Do Scale Alliances With Competitors Improve Product Performance?

A Study of the Aircraft Industry, 1949-2000

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Abstract: This paper investigates the performance impact of undertaking activities through scale alliances with competitors rather than undertaking these activities autonomously. Based on a governance and competence perspective, we propose that, when compared to autonomous production, scale alliances have a bi-directional effect on the performance of the activities they cover: while they improve the firms' ability to reach the activity minimum efficient scale through enhanced sales, they also create specific cooperation costs that increase this minimum efficient scale. We test our predictions on a sample of 225 aircraft projects undertaken either through scale alliances or on a single-firm basis. We find that, taking into account the endogeneity of the choice between collaborative and autonomous production, firms forming scale alliances achieve greater commercial success than if they had chosen to launch the same projects autonomously. However, collaborative projects incur higher up-front costs than similar projects undertaken by similar firms on their own.

Key Words: Strategy, Governance, Alliance, Cooperation, Performance, Scale Economies, Aircraft

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This paper investigates the performance impact of undertaking activities through scale alliances rather than undertaking the same activities autonomously. Scale alliances are horizontal alliances in which all partners contribute similar resources and assets. Previous research has shown that incumbent firms form scale alliances rather than invest autonomously when they undertake activities with higher minimum efficient scales (MES) and if their ability to reach the activities' MES on their own is more limited (Garrette, Castañer, Dussauge, 2006). Scale alliances are thus a means for competitors to jointly increase the scale of their activities and to compensate for their limited resource endowment by pooling resources and joining forces with other firms facing the same predicament. The objective of this paper is to investigate the extent to which scale alliances fulfill these objectives. More specifically, we examine whether activities carried out in the context of scale alliances outperform or under perform similar activities carried out on a single firm basis. We do so taking into account the endogeneity of governance mode choice (scale alliance vs. autonomous production). Indeed, factors driving a firm to select a scale alliance over autonomous production to undertake a given activity might in themselves influence the performance of this activity. Based on the alliance outcome literature, on the resource-based view of the firm and on transaction cost economics, we propose that, when compared to autonomous production, scale alliances have a bi-directional effect on the performance of the activities they cover: while they improve the firms' ability to reach the MES, they also create specific costs that increase the MES. In doing so, we try to disentangle the performance impact of collaboration by examining both the benefits it produces and the costs it generates.

The empirical setting for our study is the global aircraft industry. We test our predictions on a sample of 225 aircraft projects undertaken either through scale alliances or on a single-firm basis by 82 aircraft manufacturers in the Western hemisphere from 1948 until 2000.

We find that, taking into account the endogeneity of the choice between collaborative and autonomous production, firms forming scale alliances achieve greater commercial success than if they had chosen to launch the same projects autonomously. However, collaborative projects incur higher development costs (therefore higher up-front investments) than similar projects undertaken by firms with equivalent features on their own.

SCALE AND LINK ALLIANCES

The literature on horizontal inter-firm alliances has suggested that pursuing scale benefits and leveraging complementarities are two main motivations for firms to collaborate (Kogut, 1988). This has led to categorize horizontal alliances as either scale alliances or link alliances (Hennart, 1988). This typology classifies alliances according to the partners' contributions to the joint activity. In scale alliances, the partner firms contribute similar resources to the same stage or stages in the value chain. Scale alliances are arrangements between industry incumbents which include joint R&D efforts, the joint production of components, sub-assemblies or even an entire product. Link alliances, in contrast, aim at combining different skills and resources contributed by each partner. Link alliances include partnerships in which one partner provides market access to technologies or products that the other firm has developed. Surveys of horizontal alliance activity support Hennart's scale/link categorization and show that complementary alliances are more prevalent in some industries and scale alliances in others (Hergert and Morris, 1987; Dussauge and Garrette, 1995; Gomes-Casseres, 1996). Furthermore, research on the performance impact of alliances suggests that scale and link alliances are formed by firms pertaining to different strategic groups and lead to contrasted outcomes (Nohria and Garcia-Pont, 1991; Dussauge, Garrette, and Mitchell, 2000; 2004; Garcia-Pont and Nohria, 2002). Partners in scale alliances are more similar in size and geographic origin than partners in link alliances; link alliances are less stable than scale alliances and lead to more asymmetric outcomes for the involved partners (Dussauge et al., 2000, 2004). While this categorization of alliances is widely accepted, research on alliance formation, management and outcomes has primarily focused, explicitly or implicitly, on link alliances. As a consequence, conclusions derived from the analysis of link alliances are often assumed to be applicable to all forms of horizontal alliances.

In this paper, we focus specifically on scale alliances and examine the performance impact of turning to such an arrangement to carry out an activity that the considered firm could have chosen instead to undertake on its own. Prior research has shown that firms are more likely to undertake an activity through a scale alliance rather than autonomously when the activity has a higher minimum efficient scale and targets a smaller market, when the size of the firm is smaller and its experience in the considered activity is more limited (Garrette, Castañer, Dussauge, 2006). These results support the idea according to which scale alliances are primarily formed to undertake projects that require higher investments and by competitors suffering from a more limited resource endowment. This raises the issue of the efficiency of scale alliances as a mechanism for firms to pool the resources they need to undertake activities requiring high levels of investment.

ALLIANCE PERFORMANCE AND OUTCOMES

Several perspectives have examined alliance performance and outcomes (Uzzi, 1996; Gulati, 1998). A first early stream of research has focused on the success of the alliance itself and has often used alliance stability and duration as an indicator of success. Later research has examined the impact of alliance outcomes on the involved partner firms and has focused primarily on inter-partner learning. More recently, a third approach has investigated the performance impact of collaboration compared to other governance modes (e.g. internal growth or acquisitions) while taking into account the endogeneity of the governance mode choice.

Most early studies on the outcomes of joint ventures tried to identify factors, such as partner asymmetries, joint venturing experience, joint venture scope, industry structure, R&D intensity, inter-partner rivalry, and governance structure, that influence alliance duration and stability (Janger, 1980; Killing, 1982, 1983; Beamish, 1984, 1985; Beamish and Banks, 1987; Harrigan, 1988; Kogut, 1988, 1989; Geringer and Hebert, 1989; Blodgett, 1992; Park and Russo, 1996; Park and Ungson, 1997). These studies however examine differing levels of performance among alliances but do not investigate the performance impact of alliances by comparing them to the option of not collaborating.

A second stream of research has shifted the focus from the fate of the alliance itself to the consequences of allying for the partner firms. Studies based on stock market reactions to alliance announcements have shown that investors tend to react positively to such announcements (McConnell and Nantell, 1985; Koh and Venkatraman, 1991). These studies implicitly compare forming alliances with not collaborating but do not compare the alliance option to other means of carrying out the same activity. Other studies that examine the impact of alliances on the fate of partner firms have focused on the learning and skill acquisition that tend to occur between the allied firms, especially in alliances among competitors (Hamel, Doz and Prahalad, 1989; Hamel, 1991; Kanter, 1994; Doz, 1996; Arino and de la Torre, 1998; Khanna, Gulati, and Nohria, 1998). These studies that link alliance outcome to inter-partner learning in fact assume that alliance partners have an incentive to learn from each other, which in turn suggests that they have different capabilities. In addition, for alliances to lead to inter-partner learning, they must create a context in which each partner has access to attractive capabilities possessed by the other. This in turn is made possible if the partner firms make different contributions to the joint activity, i.e. have formed a link alliance. It thus appears that research on alliance outcomes and performance has primarily focused either on the fate of the alliance itself, without discriminating between types of alliances, or on the impact of collaboration on the involved firms in terms of learning and capability acquisition, focusing implicitly on link alliances. In contrast, very little research has explored the drivers of performance in scale alliances. A few larger sample studies have also explored the impact of alliance activity on the ongoing financial performance and survival of the parent businesses (Berg, Duncan, and Friedman, 1982; Hagedoorn and Schakenraad, 1994; Mitchell and Singh, 1996; Singh and Mitchell, 1996). These studies report that parents often benefit from alliances, but that alliance activity also carries risks and costs. Collaboration benefits include accessing complementary resources, acquiring tacit knowledge, sharing costs and investments, mitigating risks, entering new markets or new business domains, complementing product lines, and increasing market power (Arora and Gambardella, 1990; Baum et al., 2000; Dyer and Singh, 1998; Khanna et al., 1998; Oliver, 1990). Collaboration costs comprise monitoring costs, coordination costs, dependence on a partner, loss of proprietary knowledge, as well as the risk of creating or strengthening a competitor (Hamel, Doz and Prahalad, 1989; Dussauge, Garrette, Mitchell, 2000; White and Lui, 2005). However, as mentioned above, this research on alliance performance has primarily focused on a resource-complementarity arguments, downplaying the performance issues raised by scale related benefits and costs.

Finally, several scholars have investigated the performance impact of collaboration compared to other governance modes (e.g. internal growth or acquisitions). Drawing primarily upon the Transaction Cost Theory which argues that firms select governance modes based on the characteristics of the transactions they engage in, this stream of research suggests that firms tend to select the governance mode that best fits their own features as well as the characteristics of the activity to be implemented. In this perspective, what influences performance is not the governance choice in itself, but the fit between the governance mode and the attributes of both the firm and the project it undertakes (Williamson, 1975; Masten, 1993; Brouthers, Brouthers and Werner, 2003; Sampson, 2004; Geyskens, Steenkamp, Kumar, 2006). These results suggest that, when examining performance differences across governance modes, those factors that lead firms to select one governance mode over another need to be controlled for.

Our own research builds on this third approach and assesses the performance impact of collaboration by comparing activities undertaken through alliances with similar activities undertaken by similar firms on their own, taking into account the endogeneity of governance mode choice. In addition, we focus on scale alliances and seek to disentangle the costs and benefits they entail.

TOWARD A RESOURCE-BASED VIEW OF SCALE ALLIANCES

The classical resource-based approach (Penrose, 1959) suggests that a firm's resource endowment determines its growth. Indeed, according to Penrose (1959), most resources are fungible, that is, they can be redeployed to additional uses, other than the current one. The same argument has been applied to more intangible competences (Teece, Pisano and Shuen, 1997).

Because its main focus is on the growth of the firm, the resource-based view has primarily considered the use that firms can make of their excess resources. Pursuing this line of reasoning, subsequent work has examined how firms can leverage these excess resources by combining them with complementary resources possessed by other firms, when these complementary resources are not easily tradable (Teece, 1986). This view thus explains the formation of link alliances. In this perspective, link alliances are formed to pursue expansion opportunities at the frontiers of the partner firms' current businesses. As a consequence, firms engaged in link alliances have an incentive to reduce their dependence on their partner and to acquire or replicate, whenever possible, the resources they lack to carry out the new business on their own. Hence the above mentioned focus on inter-partner learning and capability acquisition as a determinant of alliance outcome and even as a criterion of success for the partner firms.

While the resource-based view has theorized the use of excess resources as a driver of firm growth, it has paid less attention to the implications of a firm's lack of resources. Indeed, existing firms in any business are assumed to possess a resource endowment which allows them to operate at an adequate level of performance. However, industry evolution and competitive dynamics may raise the minimum level of resources required to continue competing in the industry. The additional resources required may be different in nature, which then takes us back to the above examined case, or similar to those already possessed, but in greater quantities. When confronted with the latter challenge, firms must increase their stock of existing resources or disappear. They can acquire such additional resources on the market for resources (through raising capital, hiring and investing in additional assets) or on the market for corporate control (through mergers and acquisitions). An alternative option is to pool their existing resources with those of other industry incumbents facing the same challenge and form a scale alliance. Scale alliances are thus a means for industry incumbents confronted with increasing levels of minimum efficient scale, or with differing levels of MES across activities or products, to continue operating in their industry without partaking in industry concentration (Hennart, 1988; Garrette et al., 2006). This raises the issue of the performance of scale alliances when compared to other arrangements firms can turn to when faced with levels of MES they are unable to achieve on their own.

THE PERFORMANCE OF SCALE ALLIANCES

We propose that, when compared to autonomous production, scale alliances have a bi-directional effect on the performance of the activities they cover: they improve the firms' ability to reach the MES but they also create specific costs that increase this MES.

Prior research has shown that scale alliances are selected over autonomous production by smaller firms with a limited resource endowment when undertaking projects with a high MES and a narrow market potential (Garrette et al., 2006). It thus appears that scale alliances are formed to allow firms to carry out projects that they would be unable to undertake profitably on their own. Scale alliances aim at improving a firm's ability to reach a project's MES by pooling its current resources and assets with those of other industry incumbents facing similar constraints. For example, firms engaged in scale alliances can pool their R&D assets to jointly develop a new product, allocate production to their various plants and use all available sales networks to broaden the product's commercial reach. In aerospace, all Airbus partners lacked sufficient resources to undertake the production of a modern airliner on their own; by pooling their resources, they proved capable of competing successfully with Boeing. In addition, producing a single aircraft reduced competition in the industry, increasing the likelihood that all partner firms could reach the MES and achieve acceptable levels of profitability. Finally, such collaboration mitigates the risk supported by each partner firm; this is critical when major investments entail a risk that is too heavy to carry for any one of the partner firms.

At the same time, scale alliances entail specific costs and risks. Coordinating activities and allocating tasks across several partner firms create significant negotiation and management costs while collaborating with competitors can lead to opportunism and loss of proprietary knowledge. These monitoring and coordination costs (White and Lui, 2005) will increase the overall cost of a project carried out through a scale alliance when compared to that of a project undertaken on a single firm basis. In the case of Airbus, for instance, implementing the project as an alliance between four firms originating in four different countries has led to lengthy negotiations on the distribution of tasks among partners and to a duplication of final assembly lines in two different locations (Toulouse in France and Hamburg in Germany). As a result, undertaking a project through a scale alliance creates coordination costs that are likely to increase upfront investments as well as ongoing costs and, thus, drive up the MES of the project, when compared to carrying out the same project autonomously.

Overall, when compared to autonomous production, scale alliances have three main impacts on the economy of a project being undertaken by a given firm. First, scale alliances allow for a sharing of upfront investments among the partners but also entail a sharing of profits along the same lines: this lowers the hurdle for each partner but has no effect on the profitability each of them derives from the project. Second, as mentioned above, scale alliances create specific costs that increase the MES of the project. Third, they make it easier for the partner firms to reach the project's MES by expanding the market through the pooling of the various partners' customer bases and the leveraging of all partners' distribution networks. In addition, the formation of a scale alliance prevents the allied firms from each launching competing projects on their own. In oligopoly situations, a scale alliance thus limits the number of competing products and increases the likelihood the joint product will reach its MES. The main benefit of scale alliances is thus to increase the potential sales volume of collaborative projects when compared to single-firms projects. In a nutshell, by engaging in a scale alliance, each partner has a smaller share of a project that is likely to achieve larger sales and thus reach its MES more easily, despite greater overall costs.

Compared to autonomous production, scale alliances therefore have a bi-directional effect on the economy of a project being undertaken by a given firm. On the one hand, they create specific costs that increase the MES of the project. On the other hand they enhance sales and thus make it easier for the firm to reach the project's MES. Hence the two following hypotheses:

H1: Activities undertaken in the context of scale alliances achieve greater sales volumes than similar activities undertaken by each partner on a single-firm basis.

H2: Activities undertaken in the context of scale alliances entail higher costs than similar activities undertaken by each partner on a single-firm basis.

METHODS

Empirical Setting

The empirical setting for our study is the aircraft industry in the Western hemisphere. Unlike in most other industries, aircraft manufacturers have been collaborating with each other for many years to develop, manufacture and commercialize new products. In addition, most horizontal alliances in this industry, i.e. alliances between incumbent airframe manufacturers, appear to be motivated primarily by the pursuit of scale benefits.

In the aircraft industry, upfront investments, notably airframe development costs, are extremely high and have been increasing significantly over time. As a consequence, the aircraft industry has undergone major consolidation over the years. However, national security concerns – which primarily prevail in the case of military aircraft but also affect commercial aircraft because both are produced by the same firms and share technology extensively – have limited the potential for international consolidation as well as for licensing. This has led airframe manufacturers to turn extensively to collaboration to jointly produce aircraft. Most of these collaborations associate industry incumbents, even competitors, that undertake a project jointly by sharing the prime-contractorship. Joint prime-contractorship entails jointly defining product features, sharing investments, risks and benefits. In such arrangements, the partner firms usually split the development work among themselves and then each partner assumes responsibility for manufacturing (sometimes turning to subcontracting) those elements and modules it has developed. Final assembly is either entrusted to one partner through the work split agreement or, more commonly, duplicated, i.e. carried out simultaneously by several partners. Marketing and sales are either split among the partner firms on a geographic basis or entrusted to an *ad hoc* joint sales organization (Dussauge and Garrette, 1995). Overall, such joint prime-contractorship arrangements have accounted for close to 20 % of all new aircraft developed since WWII (Jane's All the World's Aircraft, 1945 – 2003). These arrangements are a means for aircraft manufacturers to deal with the minimum efficient scale issue by sharing the burden of upfront investments, reducing the number of products competing in the market and lengthening production runs through the pooling of demand originating in different countries. Based on these features, and consistent with the literature on horizontal alliances (Hennart, 1988; Dussauge, Garrette and Mitchell, 2000, 2004; Porter and Fuller, 1986; Ghemawat, Porter and Rawlinson, 1986; Nohria and Garcia-Pont, 1991), most joint prime-contractorship agreements in the aircraft industry can be interpreted as scale alliances. Indeed, they associate industry incumbents, even competitors, that undertake a project jointly by contributing similar assets and resources at the same stages in the value chain.

We acknowledge that joint prime-contractorship is only one of the multiple forms that inter-firm collaboration can take on in the aircraft industry. Airframe manufacturers routinely collaborate with complementors such as engine makers or electronic equipment providers. They also collaborate with first tier suppliers on entire modules and subsystems through risk sharing agreements. These arrangements, however, cannot be considered as scale alliances because the involved partners are not incumbents in the same industry or at least do not operate at the same stage in the value chain.

The saliency of minimum efficient scale issues in aircraft manufacturing, which results in the widespread formation of scale alliances, makes this industry a particularly suitable setting in which to test our arguments. In addition, despite the prevalence of scale alliances in this industry, differences in minimum efficient scale across projects as well as differences across firms have led to different firms making different governance choices (autonomous production or production through a scale alliance) for similar projects and to the same firm making different governance choices for different projects. This makes it possible to test the hypothesized influence of undertaking a project through a scale alliance rather than autonomously on the resulting product's performance.

Population and Sample

We considered the population of civil and military aircraft projects launched in the Western hemisphere from 1944 up to 2000, i.e. projects for which aircraft deliveries began during this time span. The population includes four types of aircraft: fighter aircraft, jet transport aircraft, propeller aircraft, and helicopters. We gathered data from two sources: *Jane's All the World Aircraft* annual reports and *DMS Forecast* databases which list all aircraft models in production during a given year. *Jane's All the World Aircraft*, published since 1909, is the major reference source on aircraft programs, covering the entire worldwide production. The *Jane* reports classify aircraft by country of origin and, within each country, by prime-contractor (e.g. the Dassault Rafale fighter is listed in the "France" section under the "Dassault" heading).

Multiple prime-contractor programs are listed under the headings of all prime-contractors (e.g. the V22 tilt-rotor aircraft is in the US section and listed twice under both the Bell Textron and Boeing headings). Programs undertaken by multiple prime-contractors from different countries are listed in an "International Programmes" section under a heading identifying all prime-contractors. We classified all aircraft projects included in our sample as either alliances or autonomous projects based on whether they were listed under one or more prime-contractors in *Jane* reports.

We did not include production under license in our analysis. Indeed, in licensed production, the licensee takes on none of the responsibilities of a prime contractor: in particular, licensees do not participate in the definition of essential product features or in technology development and limit their contribution to manufacturing a pre-existing product and commercializing it in a specific market area. Licensed production is therefore neither autonomous production (single prime-contractorship) nor an alliance (shared prime-contractorship). Licensed production can be viewed instead as a market transaction on technology and product design. In addition, were we to consider licensing agreements as alliances, they would fall into the link alliance category because the firms involved make asymmetric and complementary contributions to the venture: design and technology by the licensor and manufacturing and sales in a given area by the licensee.

The objective of our study is to examine the performance impact of launching a new aircraft either on a single firm basis (i.e. by taking on the full prime-contractor responsibility), or in collaboration (i.e. by sharing the prime-contractor responsibility with another aircraft industry incumbent). The unit of analysis is thus an industry incumbent launching a new aircraft project, either on its own or through a scale alliance. We therefore considered each firm-project combination a different observation. Each single-firm program resulted in one observation while each alliance resulted in as many observations as there were co-prime contractors involved in the project. We were able to gather the necessary information for 225 aircraft project-firm observations with deliveries taking place between 1948 and 2000.

These 225 observations corresponded to only 82 different firms, as several firms had launched more than one project in the considered period. The 225 sample cases consisted of 56 collaborative project-firm observations (involving 30 firms) and 169 single-firm projects launched by 71 different firms. We only considered incumbent firms. In others words, all projects in our dataset were launched by firms with prior sales experience in the same business domain (i.e. fighter aircraft, jet transport aircraft, propeller aircraft or helicopters).

Statistical Methods

To test our hypotheses on the performance impact of scale alliances while accounting for the endogeneity of governance mode choice (scale alliance vs. autonomous production), we used two-stage treatment effect models (Shaver, 1998; Greene, 2003; Hamilton and Nickerson, 2003). In the first stage of the treatment models, we linked the governance mode choice to a set of explanatory factors using a probit regression on our sample of 225 projects.

In the second stage, we used OLS regressions to compare the sales and cost performance of projects undertaken either autonomously or through scale alliances, controlling for the endogeneity of governance mode choice.

The multiple observations for some firms (225 projects for 82 firms) are not totally independent from each other, raising a concern of possible heteroscedasticity. To address this issue we clustered our data by firm (Wooldridge, 2002, § 13.8.2). Such an approach provides a robust estimator where observations are assumed to be independent across firms but not independent within firms (Leiblein, Reuer, and Dalsace, 2002).

In the first step of our analysis (see model 1), we ran a probit regression to model the choice of forming a scale alliance or producing autonomously, based on a set of factors derived from prior research (Garrette et al. 2006). This produced a self-selection variable that captures the endogeneity of governance mode choice. This variable λ was obtained by using inverse Mill's ratios (Greene, 2003) and was introduced as a control variable in the second stage of our analysis.

In the second stage of our analysis (see models 2 & 3), we examined the performance of projects undertaken either through scale alliances or on a single-firm basis while controlling for the endogeneity of governance mode choice. We argued that, compared to autonomous production, scale alliances have a bi-directional effect on project performance. While they create specific costs that increase the MES of the project, they enhance sales and thus make it easier for the firm to reach the project's MES. Hence, we assessed performance through the two following dependent variables: (1) project sales and (2) project development time (in models 2 and 3 respectively). Both models use governance mode as an independent variable along with several control variables.

Variables

Governance mode

We defined a dummy variable indicating whether a given firm undertaking a particular aircraft project is doing so as the single prime contractor (Scale alliance = 0) or by sharing the prime contractorship with one or several other industry incumbents (Scale alliance = 1).

This variable was used as the dependent variable in the first stage of our analysis and as an independent variable in the two second stage models.

First stage independent variables

In the first stage of our analysis (model 1), we used ten variables that may influence the choice of one governance mode over another: Project Scale, Market Size, Firm Size, Domain-Specific Know-How, Cooperative Competence, Prototype Year, Product Type, Military, Number of Competitors, State-Owned. These variables were estimated at the beginning of product development, i.e. one year before the prototype first flight.

We first assessed **Project Scale** through a proxy capturing the level of upfront investment required to develop and produce the aircraft being launched. This proxy is the product's technological complexity which is associated with the number of components and technologies to be combined, the sophistication of these components and technologies, as well as the way of combining them (Henderson and Clark, 1990). By technological complexity we thus refer to the position of the new product in the existing product range, in terms of performance, attributes and, therefore, development cost. We measured **Project Scale** with the logarithm of the aircraft's maximum speed (in km/h) multiplied by its range (in km) and takeoff weight (in kg), as reported by *Jane's* and *DMS Forecast*. We used logarithms in order to account for the fact that the (speed * range * weight) product increases exponentially with technical complexity.[2] Such a measure has been frequently used in other studies on the aircraft industry (Frenken and Leydesdorff, 2000).

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[2] By using the logarithm, we considered the interval between a (speed * range * weight) product of 100 and a (speed * range * weight) product of 200 to be equivalent to the one between (speed * range * weight) products of 1,000 and 2,000. In contrast, using (speed * range * weight) products directly would have led to equate an increase from 100 to 200, which is significant, with an increase from 1,000 to 1,100, which is not significant.

We assessed the size of the market accessible to a given firm launching a particular project by using the GDP of this firm's home country a year prior to the prototype first flight. GDP for the 1948-1999 period was collected from Maddison (2003). Because the distribution is highly skewed, we log-transformed this data to generate our **Market Size** variable. This indicator is a proxy for the size of the demand a new aircraft launched by any one prime contractor can expect to tap into. We also estimated the **GDP growth** in the firm's home country at the time the governance mode was chosen by averaging the GDP growth over five years before the prototype first flight. Annual GDP growth were also obtained from Maddison (2003).

We assessed **Firm Size** by using a revenue proxy which we constructed by considering all the firm's different aircraft in production in the four product types a year prior to the focal prototype first flight. We estimated the annual volume of production for a given model by dividing the total volume produced in its entire life cycle (i.e. up to 2000) by the number of years during which the model was manufactured, assuming a yearly constant production volume. These data come from both *Jane's* annual reports and *DMS Forecast* database. Then, we determined the annual revenues each model generated by multiplying its annual volume by the mean of its *DMS Forecast* estimated price range in 1999 dollars. We replaced missing prices by price estimates that we obtained by regressing prices on products' technical characteristics: maximum speed, range and takeoff weight.[3] Summing the annual revenues for all the aircraft products manufactured that year, we obtained an estimate of each year's firm aircraft revenues. We were forced to turn to such an estimate because our data spans a fifty year period and covers 18 countries[4], making it very difficult to collect comprehensive data on aircraft sales for each

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[3] We conducted a price regression for each of the four different product types (propellers, jets, helicopters, and fighters) and obtained significant models with a R^2 ranging from .76 to .94.

[4] Argentina, Brazil, Canada, China (cooperation only), France , Germany, India, Indonesia, Israel, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, Taiwan, United Kingdom, United States

considered company (many of which have long disappeared). Also, isolating aircraft sales in the total revenues of large diversified groups is almost impossible for periods of time or in countries where reporting business line figures was not mandatory. Again, we also we log-transformed this data to generate our **Firm Size** variable**.**

We captured the firm's **Domain-Specific Know-How** with a variable based on the number of projects that the firm has previously developed as a prime contractor in the same product type as the considered project (fighter aircraft, jet transport aircraft, propeller aircraft, or helicopters). We gathered this data from *Jane's* annual reports. In addition, to denote the fact that domain know-how is unlikely to increase linearly with the cumulated number of past projects, we considered the logarithm of the number of past projects.

In a similar way, we measured firms' **Cooperative Competence** in the considered product area by the logarithm of the number of past collaborative projects (i.e. projects undertaken in collaboration with other prime contractors) at the time of the focal project launch.

We also controlled for project year by using the project's prototype first flight year (**Prototype Year**) to eliminate the trend effect, as the overall propensity to form alliances in aerospace appears to have increased over time, like in many other industries (Hagedoorn, 1993). Similar to other studies (Gulati, 1999), we used this quantitative measure rather than a dummy for each year (49 dummies) in order to economize on the number of predictors. Furthermore, prior research has found the same results whether quantitative or dummy variables are employed (Gulati, 1999).

We also controlled for the four product types by creating four dummies (**Helicopter, Fighter, Jet and Prop**) because the resource requirements and/or the potential market size, and therefore the likelihood of cooperation vs. autonomous production might vary across them. For example, in the case of helicopters, the potential market is smaller and upfront investments (i.e. project scale) are greater than for other product types. Thus, we would expect firms undertaking a helicopter project to be more likely to form an alliance rather than to go for it on their own, when compared to developing other products. We coded Product Type with mean effect dummies[5].

We controlled for industry concentration in each product domain at the time of project launch. This was done with a variable (**Number of Competitors**) that captures the number of incumbents actually producing and marketing aircraft of the considered type. While prior literature on alliance formation, which we claim primarily, focuses on complementary alliances, has suggested that more fragmented industries offer greater opportunities for collaboration, thus leading to a greater collaborative propensity, we argue that, because of the specific logic of scale alliances, greater industry concentration favors collaboration. Indeed, as mentioned previously, greater concentration enhances the price control benefits of alliances. In addition, based on our argument that scale alliances are formed by weaker competitors, we anticipate that industry concentration will increase the market power of leading incumbents and therefore the vulnerability of weaker competitors, which in turn will increase the latter's need for collaboration or even collusion.

We distinguished between projects developed for military purposes only (**Military** = 1) and those designed for a commercial or a dual use (**Military** = 0). Relative to projects with commercial applications, exclusively military projects might have a smaller potential market and therefore be more likely to be developed in collaboration. However, on the other hand,

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[5] As specified by Dussauge, Garrette and Mitchell (2004: 708) "Mean effects dummies are appropriate when there is no conceptually motivated base case to compare the other cases to. The value of this approach is that the statistical test determines whether the effect of a variable differs significantly from the mean of the set of variables, rather than from a single omitted base case variable."

exclusively military projects might be less likely to be carried through cooperation than autonomously for political and national security reasons.

Finally, we also included a variable recording whether the firm was **State-owned**. Although being state-owned might influence a firm's governance mode choice, the direction of the effect is unclear. On the one hand, state-owned companies may enjoy government subsidies that help them overcome a lack of resources needed to internally develop aircraft. On the other hand, state-owned companies may be compelled to enter into collaborative ventures for political reasons.

We now turn to the second stage of our analysis, concerning the influence of governance choice on sales and cost performance while controlling for the endogeneity of governance mode choice.

Second stage dependent variables

We first estimated **Project Sales** by the cumulative number of units sold over the entire life cycle of the project. For the 64 programs that had not reached the end of their production life by the end of the study period (2000), we extrapolated Project Sales based on the sales schedule of those programs that had ended by the end of the study period. Based on the 38 programs for which annual sales were available in the *DMS Forecast* database, we found that, on average, programs achieved 6% of their total production volume in the first year, 13% by the end of the second year, 68% by the end of the tenth year, 86% by the end of the fifteenth year. This enabled us to estimate the total production for the 64 programs that had not reached the end of their production life by 2000.

Second, we assessed the cost performance of aircraft programs by recording their **Development Time**. This variable measures the time elapsed between the first flight of the aircraft prototype and the first delivery of production aircraft.

Second stage control variables

When modeling the influence of governance mode (scale alliance vs. autonomous production) on sales performance (model 2, dependent variable: **Project Sales**), we controlled for eight variables that may also influence the sales of a specific project: Firm Size, Domain-Specific Know-How, Market Size, Product Type, Military, Project Scale, Year and Number of Competitors. These variables were similar to the ones used in the first stage model but they were estimated one year before the deliveries of the focal aircraft began, instead of being measured one year before the prototype first flight.

We controlled for **Firm Size** because we suspected larger firms to more easily reach greater sales on any given new project. We also included **Domain-Specific Know-How** because firms with more experience in a given line of business might be more able than others to achieve greater sales of aircraft in the same business domain. As new aircraft sales are likely to be impacted by the size of the market the focal firm has a privileged access to, we included the **Market Size** variable in the analysis. We also introduced **Product Type** (with four dummies: fighter, jet, prop and helicopter) to take into account demand differences between product types. We included a dummy variable recording whether the product was exclusively designed for a military use (**Military**) in order to capture possible differences between commercial and military markets and products. We also controlled for the level of upfront investment required to develop and produce the considered aircraft (**Project scale**) because, even within the same product type, products presenting very different features are likely to reach different levels of sales volumes.

To capture any trend effects, we included a variable recording the year of the first deliveries (**Year**). We also included a variable estimating the structure of competition in the business area (**Number of Competitors**), because we expect a higher number of competitors in the product category to make it more difficult for any aircraft to reach larger sales.

When modeling the influence of governance mode (scale alliance vs. autonomous production) on cost performance (model 3, dependent variable: **development time)**, we controlled for six variables (Firm Size, Domain-Specific Know-How, Product Type, Military, Project Scale, Prototype Year) that may influence the development time of a given product. As in the first-stage model, these variables were estimated at the beginning of product development, i.e. one year before the prototype first flight.

We first controlled for **Firm Size** and **Domain-Specific Know-How** because we suspected that larger and more experienced companies, which benefit from either larger or more specialized resource endowments, are more likely to develop products in a shorter period of time than smaller and less experienced companies. To take into account differences in product life cycles and systematic differences in development times between different lines of business, we included the **Product Type** variable with its four above listed dummies (fighter, jet, prop and helicopter). We also included the **Military** variable because we suspected interactions between producing firms and bureaucratic customers to result in additional delays in development. We controlled for **Project Scale,** anticipating that more technologically complex products are longer to develop. Finally, to control for the evolution of technology over time, we included the **Year** variable (year prior to the prototype first flight).

FINDINGS

The impact of scale alliances on project performance

Our results support our theory: the two hypotheses we formulated are indeed verified. As far as **Project Sales** are concerned (model 2), firms launching cooperative projects reach greater sales levels than if they had launched similar projects autonomously ($b = 0.635$, $p < 0.05$). Regarding cost performance, our results show that cooperation tends to increase **Development Time** ($b = 1.976$, $p < 0.01$, model 3). These results confirm the bi-directional impact of scale alliances on project performance: choosing to undertake a project through a scale alliance rather than autonomously tends to increase the project's MES through higher development costs but increases the likelihood the project will achieve this MES thanks to greater sales.

Our findings also shed some light on the factors that lead firms to opt for a scale alliance rather than for autonomous production as well as on factors that influence project performance.. They also reveal that cooperation is not a random choice but rather a decision influenced by underlying firm and project characteristics (significant λ in models 2 and 3). This demonstrates that the endogeneity of governance mode choice must be taken into account in order to isolate the specific impact of cooperation on performance.

Factors influencing scale alliance formation

Model 1 is significant (chi-square = 77.98, $p < .001$) and confirms prior findings on scale alliance formation (Garrette, Castañer and Dussauge, 2006): firms undertaking projects characterized by higher upfront investments (**Project Scale**) are more likely to form scale alliances rather than produce autonomously ($b = .451$, $p < .05$). Regarding firm-level factors, we verified that larger firms (**Firm Size**) tend to prefer to use autonomous production than scale alliances (b = - .084, p < .05) and that firms undertaking projects in domains where they have greater **Cooperative Competence** are more likely to opt for collaborative rather than autonomous production (b = 0.791, p < .05). The significant impact of the **Year** variable (b = 0.047, p < .001) is consistent with prior alliance literature which has shown an increase in the rate of alliance formation over time (e.g. Hagedoorn, 1993). We also found that the propensity to collaborate varies significantly across **Product Types**. For example, helicopters are more commonly developed through a scale alliance than other aircraft types (b = 0.648, p < 0.1). Finally, we found that **state-owned** companies are more prone to use scale alliances than others (b = 0.629, p < 0.05). One plausible explanation for this is that, in aerospace, state-owned companies are driven into alliances for political reasons.

Other factors influencing project performance

Some of the control variables included in models 2 and 3 have a significant influence on **product sales** or on **development time** or on both.

We found that firms benefiting from a larger experience in the business domain (Domain-Specific Know-How) achieve greater sales performance on the products they launch. However, Domain-Specific Know-How has no significant influence on product Development Time. As expected, projects launched by firms with a privileged access to a larger market achieve greater sales, while products requiring higher levels of up-front investments (Product Scale) achieve smaller sales levels. Also, products designed for a military use achieve inferior sales and require a longer Development Time than civil or dual products. Finally, significant differences between product types can be noted: turboprop aircraft projects result in lower sales levels than other aircraft types, and all four product types differ significantly in terms of development time.

DISCUSSION AND CONCLUSION

Our findings suggest that initial firm and project characteristics significantly influence the decision to cooperate or produce alone. All in all, cooperation is selected when the conditions for the economic success of the project are unfavorable, i.e. when the focal firm is in a weaker position and the project is riskier and more difficult to implement profitably. Those factors that drive firms to cooperate are thus likely to have a negative impact on project performance. In other words, firms choose to cooperate when they are faced with the need to offset adverse conditions. Our results on the impact of cooperation on project sales demonstrate that scale alliances make it more likely to achieve the project MES by enhancing sales relative to what the focal firm could achieve on its own. These results do not demonstrate, however, that, on average, collaborative projects achieve greater sales than single-firm projects. Indeed, running model 2 without accounting for endogeneity (i.e. assuming that cooperation is randomly selected across firms and projects) results in a non-significant impact of cooperation on project sales.

Our results also show that even when those factors that induce cooperation are present, the impact of collaboration on performance is not unambiguously positive. Indeed, projects developed through scale alliances tend to incur higher upfront costs. Assuming the decision to cooperate is made rationally, one can infer that, for those firms and projects where cooperation is preferred over autonomous production, decision-makers expect the benefits of cooperation to outweigh its costs.

This view of inter-firm cooperation is probably specific to scale alliances, i.e. alliances through which partners pool similar resources to collectively strengthen their position relative to stronger competitors. The logic of such scale alliances is very different from that of link alliances. In link alliances, partner firms combine their complementary strengths to exploit synergies and expand their business. Past research has shown that such link alliances are formed by competitors that possess strong resources in a particular area and seek to better leverage these strong resources by combining them with complementary assets held by partners. Our findings suggest that scale alliances in contrast are formed by weak firms that seek to pool their limited resources with partners that exhibit similar weaknesses. In this respect, link alliances appear to be primarily offensive in nature while our results strongly suggest that scale alliances are essentially defensive moves adopted by weaker or vulnerable competitors. In terms of performance, link alliances create value by making it possible for firms to exploit new opportunities beyond their current business scope, while scale alliances make it possible to compensate for competitive deficiencies.

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Table 1: Statistical analysis

	(1)	(2)	(3)
	COOP.	**PROJECT SALES**	**DEVELOPMENT TIME**
FIRM SIZE (+)	-0.084*		0.078
FIRM SIZE		-0.019	
COOPERATIVE COMPETENCE (+)	0.791**		
DOMAIN-SPECIFIC KNOW-HOW (+)	0.006		-0.154
DOMAIN-SPECIFIC KNOW-HOW		0.227**	
MARKET SIZE (+)	-0.140		
MARKET SIZE		0.189***	
YEAR (+)	0.047***		0.022
YEAR		-0.027***	
NUMBER OF COMPETITORS (+)	-0.019		
NUMBER OF COMPETITORS		-0.008	
STATE OWNED (+)	0.629**		
PROJECT SCALE	0.451**	-0.206**	0.143
GDP GROWTH (+)	-5.933		
MILITARY	-0.078	-0.338*	1.346***
FIGHTER (VS. GRAND MEAN)	-0.044	0.166	0.000
HELICOPTER (VS. GRAND MEAN)	0.648*	-0.057	1.394**
JET (VS. GRAND MEAN)	-0.503	0.149	-0.848**
TURBOPROP (VS. GRAND MEAN)	-0.101	-0.257**	-0.546***
COOPERATION		**0.635****	**1.976*****
MILLS RATIO		-0.375**	-0.796*
CONSTANT	-95.038***	54.621***	-41.674
Observations	225 (56)	225 (56)	225 (56)
R-squared	0.290	0.140	0.308

Robust p values in parentheses - standard errors adjusted for clustering on firm ID
 + Estimated when development begun (one year before the prototype first flight)
* Significant at 10%; ** significant at 5%; *** significant at 1%
Two-tail tests