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COMPLEXITY, DYNAMIC CAPABILITIES, AND BOUNDARIES OF THE FIRM: A STUDY OF OPTIMAL GOVERNANCE MODES

Alex Martynov[1]

ABSTRACT

Transaction costs have been empirically shown to be a determinant of governance mode choice. Firms choosing the wrong governance mode tend to experience negative performance consequences. On the other hand, firm characteristics such as capabilities have also been argued to influence the optimal governance mode. This paper studies the situation of two firms with complementary resources choosing a governance mechanism. Using agent-based simulations, the paper shows how complexity of the firms and of the interfirm ties and the firms' dynamic capabilities may impact the amount of value created by the dyad under different governance modes. The results suggest that firm characteristics such as complexity and dynamic capabilities may impact the performance of the various governance forms in distinct ways, and that no single governance form is best in all cases. Thus, the choice of the governance form will depend both on the properties of the transaction and on firm characteristics. The paper also contributes to organizational theory by showing how the properties of the merged firm may affect its performance based on the complexity of its divisions and the complexity of interdivisional ties.

Keywords: complexity; alliances; mergers; transactions; governance; dynamic capabilities.

Introduction

What determines the optimal governance mode between two firms that possess complementary resources? The answer provided by transaction cost economics (TCE) is that the optimal mode must minimize transaction costs or maximize transactional efficiency (Williamson 1975). Partly because of variations in the definition of such terms as costs and efficiency, this conclusion has caused a certain amount of disagreement in the management field. Economic models of transaction modes conceptually start with some objective function such as $\pi(\mathbf{x};\boldsymbol{\alpha}) = R(\mathbf{x};\boldsymbol{\alpha}) - C(\mathbf{x};\boldsymbol{\alpha})$, where **x** is a vector of variables subject to the firm's control, α is a vector of parameters beyond the firm's control, R(x) is the revenue function, and C(x) is the cost function. From a TCE perspective, transaction costs affect both the revenue function and the cost function. The factors that affect transaction costs can be parameters beyond the firm's control such as some elements of α representing the extent of information asymmetry and tendency toward opportunism or factors within the firm's control such as some elements of **x** representing organizational mechanisms. For instance, a weak or inappropriate incentive system in the presence of tendency toward opportunism and information asymmetry can result in either a lower $R(\mathbf{x})$ or a higher $C(\mathbf{x})$ or both. So, in the study of transaction modes, it is not always convenient to distinguish between a firm's "effectiveness" in achieving the beneficial outcome $R(\mathbf{x})$ and its "efficiency" in controlling $C(\mathbf{x})$. Even without this confusion in terminology, there are still disagreements as to the role of transaction costs in influencing the governance structure. For instance, some strategic management scholars have argued that an uneven distribution of knowledge among agents in a joint production process can by itself dictate the choice of governance structure independent of TCE considerations (e.g., Conner 1991, Conner and Prahalad 1996; Ghoshal and Moran 1996). This argument has given rise to a vigorous debate in the field (e.g., Foss 1996; Noorderhaven 1996; Williamson, 1996; Argyres and Zenger 2008).

It should be noted, however: Williamson (1975) has long recognized that the optimal governance mode for a firm depends on both production cost considerations and transaction cost considerations. Using the notations introduced in the previous paragraph, we can split the vector of parameters α into two sets: α^P that affect production costs and α^T that affect transaction costs. The debate about the role of transaction costs, to be more precise, is concerned with whether production cost considerations alone can determine governance mode choice in the absence of transaction costs, i.e., whether a change in some element of α^P will affect the optimal governance structure even if a critical element of α^T is such that there is no tendency toward self-serving behavior. The primary objective of this paper is to examine how intrafirm complexity, interfirm dependence and firm dynamic capabilities (elements of α^P) may affect the production efficiency of the various decision making structures (elements

1. Associate Professor of Management, University of Houston – Clear Lake

of **x**) in the presence of transaction costs. Although our study does not address directly the debate on the role of transaction costs in the determination of governance mode, it suggests how production cost considerations and transaction cost considerations can interact to influence the optimal choice of governance structure. The kind of production that this study focuses on is the generation of or search for a better strategy under bounded rationality – an issue that arguably lies in the center of strategic management. The word "strategy" here is used in the sense proposed by Rivkin (2000): a specific combination of decisions that the firm's managers have made, whether deliberately or not.

The innovation of our model is that it examines the effects on optimal governance structure of such firm and transaction characteristics as intrafirm complexity, interfirm dependence and dynamic capabilities that are critical concerns in the emergent capability-based view of the firm.[1] Our agent-based simulation models suggest that different decision making structures (e.g., uncoordinated, coordinated, sequentially and simultaneously approved, centralized, and gradually centralized) yield differing joint payoffs for the two firms when they search for better strategies under bounded rationality and that the rankings of the different structures change with variation in intrafirm complexity, interfirm dependence and dynamic capabilities. The optimal decision making structure thus dictated by these firm and transaction attributes in our model has clear implications for the choice of organizational structure in the presence of transaction costs. Therefore, we show that firm and transaction characteristics jointly affect both transaction costs and the amount of value that the firms will be able to create (Bowman and Ambrosini 2000).

The paper is structured as follows. First, we briefly review the literature on firm capabilities, intrafirm complexity and interfirm dependence and their relations to transaction costs. Through this complexity lens, we examine a specific case of two firms with complementary resources. Using computer simulations, we then show how intrafirm complexity, interfirm dependence and dynamic capabilities of transacting firms may impact the optimal governance mode choice. Finally, we integrate transaction cost considerations with capability-based considerations to explore their joint impact on governance mode choice and thus, the boundaries of the firm.

Capabilities, complexity, and boundary choice

While TCE has long been seen as the primary theory that describes optimal governance mode choice (Coase 1937, Williamson 1975, 1985, Poppo and Zenger 1998), an alternative attempt to draw a different perspective on firm boundary decisions was made by the comparative capability approach (e.g. Barney, 1999, Leiblein and Miller, 2003, Jacobides and Hitt, 2005). The principal argument made by comparative capability theorists is that firms will be more likely to conduct internally those activities in which they have superior capabilities and outsource those activities in which they are relatively less competent compared to other firms. This approach was critiqued by Argyres and Zenger (2008) who noted that capabilities that the firm has at present may well be the results of yesterday's choices regarding firm boundaries. According to Argyres and Zenger (2008), TCE is not as far from the resource-based view of the firm: "…in the transaction cost literature, the origin of a given supplier's capability is understood to arise from investments made either by the buyer or by the supplier that are specific to the exchange between them." (p. 11) Argyres and Zenger (2008) go on to argue that persistence of firm boundaries, while apparently based on firm-specific capabilities, can be explained by transaction costs of acquiring and selling capabilities. They cite the problems of standardizing incentives and governance arrangements, transaction costs of selling business units in thin markets, and poorly specified property rights as the main reasons why firms may lack certain capabilities and source them internally, while having superior capabilities in other areas.

However, not all relationships between firms require significant transaction-specific investments in advance. Often, two firms hope to use each other's resources and thus access or create new capabilities. We will show that the governance mode choice for this kind of transaction may depend on the properties of both the transaction and the partners in the transaction. We will view capabilities as based on routines arising out of interaction of the resources that the firm and its partner own (Nelson and Winter 1982).

Firm capabilities have been extensively discussed in the literature (e.g. Collis 1994, Winter 2003, Helfat and Peteraf 2003). For the purposes of this paper we will concentrate on two specific aspects of capabilities: their complexity and routine-based nature. We will argue that capabilities understood as complex routines arising out of interaction of the firm's resources may influence the drawing of the firm's boundaries together with and inseparably from transaction costs. We will also argue that this complexity-based logic is conceptually distinct from the transaction-cost logic, even though (1) both transaction costs and capabilities are at work simultaneously determining firm boundaries, and (2) their predictions may be similar.

Different authors defined firm capabilities in various ways. However, in definitions offered by the leading scholars within RBV and its main offshoots (KBV, dynamic capabilities) a common theme emerges. Teece et al. (1997) stated that "[t]he essence of competences and capabilities is embedded in *organizational processes* of one kind or another." (p. 518, emphasis added) Kogut and Zander (1992) maintain that "…the capabilities of the firm in general… rest in the *organizing principles* by which relationships among individuals, within and between groups, and among organizations are structured." (p. 384, emphasis added) Amit and Schoemaker (1993) define capabilities as "a firm's capacity to deploy [r]esources, usually in combination, using organizational processes, to effect a desired end. They are information-based, tangible or intangible *processes that are firm-specific and are developed over time through complex interactions among the firm's Resources*." (p. 35, emphasis added) Finally, Winter (2003) gives the following definition: "An organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type." (p. 991)

Two common themes emerge in the abovementioned definitions. First, capabilities are distinct from resources (cf. Makadok 2001). Capabilities of the firm are based on the way its resources interact with one another, but are not reducible to the mere collection of individual resources. In order to exhibit firm-specific capabilities, the firm must configure its resources in certain ways that enable them to create more value together and/or enable the firm to implement strategies that would be impossible if those resources did not interact. Second, capabilities are connected to routines in important ways. Capabilities that give rise to distinctive competences of the firm and ultimately to competitive advantage are developed when a specific combination of resources interacts over a period of time.

An important property of routines is that they are ultimately stored in the procedural memory of individuals. Cohen and Bacdayan (1994) conducted a study in which they asked subjects to engage in cooperative behavior in order to solve problems. An important finding of this study was that routines quickly emerged that allowed subjects to economize on making decisions and to take shortcuts. This led to significant increases in speed and productivity over time. Thus, routines are cognitive and social phenomena. Routines tend to improve efficiency but for reasons different from those advanced by TCE: they help people economize on their limited cognitive resources and not make every single decision consciously. The ultimate value of routines to the firm lies in their ability to improve efficiency and to facilitate integration of specialist knowledge distributed among individual employees. According to Grant (1996), "[i]ntegration of specialist knowledge to perform a discrete productive task is the essence of organizational capability, defined as a firm's ability to perform repeatedly a productive task which relates either directly or indirectly to a firm's capacity for creating value through effecting the transformation of inputs into outputs. Most organizational capabilities require integrating the specialist knowledge bases of a number of individuals." (p. 377)

How can this understanding of capabilities be applied to the question of the boundaries of the firm? Let us consider the situation of interaction between two firms. According to TCE, they will be more likely to integrate if one or both of them have to make transaction-specific investments which expose the investing firms to the risk of expropriation or hold-up. But what if little transaction-specific investment is necessary? Each firm may own some resources that are complementary with certain resources of the other firm, which can be considered a form of asset specificity or co-specialization. In this case, the two firms may enjoy private synergies by choosing to transact and use the resources of each other without making significant transaction-specific investments. The goal of entering such a mutual dependence situation is to create new capabilities that neither firm had before. Since capabilities arise out of complex interaction of resources, each firm may be able to create new capabilities because it will access new resources and form new resource configurations.

So far, this logic corresponds to the reasoning advanced by knowledge-based theorists. The firm is seen as a creator of positive (Conner 1991). Presumably, each firm will be able to create more value for its customers as a result of this transaction. But how will the firm boundaries be drawn in this case? Should the two firms merge, or form an alliance, or contract in the market? And what is the source of transaction costs in this case?

Let us begin with the last question. According to Dyer (1997), "[a] central premise of transaction cost theory is that transaction costs increase as transactors make greater asset-specific investments. The standard reasoning is that as asset specificity increases, more complex governance structures (i.e., more complex contracts) are required to eliminate or attenuate costly bargaining over profits from specialized assets…" (p. 535) However, neither firm is making significant transaction-specific investments in our case. What each firm will have to do is adjust its resource-based strategy to accommodate possible complementarities and synergies that exist when it uses the resources of the other firm. This adjustment of strategy is less likely to be as irreversible as investing in transaction-specific assets. Thus, asset specificity may be manifested in this case as asset co-specialization that existed even before the transaction. Nevertheless, transaction costs may still be present. If the firms become asymmetrically dependent on each other's resources, the less dependent firm may try to use its position to extract value from the other firm by threatening to withhold the resources that it owns (Pfeffer and Salancik 1978, Casciaro and Piskorski 2005). If the more dependent firm has already adjusted its resource-based strategy to the use of the resources of the other firm, it may find it costly to go back to its original strategy. Since the less dependent firm can pose a credible threat of withholding its resources, the more dependent firm may be reluctant to enter such a relationship without additional safeguards. As a result, transaction-cost-based reasoning suggests that we may expect to see more hierarchical governance if an asymmetric shift in resource dependence is likely. In addition, more interdependent pairs of firms are likely to face greater contracting and bargaining costs than firms that are weakly interdependent. Therefore, all else being equal, higher mutual interdependence may necessitate tighter integration (see Casciaro and Piskorski 2005 for a resource-dependence-based treatment of this question).

Another factor to consider is the relative complexity of the firms. According to the logic described above, complexity as measured by the number of inter-resource interactions may serve a proxy for firm capabilities. As shown by Levinthal (1997), firms with many connections among their resources are able to find many different resource-based strategies with relatively high performance, while a firm whose resources operate independently can implement only one "good" strategy. A complex firm faces potentially many "good" strategies because it operates on a rugged landscape with many local peaks (Levinthal 1997, Kauffman 1993).

When two firms decide to join forces and use each other's resources, they create or access possibilities that were not available to them before. Each partner may find new ways of creating value. One possible complication arises because payoffs to decisions made by one firm become dependent on decision made by the other firm. This interdependence may be seen as a problem of externalities that firms impose on each other. These externalities may also be seen as a form of transaction costs. In order to decrease these costs, partners may decide to move from market governance to an intermediate form such as an alliance or even decide to merge.

In addition to 'zero-order' capabilities (Winter 2003) described above, firms may have higher-order capabilities. Some firms may be better than others at finding and implementing new value-creating strategies. Collis (1994) called this "the third category of capabilities" (p. 145). If a firm has these capabilities, it is flexible and adaptable, which gives it an advantage in turbulent markets. Besides, such a firm may implement new strategies ahead of its competitors that may not only match but create environmental change via altering the competitive landscape. Thus, such capabilities can be called dynamic (Eisenhardt and Martin 2000).

Having these dynamic "search" capabilities can be a definite strength in transactions. After gaining access to new resources provided by its partner, the firm with higher dynamic capabilities may quickly find a "good" strategy. When it needs to adjust its strategy because of its partner's decisions, the dynamically-capable firm may do so more quickly. In fact, quick decision-making by the dynamically-capable firm may disrupt the slower adaptation of its partner. Conventional wisdom in this case is that the slower-to-adapt firm will want additional safeguards in the form of an alliance or integration.

Thus, there are three sources of transaction costs in the case of firms with potential synergies between their existing resources.

1. *The initial adaptation costs*, which manifest themselves as initial search costs and misadaptation caused by the fact that the firm faces a new landscape and its current strategy may not be optimal. As argued above, the firm that is able to find a good strategy quickly will enjoy advantage in the alliance because the other firm will have to strategize on the landscape that has already been altered by the actions of the faster-adapting firm, especially in situations of asymmetric resource dependence (McKelvey 1999, Ganco and Agarwal 2009).
2. *Externalities:* each firm may pose externalities on the other when it changes policies that affect the other firm's fitness. This can be seen as a kind of transaction costs as well: these costs are specific to the transaction and to the behavior of the partner.
3. *Contracting and bargaining costs.* Each firm is in potential danger of losing the resources that the partner has provided in this alliance. It is reasonable to assume that withdrawal of resources by one firm will lead to reciprocal action by the other firm, that is, to a *de facto* termination of the alliance. Each firm may lose as a result of that. However, if one firm can lose more that the other as a result of ex-post termination of the alliance (a possible *ex post* loss), it may want to have greater *ex ante* safeguards before entering this transaction in the first place. In addition, in the case of an alliance, the firms may face costly bargaining for the jointly created profits.

Summing up the previous discussion, we view capabilities determined by intrafirm complexity and interfirm resource dependence as the limiting factor on the amount of value that the firms will be able to create (Bowman and Ambrosini 2000), while transaction and organizing costs dissipate this value and thus determine the actual amount of value that will be captured by the firms. The main research question that we would like to investigate is how various governance forms differ in terms of their value-creating potential given the characteristics of the transaction (resource interdependence) and of the firms (complexity and dynamic capabilities). We will also use theoretical and empirical findings of previous researchers to hypothesize about the overall costs in each situation and thus to build a theoretical model.

Description of the simulation model

In order to investigate these questions, we conducted a series of agent-based computer simulations using a variant of the NK[C] model (Kauffman 1993, McKelvey 1999, Ganco and Agarwal 2009). NK[C] models allow researchers to study the behavior of complex interdependent systems. The firm is seen as a vector of N resource-based decisions or policy choices. Each decision is binary and can take values of 0 or 1. This binary nature of modeled decisions does not affect the generalizability of the results (Levinthal 1997). Each decision contributes equally to the calculation of the firm's fitness (or value creation), so that the firm's performance is a simple average of payoffs to all individual decisions (Gavetti and Levinthal 2000, Rivkin 2000, Ganco and Agarwal 2009). Performance contributions of all possible individual decision combinations were generated before the start of each simulation by drawing them from uniform distribution U[0, 1] (Rivkin, 2000, Gavetti and Levinthal, 2000).

Since our model includes two firms, the parameter N is the total number of decisions controlled by both firms, with N/2 decisions controlled by each firm. In our simulations, N = 12, and each individual firm controls N1 = N2 = 6 decisions. This value of N is in line with other studies using the NK[C] methodology (e.g. Levinthal 1997, Gavetti and Levinthal 2000, Rivkin and Siggelkow 2003, Ganco and Agarwal 2009). Higher values of N lead to exponentially increasing computing time while providing qualitatively similar results.

Parameter K defines the complexity of the firm. Formally, K is the number of interdependencies between the payoffs to any particular decision and other decisions of the same firm. If K = 0, the firm is perfectly modular, and its resource-based decisions are completely independent. If K > 0, the payoff to any decision made by the firm depends not only on the decision itself, but also on how the firm resolves K other decisions. In other words, a higher K value corresponds to a more tightly coupled firm that has multiple internal resource interactions. In order to investigate the effects of differential firm complexities, we used two values, K1 and K2, to account for the fact that the two partners can have different numbers of internal resource interdependencies. K1 and K2 can take on values from 0 to N1 – 1 and N2 – 1, correspondingly. In our simulations, K1 and K2 varied from 0 to 5 for each firm.

Ganco and Agarwal (2009) used a similar methodology to study the behavior of diversifying entrants and entrepreneurial start-up in situations of new market entry. They modeled diversifying entrants as having higher complexity (K1 = 4) than entrepreneurial start-ups (K2 = 1). The main reason is that incumbents have had more time to develop firm-specific routines and capabilities that arise out of interaction of resources. In line with Ganco and Agarwal (2009), we will interpret differences in K as a proxy for differential zero-order, routine-based capabilities of firms (Winter, 2003).

Parameter C determines interfirm dependence. For our model, we used a simple interpretation of C as the number of dependencies that each firm's payoffs exhibit on the decisions of the other firm. To model potential asymmetries in resource dependence, we used two values, C1 and C2. C1 is the number of dependencies of payoffs to resource decisions of firm 1 on resource decisions of firm 2, and vice versa. Thus, if C1 = C2, there is a symmetrical resource interdependence. If C1 > C2, firm 1 is more dependent on firm 2 than firm 2 is on firm 1. The minimum possible value of C1 and C2 is 0, which corresponds to the situation of no resource interdependence. The maximum possible value of C1 and C2 in our models would be 36 (N1 times N2), which corresponds to the situation when the payoff to each decision of one firm depends on every decision of the other firm. For the purpose of this study, we let C1 and C2 vary discretely from 2 (low dependence) to 10 (medium dependence) to 25 (high dependence).

In order to investigate all possible parameter combinations, we ran simulations for each set of possible values of K1, K2, C1, and C2. We coded the models using Delphi 7, a high-level programming environment based on programming language Pascal. In order to ensure statistical significance of the results, we ran the models with each set of parameters for 10,000 times (cf. Ganco and Agarwal 2009).

At the beginning of each simulation, the program randomly generated (1) the dependence matrix for both firms based on the values of K1 and K2 and (2) the landscape from which it would draw fitness contributions of individual decisions. These fitness contributions were created for every possible combination of decisions, considering interactions among individual decisions. Formally, performance of firm A was calculated as $\Sigma\ p_i(i, i_1, \ldots, i_K, i_j, \ldots, i_{CA})/N$, where p_i is the performance contribution of decision i; $i_1, \ldots, i_K$ are all the other decisions of firm A that influence the payoff to decision i; $i_j, \ldots, i_{CA}$

are all the decisions of firm B that effect the performance of decision i; A = (0, 1); B = (1, 0).

Each firm started with a randomly generated strategy – a sequence of 0's and 1's. Then each firm had 50 cycles in which to find a better strategy independently of the other firm. Some simulations used local search (Levinthal 1997, Cyert and March 1963) in which a firm only varies one policy choice at a time. Other simulations used more distant search, represented by varying two decisions at the same time. The firms that used more distant search were said to have greater dynamic capabilities than those that only used local search (Collis 1994, Teece et al. 1997, Eisenhardt and Martin 2000). We chose 50 cycles of independent adaptation because most firms had settled on a local peak by this time and thus had stopped adapting (cf. Levinthal 1997, Ganco and Agarwal 2009). This local peak corresponded to the strategy that the firm was implementing prior to entering the transaction. The significance of finding a local peak prior to engaging in cooperation was conceptual: we wanted to model interactions between mature firms that had had the time to find a locally optimal strategy.

The interfirm dependence section of the matrix was initially filled with zeroes, indicating that there were no interdependencies during the period of initial adaptation. Thus we assume that the firms were completely independent in the beginning. At cycle 51, the interfirm dependence sections of the matrix were randomly filled with C1 and C2 interdependencies, correspondingly. Then joint adaptation was conducted for another 100 cycles in different ways to simulate various governance modes. All ventures settled on a local peak by this time and stopped adapting. We wanted to determine the maximum long-term performance that could be reached by the venture, not its short-term performance because alliances and mergers are usually seen as long-term value creation vehicles as opposed to short-term contracts that often characterize supplier-buyer relationships.

Local search was implemented as "hill climbing" (Levinthal 1997) where the firm changed one decision and only accepted a change in strategy if it led to an increase in fitness. More distant search (in radius 2), in which the firm changed two decisions at a time, allowed the firm to jump from one hill to another, if there was one in the vicinity and if it was higher than the current position of the firm. The performance of any alliance or merger was measured as the sum total of the performances of both firms. This is the correct way of measuring the combined performance because it explicitly accounted for all interdependencies ("synergies") between the firms.

Table 1 summarizes the variables used in the model.

Table 1: Parameters used in the simulations

Parameter	Description	Value(s) in this simulation
N	Combined number of resource-based decisions controlled by both firms	12
N1	Number of decisions controlled by firm 1	6
N2	Number of decisions controlled by firm 2	6
K1	Complexity of firm 1: number of decisions of firm 1 affecting payoffs to the focal decision of firm 1	0 (modular firm) 2 (moderately complex firm) 5 (tightly-coupled firm)
K2	Complexity of firm 2: number of decisions of firm 2 affecting payoffs to the focal decision of firm 2	0 (modular firm) 2 (moderately complex firm) 5 (tightly-coupled firm)
C1	Dependence of firm 1 on firm 2: the total number of distinct cases when a decision of firm 2 affects the payoff to a certain decision of firm 1	2 (little dependence) 10 (moderate dependence) 25 (high dependence)
C2	Dependence of firm 2 on firm 1: the total number of distinct cases when a decision of firm 1 affects the payoff to a certain decision of firm 2	2 (little dependence) 10 (moderate dependence) 25 (high dependence)
Search width	Number of decisions the focal firm can change simultaneously	1 (local search) 2 (wider search)

Model 1: Market. The simplest form of joint adaptation was for each firm to continue adapting on its own after cycle 50 without considering any externalities to the partner's fitness. This mode of joint adaptation was used to simulate market governance where each firm pursues its own interests, and the only interaction that takes place is the resource interdependence.

Model 2: JV1. The second form of joint adaptation required firms to explicitly consider each other's interests after cycle 50. Under this form, each firm was allowed to make changes to its strategy only if this move did not decrease its partner's fitness. This mode simulated a restrictive alliance or Joint Venture (JV) where both partners have strict enforceable contractual obligations to consider each other's interests at all times but remain legally separate firms.

Model 3: JV2. In order to model the alliance in a different way, we ran another model with a different set of assumptions. It required the adapting firm to consider both its own interests and the interests of the combined venture. The difference between Models 2 and 3 was as follows: in Model 2, the adapting firm was allowed to proceed only if its move did not hurt the partner's fitness. In Model 3, the adapting firm was allowed to hurt the partner's fitness as long as the overall gain to the JV was positive. Model 2 was more myopic than Model 3 because it did not allow one firm to make an adaptive move while hurting the partner's fitness even when the loss to the partner's fitness was small and the gain to the adapting firm's fitness was large. Such an arrangement can arise if punishment for damage to the other party is high (e.g., separation) but the costs of negotiating side payments are also high. The increasing fitness of the combined venture in Model 3 meant that the loss of fitness of the second firm was less than the gain of fitness of the first firm. The adapting firm was assumed to compensate the partner via a side payment for any loss it might incur.

Models 4 and 5: Sequent.divisional and Simult.divisional. The next form of joint adaptation involved merging the two firms after cycle 50. They became divisions in a new firm and were responsible for sending up strategy change proposals to the corporate managers (this idea was borrowed from Rivkin and Siggelkow 2003). The corporate managers had the power to approve or reject any proposal. The criterion for approving a proposal was whether the proposal increased the fitness of the whole merged firm. Neither division considered the interests of the other division when sending up proposals. This mode simulated a decentralized, divisional firm in which the corporate management played the role of an arbiter and ultimate judge of strategies rather than an active strategizer. We ran this model in two versions: sequential (Model 4) or simultaneous (Model 5) proposals by the two divisions in order to investigate possible differences in fitness (cf. Sah and Stiglitz 1986 who showed that the structure of decision making matters).

Model 6: Centralized. The next form of adaptation involved merging the two firms after cycle 50, but in a more centralized fashion. The merged firm searched for new strategies over the entire landscape of possibilities without any regard to divisional structure. This mode simulated a centralized firm with an actively strategizing corporate management.

Model 7: Grad.centralized. Finally, the last form of adaptation involved merging the two firms after cycle 50, operating in a simultaneous divisional fashion until cycle 100, and then switching to the centralized organization. Thus, Model 7 was a sequence of Models 5 and 6. This governance mode simulated a gradual move from two independent firms to one merged but decentralized firm to a merged centralized organization that exploits the full array of possibilities conferred by its resources.

Simulation results

In order to gain insights into potential value of the various governance forms for two firms with complementary resources and activities, we ran models with different values of the parameters: K, C, search width, and governance form. The values of K varied from 0 to 5; C could take on values 2, 10, or 25; search width could take on values 1 or 2. The main question of interest is how the complexity within and between firms interacts with their dynamic capabilities to affect the performance of various governance modes.

The graphs below summarize the main findings of the simulations. Each graph contains performance of the combined firm (the sum total of the two separate firms or the merged firm) at the end of cycle 150 for all possible governance modes. For convenience we multiplied the results by 1000 to get rid of the decimal part. Differences of 5 and greater are significant at the .05 level. We are reporting results for the values of K1 and K2 equal 0 (modular firm), 2 (moderately coupled firm) and 5 (tightly coupled firm). Results for the other values of K1 and K2, as well as complete results of the simulations, are available upon request.

Figure 1: Performance of the combined venture/firm under various governance forms in the situation of low interdependence (C1=C2=2) and local search.

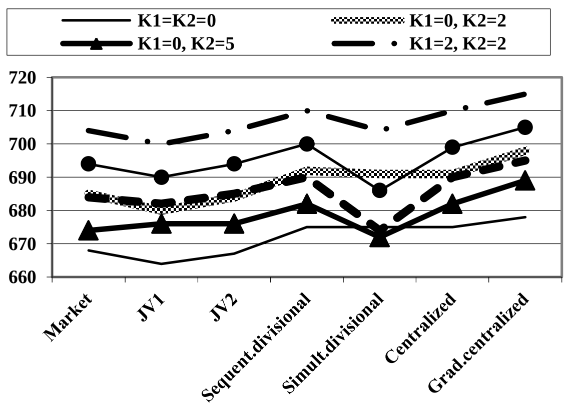


Figure 2: Performance of the combined venture/firm under various governance forms in the situation of medium interdependence (C1=C2=10) and local search.

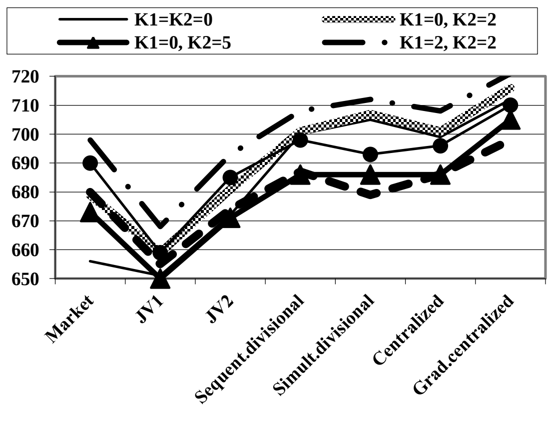


Figure 3: Performance of the combined firm under various governance forms in the situation of high interdependence (C1=C2=25) and local search.

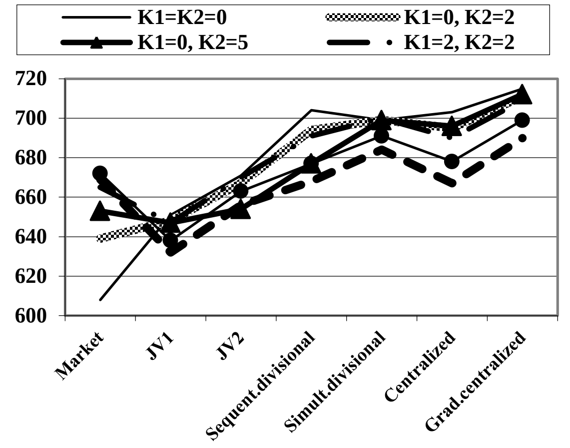


Figure 4: Performance of the combined firm under various governance forms in the situation of asymmetric dependence (C1=2, C2=10) and local search

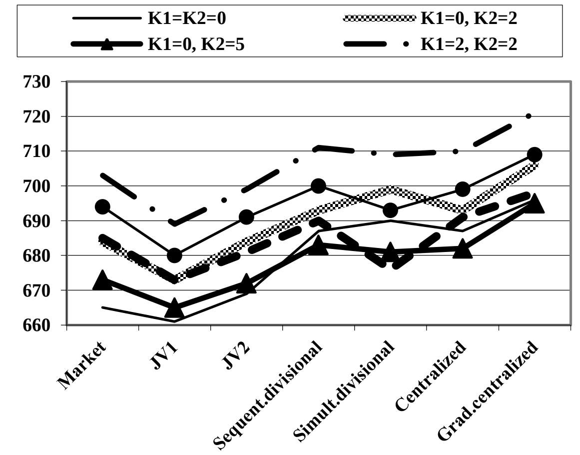


Figure 5: Performance of the combined firm under various governance forms in the situation of asymmetric dependence (C1=2, C2=25) and local search

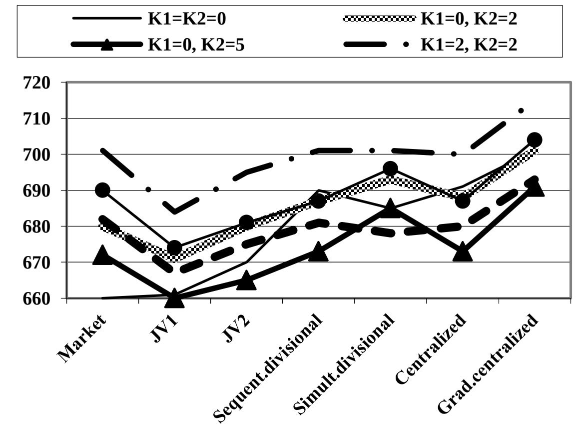


Figure 6: Performance of the combined firm under various governance forms in the situation of asymmetric dependence (C1=10, C2=25) and local search.

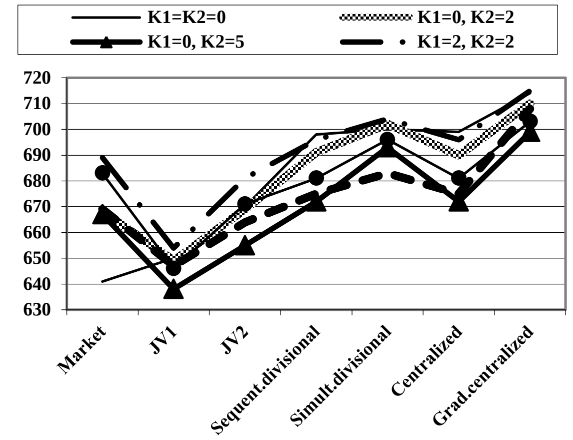


Figure 7: Performance of the combined/merged firm at the end of cycle 150. Both firms/divisions and the centralized merged firm engage in more distant search (search width = 2). Few connections between firms (C1=C2=2)

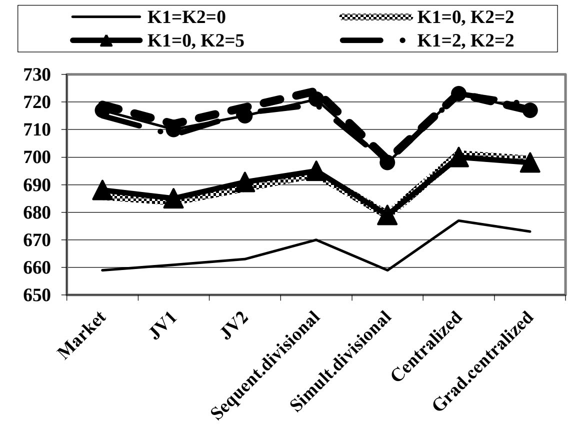


Figure 8: Performance of the combined/merged firm at the end of cycle 150. Both firms/divisions and the centralized merged firm engage in more distant search (search width = 2). Moderate number of connections between firms (C1=C2=10)

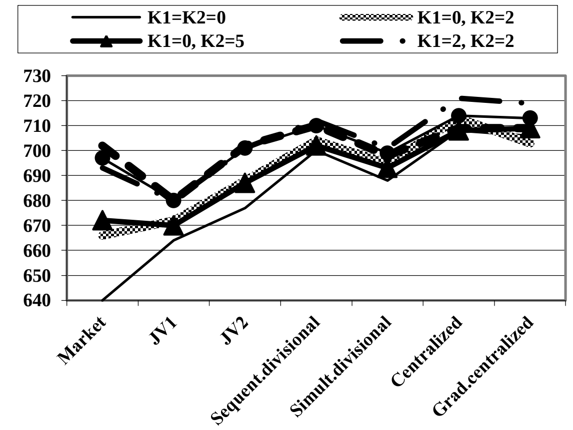
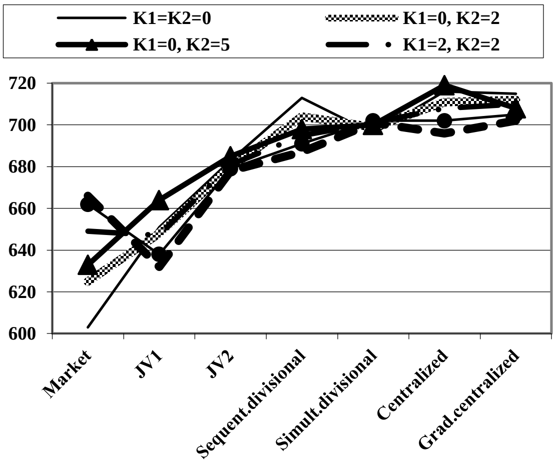


Figure 9: Performance of the combined/merged firm at the end of cycle 150. Both firms/divisions and the centralized merged firm engage in more distant search (search width = 2). Many connections between firms (C1=C2=25)



The main conclusion that can be drawn from the results is that the governance form (i.e., decision making structure) matters for value creation. Overall, tighter governance tends to lead to firms finding better value-creating strategies: most graphs tend to slope upward. However, there are notable exceptions to this. Many pairs of firms experience a drop in fitness in the restrictive alliance mode (JV1) compared to market governance (for the most extreme example, see Fig. 2). It may seem counterintuitive that always considering your partner's immediate interests in addition to your own in an alliance will lead to less value being created by the combined venture. However, there is an explanation to this phenomenon.

The partners in JV1 are constrained in their search: a move that might be beneficial for the venture in the long run is not implemented if the other partner's performance suffers in the short run. Given the bounded rationality of managers (Simon 1947), their lack of knowledge of the future, and their preference for guaranteed immediate results over uncertain future results, strategizing often tends to be myopic (Levinthal and March 1993). Managers simply do not know all possible strategies that they might find in future and the performance that will be associated with those strategies. This result is similar to that found by Siggelkow and Levinthal (2005): independent strategizing of interdependent firms may allow each of them to escape a non-benign competency trap because each firm may dislodge the other from its sticking point on the landscape and let the other firm continue improving. This happens because strategizing by one firm shifts the combined competitive landscape, so that the previous peaks may become valleys or slopes. The results of the less restrictive JV2 are a confirmation of this logic: when each firm only needs to consider the interests of the whole venture in addition to its own, the overall venture performs much better.

Another exception to the rule of greater value creation with tighter governance is the case of two firms with high dynamic capabilities that search in radius 2. When the interfirm dependence is relatively low (Fig. 7), firms do not seem to gain from more governance: the value-creation capability of a market-governed exchange is no less than that of an alliance or a merger. This phenomenon might be attributed to the fact that low interdependence between firms does not make the combined landscape much more complex. Each firm's wide search allows it to find the high local peaks without coordinating the search with its partner. However, when the interdependence becomes greater (Figs. 8 and 9), we observe the familiar pattern of increased value creation with tighter governance.

A third interesting result is that performance of the different mergers is sensitive to the complexity within and between firms. For example, in Fig. 1 we see that firms tend to do less well in the divisional merger with simultaneous consideration of divisional proposals. This effect was the strongest in the case of two tightly-coupled divisions. On the contrary, when interdependence between divisions became tight (Fig. 3), most firms benefited from divisional mergers with simultaneous consideration of proposals but many of them suffered in the centralized merger mode. A possible explanation is that simultaneous consideration of proposals from both divisions sometimes enabled the firm to make a jump in radius 2, which was beneficial on rugged landscapes characterized by many interdependencies (Levinthal 1997). When interdependence became asymmetric (Figs. 4 and 5), there was no clear pattern: some mergers did better in the divisional form while others benefited from centralization. When the two firms had high dynamic capabilities and their interdependence was not too high (Figs. 7 and 8), simultaneous consideration of divisional proposals was clearly the worst arrangement for the merged firms, perhaps because the resulting jump of length 4 might have led the firm away from the good local peak.

Capabilities, transaction costs, and firm boundaries

The governance modes modeled in the previous section reflect more precisely different structures of decision making in the search for better strategies of exploiting complementary resources of two firms that are initially independent. Each mode assumes implicitly that the decision rules embodied in it are agreed upon and enforced effectively without any cost. This would be considered unrealistic from a TCE perspective. Furthermore, in the absence of self-serving behavior, the two firms would be able to use any of the modes by delegating the power of decision making to the other or some third party agent without forming a JV or combining into a single firm. What our models actually show is that the optimal way to search for better strategies of exploiting complementary resources may dictate a certain decision making structure, which in turn may entail a corresponding incentive structure in the presence of self-serving tendency and thus transaction costs. Only the combination of the decision making structure and its corresponding incentive structure can meaningfully characterize an organizational or governance mode (Stiglitz 1989).

Even though most transaction cost considerations are not endogenized in our model, the results of the model highlight the implications of such factors as intrafirm complexity, interfirm dependency and dynamic capabilities for the choice of decision making structure and hence governance structure.

All these factors are of critical concern in the emergent capability-based view of the firm. By examining how variations in these firm and transaction characteristics affect the aggregate payoff from the joint use of the complementary resources under different decision making structures, we can gain a better understanding of the possible interactions between resource- or capability-related factors and transaction cost-related factors in influencing the optimal choice of governance structure. Since the transaction costs attributes of the various governance modes scrutinized in this study are now quite well understood, one can assess qualitatively what transaction costs problems can arise from the adoption of a governance mode that gives the highest aggregate payoff under a particular set of conditions about intrafirm complexity, interfirm dependency and dynamic capabilities. For instance, a comparison of the outcomes from the JV1 and JV2 structures can reveal how a suboptimal decision rule under the JV1 arrangement, presumably due to difficulties in contracting, dissipates the value that can potentially be created under a more efficient structure.

Furthermore, our simulation model does endogenize one important antecedent for transaction costs in a joint production process – the externality that one party's decision imposes onto the other under the condition that their respective payoffs depend on the actions of the other. Our analysis of the different decision making structures sheds light on their relative merits under differing conditions of intrafirm complexity, interfirm dependency and dynamic capabilities.

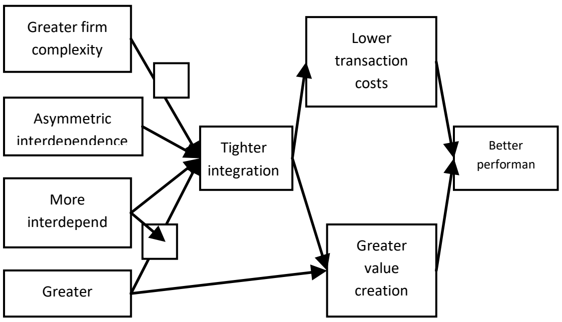
A key assumption of the agent-based simulation models is that firms search for better strategies under limited knowledge about the fitness landscape due to limited cognitive capacity. This is a form of bounded rationality that is in a sense consistent with the assumption of TCE about economic agents being "intendedly rational but limited so" (Williamson 1975), as these models also assume that the agents attempt to optimize but can only do so in a limited way (i.e., one step at a time)[2].

Based on the results of these simulations, the higher incidence of mergers between highly and symmetrically interdependent firms can thus be explained by two separate but simultaneously acting factors: (1) higher transaction costs in the market; (2) greater capability of the merged firm to find and implement superior value-creating strategies. Both of these factors work in the same direction but are conceptually distinct. The former refers to the greater ability of mergers to prevent value dissipation in costly contracting and bargaining while the latter describes the greater ability of merged firms to create value.

Asymmetric resource dependence does not alter the general results (see Figs. 4-6). While asymmetry in resource dependence can certainly affect transaction costs and thus the optimal governance choice (see Casciaro and Piskorski 2005), it does not greatly affect the value creation capabilities of the dyad. What seems to matter most is the overall level of complexity in the dyad. Given the fact that we concentrate on the dyad as our level of analysis, examination of benefits and costs to individual firms is beyond the scope of this study.

Finally, a novel contribution of this paper is in considering dynamic search capabilities as a factor that impacts creation of value in the different governance modes. We are not aware of any studies that considered such capabilities in discussions of firm boundaries. According to our simulations, higher dynamic capabilities tend to increase the value-creating potential of the market governance mode and depress the value-creating potential of the divisional merger with simultaneous consideration of proposals, especially in situations of low and moderately high interdependence. As argued before, long jumps (radius = 4) resulting from simultaneous divisional mergers may be counterproductive on smoother landscapes: the firm may "miss" the peak of the hill it is currently climbing and not implement any strategy change at all, even if better strategies exist. Meanwhile, independent market-governed decision making may help firms dislodge each other from competency traps (Siggelkow and Levinthal 2005). Thus, interdependent firms with higher dynamic capabilities may be less inclined to merge, especially in the abovementioned divisional fashion with simultaneous consideration of proposals.

The results of our simulations and the transaction-cost-based arguments can be summarized in the following model (Fig. 10)



Dynamic capabilities of the partners are postulated to be negatively related to the need to integrate and positively related to value creation. Interdependence is postulated to moderate the relationship between dynamic capabilities and integration: for low interdependence, firms with greater dynamic capabilities will be less likely to integrate than analogous firms with lower dynamic capabilities. However, this effect is hypothesized to diminish or disappear with the growth of interdependence (see Figs. 7-9), so that for pairs of firms with high interdependence, the need to integrate will be about the same whether firms have high or low dynamic capabilities.

Internal complexity of the transacting firms is also postulated to be negatively related to the need to integrate. A careful look at the graphs shows that pairs of tightly-coupled firms have a smaller difference between the performance of market-governed ventures and mergers than modular firms. Interestingly, dynamic capabilities do not seem to affect this relationship in a significant way. Thus, both zero-order and higher-order capabilities may affect the need to integrate, but for different reasons: zero-order capabilities affect the shape of the landscape while higher-order capabilities affect the way the firm searches the landscape.

Discussion and Limitations

Computer simulations using NKC models are a useful way of investigating complex interactions within and between systems. However, such models are necessarily a great simplification of reality. Therefore, the results of these simulations should be interpreted with caution.

First, the governance modes that were studied in our models are stylized representations of what happens in real life. Given the nature of NKC models, we were able to investigate only the decision-making patterns resulting from interactions and constraints built into the models. In real life, the same governance form can have very different decision-making rules and contractual constraints across the population of firms. Thus, the results described above should be interpreted as reflecting the decision making rules and structures rather than specific ownership forms. Obviously, a merged firm will be more likely to use centralized decision making than an alliance, which in turn will be more likely to employ tighter contractual constraints than a market-governed transaction. Because of this, future empirical research may find confirmation of these results using specific governance forms instead of decision making rules.

Throughout the discussion of the results, we deliberately refrained from comparing performance of the same governance form depending on the varying complexities of the firms, even though it might be tempting to make such comparisons. In NKC models, the topography of the landscape on which the firms strategize is determined by mathematical properties of the underlying model. In other words, NKC models are formal abstractions that allow us a glimpse into complex interactions among interdependent decisions made by different firms. Future research may find that alliances between firms of certain complexity outperform others. If this is the case, then researchers may look at complexity as a factor that contributed to this effect along with other factors, such as transaction costs.

In all of the abovementioned models, we used firms of the same size. In order to check the robustness of our results, we performed the same simulations on firms of different sizes and found that varying the size of the firms does not change the overall outcomes. Space limitations do not allow us to present the results of these simulations in this paper. These results are available upon request.

NKC models do not allow researchers to model transaction costs and other costs explicitly. The main focus of this paper is on positioning of firms on fitness landscapes which we interpret as the amount of value creation. While there could be other ways to interpret firm fitness, we chose value creation for the following reason. Value creation depends on the use of the firm's resources. Depending on how the firm will configure its resources and what decisions it makes regarding the use of these resources, it will be able to reach different fitness levels. NKC models shed light on the process of search for good resource-use strategies but they are silent about the costs that the firm incurs while implementing a certain strategy.

Dynamic capabilities were modeled in this paper as search width. Arguably, if a firm is able to implement changes in more than one policy at a time while incurring the same costs as a local searcher (an implicit assumption in our models), it is more flexible and adaptable. In addition to this approach to dynamic capabilities, another one that was suggested by Eisenhardt and Martin (2000) can be modeled. In this other approach, firms will change configurations of their resources by altering patterns of dependencies among them. Eisenhardt and Martin (2000) stated that dynamic capabilities are exercised when a firm deliberately reconfigures its resource base in order to match or even create environmental change. Future research on effects of dynamic capabilities on optimal governance form decisions will need to model and investigate this type of dynamic capabilities as well.

Another limitation is the fact that NKC methodology does not explicitly model resource heterogeneity. As has been suggested before (Dyer et al. 2004, Xiaoli and Shanley 2008, Casciaro 2003), the kinds of resources being exploited together impact the optimal governance mode. For example, Casciaro (2003) found that manufacturing alliances were more likely to be implemented as equity joint ventures and R&D alliances were less likely to be implemented as equity joint ventures. While our simulations consider the degree of complexity and interdependence, they do not address the question of qualitative differences in resources.

The model presented in the previous section is but one general result of our simulations. Figures 1-9 show complex dynamics of value creation capacities of the various governance modes depending on the properties of the two firms and the degrees of interdependence. Lack of space prevents us from formulating all possible propositions evident from the graphs, many of which should be empirically testable.

Conclusion: When two firms are considering a governance mode for exploiting possible resource complementarities between them, they should consider each other's complexity and dynamic capabilities in addition to the properties of the transaction to arrive at the best governance mode. The firms should choose the governance form that maximizes the difference between value created and value dissipated via transaction costs and organizing costs.

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Endnotes

[1] The idea that the characteristics of a firm’s business affect its choice of decision making structure is not new. For instance, using a series of mathematical models, Sah and Stiglitz (1986) show that the relative costs of decision errors to those of executive time affect the choice of decision making structure (e.g., hierarchy vs. committee).

[2] Agent-based simulation apparently assumes a more limited form of bounded rationality than the form of assumed in TCE. Specifically, TCE assumes that economic agents do not possess complete or perfect information about the contractual “landscape” (so to speak), but can still make probabilistic predictions regarding the expected outcomes of a contractual choice. Agent-based modeling, however, in general assumes that an agent can only engage in random search with the option to discard any strategy that degrades its fitness.

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