties fail to reach an agreement they still have the option to develop and produce the new product themselves.

This option of own development constitutes the threat point to the joint venture negotiations¹. Firms spend resources on R&D, R_i , which will be transformed into a knowledge base: $X_i = \sqrt{R_i}$ where the specification allows for diminishing returns to R&D expenditures (see

1. An alternative threat point could be other companies as possible partners. This scenario is discarded here through the assumption that there are only two firms which have the necessary technological know-how.

also De Bondt et al. (1989)). Own development allows the firms to keep their know-how proprietary. Knowledge is created solely on the basis of own expenditures on R&D implying zero spillovers. Also the option to cross-license technologies is ignored. This knowledge base, when implemented will result in lower marginal production costs: $c_i = A - 2\alpha X_i$, where α measures the efficiency of the knowledge base in reducing production costs. Without R&D, costs are prohibitively high so that no production is possible. In addition, production requires fixed setup costs F_p . Both companies will compete in R&D as well as in output in a Cournot-Nash fashion. Due to the irreversible nature of R&D investments, R&D and production decisions are modelled in a sequential, two-stage setting. In the output game, simple linear demand $p = a - bQ$, and constant marginal costs c , are assumed.

When both parties enter into an agreement, they provide the joint R&D lab with the necessary inputs. Each firm brings in its specialized know-how as for instance embodied in a number of researchers sent to the joint lab. The exact size of these R&D inputs is determined in the agreement as constituting for each partner R_i^V , half of the expenditures which are necessary to maximize the profits of a successful venture R_V . In addition, any other costs of setting up this venture, F_V , will be shared on an equal basis, given perfect symmetry between both parties. Within the venture structure, R&D brought in by the partners cannot be kept fully proprietary. Firms can learn from the specific know-how of their venture partner.

The venture transforms these R&D inputs into a knowledge base: $X_V = \sqrt{(R_1^V + R_2^V)}$. This knowledge base, when implemented, will again result in lower marginal production costs: $c_V = A - 2\alpha_V X_V$. Synergy effects allow the venture's know-how to be more effective in reducing costs as compared to the threat point scenario of own development. Formally

$\alpha_v = \alpha(1+\Omega)$, where the term $(1+\Omega)$ measures the extent of the synergy effects that can be realized. The more complementary the partner's know-how, the larger these synergy effects.

After the R&D stage the venture will start producing and marketing the good, which is assumed to be independent of the parents' old products, to ease the computations. While this assumption discards any (dis)incentives to form joint ventures to enhance product market competition in the "old" market, it nevertheless seems to correspond to a substantial part of actual joint ventures. For a survey of 417 joint ventures, as appeared in the Belgian and international press between 1986 and 1991, on average about one third of the ventures seem to be operating in different sectors than their parent companies ²:

Parents in different industries°:	41.9 %
Joint venture in different industry than any parent	44.3%
Joint venture in same industry as any parent	55.7%
Parents in the same industry:	58.1 %
Joint venture in different industry than parents	25.4%
Joint venture in same industry than parents	74.6%
° : Industry as defined on Nace-3-digit level	

Once the venture arrangement is specified, the partners have the option either to comply with or to cheat on the arrangement. This decision on whether to cooperate or to defect is taken simultaneously by both parties.

The defecting firm performs R&D to develop and market the product by itself. In this process, it hopes to benefit from what it learns through the venture from the loyal partner's know-how while at the same time keeping its know-how proprietary, preventing the transfer of its core skills to the partner. In order to avoid detection, the defecting

2. This number can be considered as an underestimation, given that the same Nace 3 industry doesn't necessarily indicate the same product or (geographical) segment of the market.

firm has to supply the contractually specified inputs, but the "quality" of these inputs is nil. For instance, the cheating firm is sending its R&D engineers to the joint lab, monitoring carefully the information being transferred. These engineers get clear instructions concerning the own skills and technologies that are off-limit to the venture while at the same time being fully receptive to the information brought in by the loyal partner. As a result, the venture's effective knowledge base will only depend on the loyal partner's know-how and hence no synergy effects from combining complementary technologies can be realized:

$X_v = \sqrt{(\theta_1 R_1^V + \theta_2 R_2^V)}$ $\alpha_v = \alpha(1 + \Omega \theta_1 \theta_2)$	where $\theta_i = 0$ if firm i defects; else $\theta_i = 1$
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If both firms cooperate and send their 'best' researchers, who are instructed to share their know-how on a fruitful basis, $\theta_1 = \theta_2 = 1$ and $X_v = \sqrt{2R_i^V}$ while $\alpha_v = \alpha(1 + \Omega)$, as noted supra. If one of the partners cheats, say firm j , $\theta_j = 0$, the venture's know-how will be limited to the loyal partner's R&D input, $X_v = \sqrt{R_i^V} = \sqrt{0.5R_v}$ while $\alpha_v = \alpha$, i.e. the venture has no comparative advantage over single development. The knowledge base of the cheating firm is built, besides on its own R&D input, on what it learns from the loyal partner. More formally, $X_j = \sqrt{R_j} + \beta X_v$ where the spillover parameter β , $0 \leq \beta \leq 1$, may be smaller than 1 to reflect imperfections in information transmission or imperfect appropriability of external technology. As a result of this learning, the defecting firm may improve its cost position relative to the venture, while retaining its proprietary technology: $c_j = A - 2\alpha X_j < c_v = A - 2\alpha X_v$ when $X_j > X_v$.

The cheating firm is postponing the detection of its defection through supplying the required inputs to the venture, and this until it is too late for the loyal partner to reciprocally secure its own know-how and too much valuable time has been lost for own development in turn, to be still a viable reaction to defection. This time pattern of

detection is important for the profitability of the cheating option, since it will allow to generate a cost advantage of the cheater relative to the venture. However, this detection cannot be postponed indefinitely. Once the R&D stage is completed and production can start, the industry observes who has the necessary R&D output to produce the good. Hence, if any of the partners have defected, the other partners will find out before production starts. Once detection has been observed, the venture will be dissolved, as can be specified in the initial agreement. The loyal partner will still be able to start production with the R&D output available within the venture, which is based solely on the inputs of the loyal partner, $X_i = \sqrt{R_i}^V$. This specific scenario serves to rescue for the loyal partner as much as possible from the venture agreement, once cheating has occurred³. The output market will be an asymmetric duopoly, with both the cheating firm and the venture, i.e. the loyal partner, producing and marketing a homogenous product.

When both firms cheat, the venture will turn out to be an empty shell: $X_V = 0$ and no production can take place within the venture. Both parties reveal nothing from their proprietary know-how, hence there are no learning possibilities within the venture. All this implies that the partners can only rely on their own know-how for their R&D activities as in the no-agreement outcome. Actually the firms end up in the same symmetric market outcome with homogeneous products as the no-agreement outcome, but with the difference that they have to provide the formally

3. An alternative to this scenario may be specific performance contracts, specifying a liquidating damage measure to be paid upon breach of the joint venture contract (see e.g. Huberman and Kahn (1988)). With such a contract in place, cheating, once detectable, could of course be perfectly prevented. However, given the fundamental uncertainties surrounding R&D activities and hence detection, these types of contracts may not be perfectly enforceable in court.

specified inputs to the joint venture. Figure 1 summarizes the model structure.

- Figure 1 -

A cooperative outcome allows to share the cost of R&D and production, establishes a more efficient R&D process because of synergy effects and at the same time results in a monopoly in the output

market⁴. On the other hand, there are the costs associated with setting up a venture, F_v . In addition, only half of the benefits are attainable by each partner and there is always the danger of cheating.

The incentive to cheat on a loyal partner comes from the possibility that the firm instead of having to be satisfied with only half of the monopoly profits of the "new" market, may obtain more than half of the total market profits, be it in a duopoly market. This duopoly share can be larger when the defector has a superior cost position relative to its joint venture rival⁵. Not only does the cheating firm prevent its know-how from being used in the venture, prohibiting a more efficient R&D process as captured by the synergy effect, but more importantly, it also increases its know-how through tapping on the information that the loyal partner faithfully brings in the alliance. Figure 2 summarizes the basic (dis)advantages as well as the profit levels for each of the possible outcomes for both parties.

Which of these outcomes can be traced as a (subgame perfect) Nash equilibrium of this game where players have perfect foresight, depends on the structure of payoffs. The outcome of mutual defection, which leads to an empty venture, cannot be a Nash equilibrium in pure strategies⁶, given that it is dominated by the threat point outcome of own development. If parties can correctly foresee this mutual defection to be the equilibrium situation in case of an agreement, they prefer to not join an agreement in the first place, given the cost of setting up a venture which will turn out to be empty: $V_i^{dd} < V_i^0$.

4. In addition, a joint venture may result in learning opportunities for own research of the partner's "old" products. But this effect is not modelled explicitly here. Given the assumption of independence between the "old" and the "new" market, possible spillovers to the old market may enhance the attractiveness of the venture to the parents, but does not induce any strategic effects.

5. When the output game would be specified as Bertrand instead of Cournot, this cost advantage would be even more rewarding.

6. It may however be part of a mixed strategy equilibrium, see section V

- Figure 2 -

A successful and stable joint venture will result if firms have an incentive to form a joint venture in the first place, when V_1^{cc} (which is equal to $0.5V_v$) is larger than V_1^o , and if firms have no incentive to cheat on a loyal partner, when $V_1^{dc} < V_1^{cc}$. If they have an incentive to cheat ($V_1^{dc} > V_1^{cc}$), no venture is formed in the first place if in addition cheating provokes reciprocal cheating: $V_1^{dd} > V_1^{cd}$. Partners correctly foresee the incentives to cheat and hence will defect if an agreement would be formed, as a defensive strategy to prevent being exploited by a non-loyal partner, or else to exploit the loyal partner. Given this, it is better not to join an agreement in the first place: $V_1^{dd} < V_1^o$, although there may be clear advantages from cooperating, $V_1^{cc} > V_1^o$.

A breakdown of the venture as equilibrium of this symmetric setting, requires first that despite the gains from cooperation, more

can be gained from cheating, $V_i^{dc} > V_i^{cc}$, which will not trigger a reciprocal defection by the partner, $V_i^{dd} < V_i^{cd}$ and second that firms prefer such an outcome to own development: $V_i^{cd} > V_i^o$ and $V_i^{dc} > V_i^o$. Of course, asymmetric settings are also possible, and perhaps more natural, settings able to generate asymmetric breakdown outcomes. Given that a number of authors such as Hamel, Doz & Prahalad (1989) and Lewis (1990) argue that success of a venture is not necessarily defined by its stability, but by the ability of the firm to erode its partner's position, the conditions for this successful unilateral cheating need to be established.

III. DISCUSSION

The basic focus of the analysis is to predict the emergence of stable joint ventures, as a function of critical variables such as the size of the synergy effects, as measured by the parameter Ω , and the spillover or learning effects, as measured by the parameter β . For this, the effect of these parameters on the incentives to form a joint venture as well as the incentives to cheat, are examined first. The next section will then detail the industry outcomes that can be sustained as equilibrium configurations.

a) Incentive to form a joint venture: $V_i^{cc} > V_i^o$

OWN DEVELOPMENT (o)		SUCCESSFUL JOINT VENTURE (cc)	
X_i	$\frac{4\alpha(a-A)}{9b-8\alpha^2} \quad (1)$	X_v	$\frac{\alpha(1+\Omega)(a-A)}{2[b-\alpha^2(1+\Omega)^2]} \quad (2)$
V_i	$\frac{(a-A)^2(9b-16\alpha^2)}{(9b-8\alpha^2)^2} - F_P \quad (3)$	V_v	$\frac{(a-A)^2}{4[b-\alpha^2(1+\Omega)^2]} - F_P - F_v \quad (4)$

The larger are the synergy effects, the larger will be the knowledge base of the venture and the larger the fruits from cooperation. Deriving (2) and (4) w.r.t. $(1+\Omega)$ yields:

$$\frac{\delta X_V}{\delta(1+\Omega)} > 0 \quad \text{and} \quad \frac{\delta V_V}{\delta(1+\Omega)} > 0$$

If fixed costs are ignored or if the setup cost of the venture, F_V , does not outweigh the fixed setup costs of production, F_P , firms will always benefit from a successful cooperative venture. From comparing (3) and (4), while taking into account that $V_i^{cc} = 0.5V_V$ and assuming $F_V = F_P = 0$, it can be established that :

$$V_i^{cc} - V_i^o = \frac{(9b - 16\alpha^2)[b + 8\alpha^2(1+\Omega)^2] + 64\alpha^4}{(9b - 8\alpha^2)28[b - \alpha^2(1+\Omega)^2]}$$

which is positive given the restrictions on the parameters that are necessary for positive output and knowledge levels ⁷.

Of course the higher are the synergy effects, the larger is the advantage of the venture over own development. It is however not clear whether firms will be spending more or less on R&D as part of a cooperative venture, than if they would develop the new product on their own. It can easily be established that if the venture would not deliver any synergy effects, i.e. if $\Omega=0$, firms would spend less in a joint venture setting than if they would develop on their own: $R_i^V < R_i^o$. These lower R&D activities can be attributed to the shared monopoly that is created through the venture, relative to the competitive outcome that would prevail in the threat point scenario.

7. It will be assumed throughout the analysis that the restrictions on the parameters that are necessary for positive output and knowledge levels, as well as the second order conditions, apply: $\alpha < \sqrt{(9b/16)}$ and $\alpha < \sqrt{b/(1+\Omega)}$.

But given that expected synergy effects will boost R&D spending in the venture, each firm may well end up spending more on R&D in a venture setting if the synergy effects are important enough. From comparing (1) and (2) the critical synergy value $(1+\Omega)^*$ for which $X_1^0 = X_v$, can easily be checked:

$$X_v > < X_1^0 \text{ iff } (1+\Omega) > < (1+\Omega)^* = \frac{[(9b-8\alpha^2)^2 + 16\alpha^2 b]^{1/2} - (9b-8\alpha^2)}{4\alpha^2}$$

This critical synergy value depends besides on the slope of the demand curve, b , crucially on the efficiency of the R&D process, as captured by α , see also section V.

b) Incentive to cheat on a loyal partner: $V_i^{dc} > V_i^{cc}$

DEFECTING FIRM (dc)		LOYAL PARTNER (cd)	
X_i^{dc}	$\frac{4\alpha(a-A) + (9b\beta - 8\alpha^2)X^{cd}}{9b - 16\alpha^2} \quad (5)$	X_i^{cd}	$\frac{\alpha(1+\Omega)(a-A)}{\sqrt{2[2b - 2\alpha^2(1+\Omega)^2]}} \quad (6)$
V_i^{dc}	$\frac{[a - A + 2\alpha X^{cd}(2\beta - 1)]^2}{9b - 16\alpha^2} - [F_p + \frac{R_v + F_v}{2}] \quad (7)$	V_i^{cd}	$\frac{(a-A)(9b - 24\alpha^2) + 2\alpha X^{cd}[9b(2-\beta) - 24\alpha^2]^2}{9b(9b - 16\alpha^2)^2} - [F_p + \frac{R_v + F_v}{2}] \quad (8)$

There is no incentive to cheat if the cheating firm does not have a cost advantage over its competitor, which is the venture as taken over by the loyal partner. A proof of the proposition can be found in the appendix.

Proposition: If $X_i^{dc} = X_i^{cd}$ then $V_i^{cc} > V_i^{dc}$ (9)

Whether the cheating firm will have a cost advantage over its rival depends on the interplay between the synergy and the learning effects:

Equation (10) follows directly from (5) and (6):

$$X^{dc} - X^{cd} = \frac{4\alpha(a-A) - X^{cd}[9b(1-\beta) - 8\alpha^2]}{9b - 16\alpha^2} \quad (10)$$

Learning possibilities clearly enhance the cost position of the cheater:

$$\delta(10)/\delta\beta = X^{cd}9b/(9b - 16\alpha^2) > 0. \quad \text{For instance, for perfect learning}$$

effects ($\beta=1$), it can easily be checked from equation (10) that the cheating firm would have a cost advantage over its rival. But for lower levels of spillovers,

$$\beta < \beta^* = \frac{8/2[\alpha^2(1+\Omega)^2 - b] + (1+\Omega)(9b - 8\alpha^2)}{9b(1+\Omega)} \quad (11)$$

no cost advantage is possible. Note that $\delta\beta^*/\delta(1+\Omega) > 0$, i.e. the higher are the expected synergy effects, the larger the learning possibilities need to be before the cheater can outperform the cost position of its rival. Larger expected synergy effects boost R&D spending by the partners and hence increase the knowledge base of the venture, even in case of breakdown. Although this larger knowledge base implies that more can be learned by the cheater, as long as these spillovers are very imperfect, it is less likely that this latter effect will provide the cheater the necessary cost advantage:

$$\frac{\delta(X^{dc} - X^{cd})}{\delta(1+\Omega)} = \frac{\delta X^{cd}}{\delta(1+\Omega)} \cdot \frac{-[9b(1-\beta) - 8\alpha^2]}{9b - 16\alpha^2} \quad (12)$$

Note that with $\delta X^{cd}/\delta(1+\Omega) > 0$ (cf. supra), (12) will be positive (negative) if β is larger than (smaller than) $1 - 8\alpha^2/9b$. Expected synergy effects may improve the relative cost position of the cheater through boosting the knowledge base from which the cheater is tapping. This effect will however only dominate if the spillover process is smooth enough. With low learning possibilities, the higher expected synergy effects will benefit more the venture company through enhancing its knowledge base.

If the cheating firm has a cost advantage, its operating profits will be higher: $\pi^{dc} > \pi^{cc}$ (and hence $\pi^{dc} > \pi^{cc}/2$) but it is not a priori clear whether this will be sufficient to offset the fact that the cheater has to cover the costs of its own R&D process and fully account for the fixed setup cost of production.

When these fixed costs of production, F_p , are ignored, the following can be established from comparing (4) and (7) ⁸:

$$v^{dc} > v^{cc} \text{ iff } \beta > \frac{[(9b-16\alpha^2b)/8]^{1/2} + \alpha^2(1+\Omega)(2+\Omega) - b}{2\alpha^2(1+\Omega)} \quad (13)$$

Whether cheating will be profitable or not depends again on the size of the spillover. Spillovers will spur the incentives to cheat. Through affecting positively the competitive cost position of the cheater, they increase the cheating profits: $\delta v^{dc}/\delta \beta > 0$. At the same time, $\delta v^{cc}/\delta \beta = 0$. But also the expected synergy effects matter. Synergy effects will stifle the incentives to cheat but only if the know-how can be kept sufficiently proprietary within the venture. As derived supra, v^{cc} is affected positively by the synergy effects. Expected synergy effects may however increase cheating profits, v^{dc} , but only if β is large enough:

$$\frac{\delta v^{dc}}{\delta(1+\Omega)} = \sqrt{R_i^{dc}(2\beta-1)} \frac{\delta x^{cd}}{\delta(1+\Omega)} > 0 \text{ if } \beta > 1/2 \text{ given that } \frac{\delta x^{cd}}{\delta(1+\Omega)} > 0$$

Indeed, the higher the expected synergy effects, the more know-how will be brought in by the loyal partner, the more information can be gained from the venture. At the same time and due to cheating, the venture firm can not capitalize on these synergy effects and improve its competitive cost position vis-à-vis the defecting firm, given that they will never be materialized.

If spillovers are smaller than $1/2$, cheating profits are affected negatively by the expected synergy effects. Hence, if $\beta < 1/2$, $\delta(v^{dc} - v^{cc})/\delta(1+\Omega)$ will be negative and the expected synergy effects will stifle the incentives to cheat from the venture agreement.

8. The RHS of (13) is smaller than 1 provided that expected synergy effects are not too large.

c) Incentives to cheat on a non-loyal partner: $V_i^{dd} > V_i^{cd}$

When firms anticipate defection by their partner, they should consider whether to still comply with the agreement, which implies bringing in and exposing own specific know-how on the basis of which production can be initiated, or to cheat likewise. Cheating on a non-loyal partner implies that spillovers of own know-how to the rival cannot occur and hence any cost advantage which the rival firm may obtain from this is avoided, but requires that in order to be able to start production, own "true" R&D activities have to be set up and financed.

LOYAL PARTNER (cd)		ALL DEFECT (dd)	
X_i^{cd}	$\frac{\alpha(1+\Omega)(a-A)}{\sqrt{2[2b-2\alpha^2(1+\Omega)^2]}} \quad (6)$	X_i^{dd}	$\frac{4\alpha(a-A)}{9b-8\alpha^2} \quad (14)$
V_i^{cd}	$\frac{(a-A)(9b-24\alpha^2)+2\alpha X^{cd}[9b(2-\beta)-24\alpha^2]^2}{9b(9b-16\alpha^2)^2} - [F_p + \frac{R_v+F_v}{2}] \quad (8)$	V_i^{dd}	$\frac{(a-A)^2(9b-16\alpha^2)}{(9b-8\alpha^2)^2} - [F_p + \frac{R_v+F_v}{2}] \quad (15)$

Given the same fixed costs of starting up the venture and producing, and given that defection requires own R&D costs, the incentives to defect on a loyal partner will exist only if larger operating profits can be expected. This requires essentially a large enough knowledge base:

$$V^{dd} > V^{cd} \text{ iff } X^{dd} > X^{dd*} \quad (16)$$

$$X^{dd*} = \frac{4\alpha(a-A)+8\alpha^2(2X^{cd}-X^{dc})}{3\sqrt{(9b^2-16\alpha^2b)}} \text{ with } (2X^{cd}-X^{dc}) = \frac{X^{cd}[9b(2-\beta)-24\alpha^2]-4\alpha(a-A)}{9b-16\alpha^2}$$

With only X^{cd} depending on $(1+\Omega)$, the more synergies the partners expect, the larger will be the knowledge base of the venture, even in case of breakdown, the less incentives firms have to cheat on a non-loyal partner (at least if $\alpha < \sqrt{[9b(2-\beta)/24]}$). Of course, the larger is β , the smaller will be this positive impact of expected synergy effects.

Likewise, spillovers will have a negative impact on the operating profits in case of breakdown and hence increase the attractiveness of cheating against a non-loyal partner:

$$\frac{\delta(2X^{cd}-X^{dc})}{\delta\beta} = - \frac{9bX^{cd}}{9b-16\alpha^2} < 0$$

When the cheating firm has a small or no cost advantage over the loyal partner, firms have less incentives to cheat on a non-loyal partner, as (16) demonstrates. But if X^{dc} is small relative to X^{cd} , firms also have less incentives to cheat on a loyal partner, see proposition (9). All this implies that a breakdown of the joint venture as a stable Nash equilibrium of a symmetric simultaneous move game, is unlikely, even if V^{dc} and V^{cd} would be larger than the threat point payoffs.

IV. EQUILIBRIUM CONFIGURATIONS

The analysis so far has shown that expected synergy effects stimulate the incentives to form a joint venture, while at the same time stifle the incentives to cheat on a loyal partner, at least if the know-how of the venture is sufficiently proprietary. At the same time, synergy effects result in less incentives to cheat on a non-loyal partner. All this implies that when partners expect out of their complementarity, large synergy effects, they are more likely to reach a stable agreement not only because they can expect more benefits out of a venture, but also because these synergy effects make cheating less likely. Given that larger expected synergy effects will boost the R&D inputs of the loyal partner, the cheater may have a hard time to obtain a large enough cost advantage against the loyal partner to make cheating profitable. Hence, in order to establish a stable joint venture, the partners need

only make sure that the partners can keep their know-how sufficiently proprietary within the venture, without sacrificing synergy effects.

When this appropriability cannot be achieved within the venture, cheating on a loyal partner is more likely because higher spillovers will increase the incentives to cheat, but also because in this case synergy effects will benefit the cheater. Whereas higher spillovers will increase the attractiveness of cheating on a loyal partner, they may lead to no venture formed in the first place, when firms have an incentive to cheat on the venture in anticipation of cheating by its partner. This latter effect may prevail when high spillover levels are combined with not too high expected synergy effects, resulting in the partners preferring to not enter a cooperative agreement, although there are clear gains from cooperating.

However, when important expected synergy effects exist and spillovers are not too high, the loyal partner may prefer to dissolve the partnership and start production with the available know-how when cheated on, rather than to reciprocate the cheating manoeuvre. However, with this combination of parameters, the incentives to cheat on a loyal partner may vanish, rendering a breakdown as equilibrium in a symmetric setting when firms have perfect foresight, less likely.

When some kind of asymmetry between both parties is built in, breakdowns are easier to establish as equilibrium outcomes. Two cases can be distinguished where the equilibrium turns out to be firm i cheating and firm j remaining loyal. The first case arises when firm j has no incentive to cheat not on a loyal partner, nor on a non-loyal partner, whereas firm i has an incentive to cheat on a loyal partner. In this case firm j has a dominant strategy, which is to comply with the agreement, in which case firm i 's best response to this strategy is to

cheat. As long as firm j earns more with the venture than in its threat point, the outcome will be a breakdown of the venture. This case may reflect a situation where own development for firm j is very costly. Although it may have developed some valuable know-how inhouse, it may lack the skills or finance to set up a fully operational R&D lab. For this firm, joining a venture agreement may be the only option to operate in this market, even if it knows that its partner is merely joining the lab to take advantage of its know-how.

A similar case arises when both firms may have an incentive to cheat on the loyal partner, but only firm i will also cheat on a non-loyal partner and not firm j . Given that cheating is a dominant strategy for firm i , firm j needs to establish its best response to this strategy for firm i , which is to remain loyal and take over the venture, at least when this yields more than its threat point payoff. This case describes a situation where own development is only worthwhile for firm j if it can enjoy some positive spillovers from the know-how brought in by its partner. If not, the costs of own development are too high. For firm i own development is such a valuable option that it will pursue this, independent of whether any learning effects can be obtained. Firm i will join the agreement given that this provides access to the partner's know-how. Firm j will join since this allows him to operate in the market through the venture company.

V. SOME NUMERICAL RESULTS

The following numerical example shows the equilibria that emerge out of the symmetric model as a function of the size of the learning effects and the synergy effects. The learning effect is represented on the Y-axis, where the β parameter is plotted, ranging from 0 (perfect

appropriability within the venture) to 1 (perfect spillovers within the venture). The X-axis measures the synergy effects, as captured by the Ω parameter. Ω is taken to be between 0 and 0.4⁹. The value for the other parameters are fixed as follows: $a-A=100$, $b=1$, $\alpha=.4$, $F_V=20$ and $F_P=5$.

- Figure 3 -

If know-how can be sufficiently appropriated within the venture, i.e. $\beta < 0.6$, the only equilibrium of this setting is that both firms will engage in a joint venture which will remain stable, and this irrespective of the size of the synergy effects. Even if there would be no synergy effects, $\Omega=0$, the shared monopoly created by the venture agreement will create enough benefits to go for the venture option. But from a public policy point of view it is important to note that it is only if the synergy effects are important enough that a joint venture setting will result in higher industry R&D levels. In the numerical example, the joint venture needs to be at least 37.5% more efficient in

9. For larger values of Ω , the equilibrium would be a stable joint venture, irrespective of the size of the spillovers.

R&D relative to own development, or in other words $\Omega > 0.15$, before R&D levels are affected positively by the venture agreement.

When appropriation of know-how within the venture becomes more problematic, complementarity between parties starts to play a crucial role in establishing stable joint ventures. From $\beta > 0.6$ on, the required synergy effects that will generate a stable joint venture as the unique industry outcome, increase. For instance, when $\beta = 0.8$, the R&D process within the venture needs to be more than 42.5% more effective than own development, or $\Omega > 0.17$, before a successful joint venture can be established as the unique outcome. When the learning effect would be slightly higher, $\beta = 0.9$, the requirement on the synergy effect has already increased to 72.5% more effective R&D relative to sole development.

As soon as $\beta > 0.75$, small to moderate synergy effects are no longer capable of stifling the incentives to cheat, leaving for the parties no other option but to refrain from a joint venture agreement, given the prospects of cheating. Own development will be the sole equilibrium in this setting.

Finally, there exists a small strip ranging from moderate learning effects and low synergy effects to high learning effects and high synergy effects, where two Nash equilibria can be established: a successful joint venture as well as an empty joint venture. Within this range of parameters, the benefits from a successful joint venture are important enough for firms to have no incentive to cheat on a loyal partner. But when cheated against, firms have no incentive to remain loyal given the important spillover effect. Although an empty joint venture cannot be ruled out as equilibrium outcome, it is clear that the payoffs to both players are lower in this case than if they could coordinate on the other equilibrium, a successful joint venture.

If the technology would only permit less efficient R&D outlays, i.e. if α would be lower, the synergy effect that can be realized within the venture boosting the efficiency of R&D, as well as the sharing of R&D become more valuable, rendering the option of own development less attractive. With α for instance reduced from 0.4 to 0.2, own development as equilibrium would vanish from the spectrum, even if learning effects would be important, as Figure 4 demonstrates. With high spillovers, the only danger that remains to stable joint ventures is that an empty joint venture could be an equilibrium, besides a successful joint venture, requiring coordination among the partners to avoid mutual defection. Whereas low α levels increase the private incentives for firms to form stable joint ventures, higher expected synergy levels are required before the joint venture will outperform own development in terms of R&D outlays. With $\alpha=0.2$, Ω needs to be larger than 0.24, or 120% more efficiency is required before this joint venture will result in larger R&D outlays.

- Figure 4 -

Although the initial size of the market, as captured by $a-A$, affects the profit levels in each of the possible outcomes, the comparison of profits between these outcomes is unaffected by the scale of operations. A steeper demand curve for the product indicating a lower price elasticity for a given price, as reflected in a higher b value, has a similar effect on the equilibrium outcomes as the reduction in α . Increasing the fixed costs of production likewise diminishes the attractiveness of own development, pushing the area where own development is the sole equilibrium further to the northwest corner.

VI. CONCLUSIONS AND EXTENSIONS

Besides the sharing of the market and costs, synergy effects are important stimuli to a joint venture agreement. But only if firms can keep their know-how sufficiently proprietary within the venture from their partner, will synergy effects stimulate the formation of a stable joint venture, increasing the incentives to form a joint venture, but at the same time stifling the incentives to cheat. If know-how becomes difficult to appropriate, cheating on the venture become an attractive option. In this case, expected synergy effects may even increase the incentives to defect through an increase in the loyal partner's R&D input from which the cheater can tap. With perfect symmetry between both parties and perfect foresight, cheating will result in the partners preferring to not enter an agreement in the first place, despite the cost of R&D and the competition which it entails. But own development allows know-how to be kept fully proprietary. Within an asymmetric setting when own development is not a viable option for one of the partners, because for instance of lack of finance or lack of expertise,

a breakdown of the venture may arise in case spillovers are high within the venture.

Although the model, integrating cooperative and non-cooperative elements, allows to pinpoint some important features that firms need to consider in designing stable joint venture agreements, the setting remains very specific. First, there is the critical role of the specification of the detection lag. Due to the sophisticated way of cheating, the loyal partner can no longer react to cheating in R&D. Only production can be adjusted. If firms could shorten this detection lag, cheating would become less attractive. A closely related issue is the specification of the joint venture agreement, including how benefits and costs are distributed and what will happen to the venture in case of breach of contract. Whereas this setting introduces a completely exogenous specification of the contract, other, perhaps more optimal, scenarios should be incorporated. A more severe punishment is one such alternative, which would again render cheating less attractive, but which is more demanding on the problem of detection and enforceability.

A common observation in cooperative agreements is the presence of nodal companies who are engaged in various cooperative agreements with the same or different partners. In the reported survey on cooperative agreements, 56% of all Belgian companies in the sample showed up in at least 2 agreements, whereas this number is even higher for non-Belgian companies where 71% occurred at least twice. For Japanese companies this number was as high as 87%. Firms engaged in repeated agreements may face different incentives to cooperate as well as to cheat. In order to capture these dynamic aspects, the static framework should be extended into a repeated game setting. If in addition, the fundamental uncertainties which surround cooperative settings in R&D are incorporated, as well as possible multiple partners, reputation

considerations can be included in the analysis as possible mechanism to stabilize joint venture agreements.

APPENDIX : Proof to Proposition (9): If $X_i^{dc} = X_i^{cd}$ then $V_i^{cc} > V_i^{dc}$

Subproposition (i): if $X^{dc} = X^{cd} = X$ then $\pi^{cc}/2 > \pi^{dc}$

$$\text{Proof: } \pi^{cc}/2 = \frac{bX^2}{\alpha^2(1+\Omega)^2} > \frac{b(a-A+2\alpha X)^2}{9b^2} = \pi^{dc}$$

$$\text{Given that } X > \frac{\alpha(1+\Omega)(a-A)}{3b-2\alpha^2(1+\Omega)} \quad (i.1)$$

(i.1) can easily be checked from substituting X for expression (6) and noting that $b(3-2\sqrt{2})+2\alpha^2(1+\Omega)[\sqrt{2}(1+\Omega)-1] > 0$.

Subproposition (ii): if $\pi^{cc}/2 > \pi^{dc}$ then $V_i^{cc} > V_i^{dc}$

Proof: if $\pi^{cc}/2 > \pi^{dc}$ then $\pi^{cc}/2 - X^2 - F_v/2 > \pi^{dc} - X^2 - F_v/2$

or given that $X^{cc} = X/2$, $(\pi^{cc} - X^{cc2} - F_v - F_p)/2 > \pi^{dc} - X^2 - F_v/2 - F_p - (1-\beta)^2 X$

which implies $V^{cc}/2 > V^{dc}$ Q.E.D.

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