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Do Experience Effects Vary Across Governance Modes? Evidence from New Product Introduction in the Global Aircraft Industry, 1948–2000

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We examine the potential for improved performance through experiential learning of three modes of new product introduction: internal development, joint development, and licensing. Drawing on the organizational learning literature, we argue that the speed of experiential learning—that is to say, the marginal performance benefit of experience—is higher when firms carry out activities that allow for a clearer understanding of cause–effect relationships, whereas experiential benefits plateau at higher levels of experience when firms are in activities involving higher levels of related task variation. We thus predict that both the speed of learning and the experience threshold are higher in internal development than they are in licensing; the speed of learning and experience threshold in joint development fall in between. This means that the potential for improved performance through experiential learning should be greatest with internal development, moderate with joint development, and rather limited in licensing. We study the performance of 278 new aircraft introductions undertaken by 94 firms between 1948 and 2000 and find support for our hypotheses.

Key words: experience; experiential learning; speed of experiential learning; experience threshold; competency traps; cause–effect relationships; related task variation; technological complexity; new product introduction; internal development; joint development; licensing; aircraft industry
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Introduction

Numerous organizational scholars have theorized over the last 50 years that experience is an important factor in firm performance (Cyert and March 1963). Experienced firms can draw valid inferences from past activities and, based on what they have learned, make and implement decisions more rapidly and become more efficient (see Argote and Miron-Spektor 2011 for a review). However, some research has found that additional experience can quickly yield redundant knowledge (Levitt and March 1988). Hence, although experience generally improves performance, this process is subject to decreasing marginal returns that eventually reach a plateau (Argote 1999). Thus, there are two factors that drive the potential for improved performance through experiential learning: (a) the *speed of learning*, defined as the magnitude of the marginal performance benefits of experience, and (b) the *experience threshold*, the level of experience at which those benefits plateau.

Our objective is to examine the potential for improved performance through experiential learning[1] of various methods of bringing a new product to market by comparing their speeds of learning and experience thresholds. Drawing on the literature on the boundary conditions for experiential learning (Levitt and March 1988, Schilling et al. 2003), we argue that (1) the speed of learning is higher when firms carry out activities that allow them to develop ex post a clearer understanding of cause–effect relationships and (2) the experience threshold is higher when firms carry out activities involving tasks that are sufficiently related to provide learning synergies between them. The tasks on which we focus when considering the potential for improvement through experiential learning are those that must be accomplished to bring a product to market. We look at who carries them out in three governance modes that firms commonly use to introduce new products (White 2000): internal development, joint development, and licensing. We predict that the experiential benefits to a firm that goes back to using the same new product introduction (NPI) mode as used in a previous NPI will vary depending on whether the firm uses internal development, joint development, or licensing. We see greater awareness of cause–effect relationships as well as a higher level of related task variation in internal development than in joint development and, in turn, a greater awareness and higher level in joint development than in licensing. We predict that when a firm again uses internal development, there will be a higher speed of learning and a higher experience threshold than is the case when reusing licensing. Moreover, we predict that the speed of learning and the experience threshold fall between the two when the firm elects to again use joint development. Hence the potential for

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improvement is greatest with subsequent use of internal development, moderate with joint development, and somewhat limited with licensing. We find general support for this in examining the performance of 278 new aircraft introductions undertaken between 1948 and 2000 by 94 incumbent firms, while recognizing that resource-poor and resource-rich firms favor different governance modes by controlling for the endogeneity of NPI-mode choice (Shaver 1998).

First, we contribute to the organizational learning literature by shedding light on two important aspects of experiential learning: the speed of learning and the experience threshold. We show that the speed of learning is driven by firm awareness of cause–effect relationships, whereas the experience threshold depends on the activity level of related task variation. Second, we extend the stream of the corporate strategy literature that examines experience effects of different governance modes. This research stream, by and large, posits that the more a firm uses the same types of expansion modes, the better it becomes at them. However, most past work suffers from a key limitation: it focuses only on one mode at a time (see Barkema and Schijven 2008 for a review). To our knowledge, there is no previous study that tests whether there is greater potential for improvement through experiential learning in one expansion mode rather than another.

Theory and Hypotheses

Experience Effects in NPI Modes

We focus on three governance modes commonly used by firms to introduce new products: internal development, joint development, and licensing (White 2000). When using *internal development*, a firm takes on technology development, prototype design, tooling development, product manufacturing, and sales on its own (Brown and Eisenhardt 1995). In a *joint development*, more than one firm shares these tasks (Gerwin and Ferris 2004). In the interest of simplicity, we consider joint developments using a modular product architecture (Schilling 2000, Brusoni and Prencipe 2001, Hobday et al. 2005); that is, each partner is responsible for the development and manufacture of specific subsystems that are then later integrated, whereas sales are divided among the partners, usually on a geographical basis (Gerwin and Ferris 2004). While this architecture allows each partner to work independently, it also provides few opportunities for interfirm learning (Sobrero and Roberts 2001). Finally, when a firm chooses *licensing*, it contractually acquires the right to manufacture and sell a product that was initially produced by another firm (Atuahene-Gima 1993, Schilling and Steensma 2002). In general, licensors carry out the tasks related to the conception of the product and pass on to the licensee tooling and manufacturing techniques they have developed. However, a licensor may have reasons to limit what is revealed to a licensee (Teece 1986); moreover, tacitness and organizational embeddedness will limit the ability of the licensee to absorb knowledge from the licensor (Mowery et al. 1996). We discuss the three NPI modes in more detail when we describe our empirical setting.

The organizational learning literature (Levitt and March 1988, Argote 1999) offers important insights into how a firm may benefit from launching a new product using the same NPI mode it has used in the past (hereafter referred to as *same-NPI-mode experience*). This literature posits that repetition makes it possible to draw valid inferences about the factors driving the efficiency of processes. Experienced firms can avoid or alter processes that have proven unsuccessful in the past, thereby achieving specific goals more rapidly and more efficiently and, ultimately, improving performance. At the same time, success in managing a particular activity generally leads firms to rely on the same technical decisions and management procedures, and this leads to entrenched practices (Levinthal and March 1993). Thus, although firms initially benefit from routinization (Cyert and March 1963), it limits investigation into new ways of doing things by creating competency traps (Levitt and March 1988, Leonard-Barton 1992), and repeatedly using the same procedures quickly yields only redundant knowledge about how to perform activities (Levinthal and March 1993). High levels of experience may sometimes harm performance when a firm, which has fallen into a competency trap, cannot timely adapt to changes in the technological or competitive environment (Miller 1990, Ingram and Baum 1997, Ahuja and Lampert 2001).

Several organizational learning scholars have drawn on this view to explain the curvilinear experience–performance relationship observed in a variety of manufacturing processes (see Argote 1999 for a review) and corporate development activities such as international expansions (Delios 2011) and breakthrough inventions (Ahuja and Lampert 2001). Similarly, other scholars have argued that going back to the same governance mode in successive expansions yields asymptotical returns. However, strength of empirical support greatly varies. Luo and Peng (1999) found a curvilinear experience–performance relationship in internal growth. Studies of experience effects in collaboration have yielded somewhat mixed empirical results, some showing decreasing marginal returns (Hoang and Rothaermel 2005), a positive and linear effect (Barkema et al. 1997), or even constant benefits (Sampson 2005), depending on the industry, purpose, or type of alliance studied and on whether general or partner-specific experience is examined. The weakest evidence of decreasing marginal experience benefits is found in the acquisition literature (Hayward 2002, Zollo and Singh 2004), with several

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studies finding a U-shaped experience–performance relationship (Haleblian and Finkelstein 1999, Finkelstein and Haleblian 2002, Nadolska and Barkema 2007), suggesting that limited experience leads firms to make inappropriate generalizations.

First, the existence of benefits to organizational experience suggests that a firm launching a new product may well derive valuable benefits from accumulated same-NPI-mode experience. A firm that chooses internal development to bring a new product to market must perform on its own all the NPI-related tasks. In its next internal development, it may be able to apply its experience with performing those tasks, enhancing their efficiency, and improving its NPI performance (Holmqvist 2004, Nerkar and Roberts 2004, Macher and Boerner 2006, Eggers 2012). In the case of a joint development, each partner is responsible for the conception and manufacture of specific subsystems and, after integration of the subsystems, for selling the final product on specific markets. When a firm enters into another joint development, it can apply its previous experience in carrying out the same kinds of tasks. The benefits will be even higher if the firm is entrusted with the same subsystems and markets (Zollo et al. 2002, Hoang and Rothaermel 2005, Sampson 2005). Moreover, joint development experience may help a firm in negotiating collaborative agreements, organizing work sharing, and handling the relationship within the partnership (Anand and Khanna 2000, Kale et al. 2002). Finally, when a firm that has introduced a licensed product introduces another one, it may enjoy benefits stemming from its previous manufacturing and sales experience. Experience with negotiating a licensing contract may also provide the skills needed to negotiate and enforce future contracts (Mayer and Argyres 2004, Vanneste and Puranam 2010).

Second, we expect the marginal performance benefits from same-NPI-mode experience to decrease and eventually to level off. A firm that has limited experience with an NPI mode, be it internal development, joint development, or licensing, is likely to have somewhat limited knowledge about the factors driving the efficiency of the various in-house tasks involved. Valuable lessons might be derived from additional experience with the same mode, thus improving NPI performance. However, as experience with that mode accumulates, ways of performing tasks become entrenched, and other ways of accomplishing them are not considered. However, each incremental experience yields fewer lessons. Thus, beyond a certain level of experience, any additional same-NPI-mode experience is unlikely to result in higher NPI performance. In sum, whereas firms can benefit from accumulated same-NPI-mode experience, there are decreasing marginal experience returns, as shown in the following hypothesis.

Hypothesis 1 (H1). *Same-NPI-mode experience yields positive but diminishing marginal returns in internal development* (A), *joint development* (B), *and licensing* (C).

Relative Speed of Experiential Learning of Different NPI Modes

Is the speed of experiential learning—that is to say, the marginal performance benefit of experience—the same regardless of whether the NPI mode is internal development, joint development, or licensing? To answer this question, we draw on a boundary condition for the benefits of experience identified by the organizational learning literature. Lippman and Rumelt (1982) and Rumelt (1984) argued that when a firm is unable to measure the marginal performance impact of the productive processes involved in a given activity, or even come up with an unambiguous list of the processes involved, it will be unable to determine the activity's causal drivers of performance. In essence, if the link between processes and outcomes cannot be established, then experience cannot be translated into increased performance (Lounamaa and March 1987, Levitt and March 1988). It follows then that when a firm carries out an activity that does allow for a clear understanding of cause–effect relationships, it has a better chance of making accurate inferences about the efficiency of the processes used and can draw on them to refine its actions and achieve increased performance subsequently in similar endeavors. This suggests that the speed of experiential learning is highest with the mode that provides the clearest understanding of the causal links between processes the firm performs in-house and outcomes achieved. As we explain below, the speed of learning from same-NPI-mode experience is thus higher in internal development than in licensing, with the speed of learning in joint development falling between the two.

Typically, an internal development means that a firm breaks down product expansion into subproblems that it then solves on its own (see Eisenhardt and Tabrizi 1995), although this may be difficult and time consuming. In the end, though, the firm is aware of the range of challenges and, ideally, the appropriate means of addressing them. Such awareness helps a firm determine which factors make what marginal contributions to overall product performance, leading it to draw valid cause–effect inferences about factors driving the efficiency of the various processes used. Specifically, it may derive accurate lessons from the way it handled product conception, manufacturing, and sales. When undertaking a subsequent internal development, it can build on and refine the efficiency of its actions, ultimately enhancing NPI performance. In the case of licensing, overall performance is a result of a combination of tasks performed by both parties (the licensor and the licensee). Furthermore, because the product is ready-made, processes used by the licensor are not necessarily known by the licensee (Schilling and Steensma 2002). This makes cause–effect relationships difficult to identify. Indeed, it may not

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be possible for licensees to relate, even ex post, overall performance to processes used by either party and, hence, to draw valid performance implications even from the manufacturing and sales tasks that they themselves have performed (Mulotte et al. 2013). The licensees are thus often unable to make valid inferences about factors that drive the efficiency of the tasks that licensing requires. Hence, former licensees who are in new licensing agreements often gain little benefit from experience. The speed of learning from same-NPI-mode experience is thus likely to be lower in licensing than in internal development.

The joint development mode falls between the internal development and licensing ones in terms of awareness of cause–effect relationships and ensuing speed of experiential learning. In a joint development, a firm normally takes on responsibility for the conception and manufacture of specific subsystems of a modular product system. As we know from the literature on modular product architecture (Brusoni and Prencipe 2001, Hobday et al. 2005), to ensure a good fit, each firm sharing in the development of a modular product system needs to have a minimum level of understanding of partner output. This is especially true when the product is technologically complex (Singh 1997). Although it is clearly in the interest of the parties involved in a joint development to exchange information, the systemic nature of overall product performance is likely to harm the ability of each party to accurately determine the marginal performance implications of the tasks performed in-house. Thus, it is unlikely that the awareness of the factors driving the efficiency of the tasks performed will reach in joint development the level attainable in producing in-house all of the subsystems of a product, as is the case in internal development. Nonetheless, one would expect a firm to be able to more accurately determine causal links between actions and outcomes when bringing a jointly developed project to market than when introducing a ready-made product through licensing. However, we argued that the awareness of a cause–effect relationship is a pivotal driver of the speed of learning in that it determines the ability of firms to derive valuable inferences about factors driving the efficiency of the various processes used. We thus expect the speed of learning to be higher when a firm handles alone the full range of tasks associated with bringing a product to market, as is the case with an internal development, than when it works with other firms in a joint development—and even more so than in licensing. Hence, we hypothesize the following.

Hypothesis 2A (H2A). *The speed of experiential learning is higher in internal development than in either joint development or licensing.*

Hypothesis 2B (H2B). *The speed of experiential learning is higher in joint development than in licensing.*

Experience Threshold in Different NPI Modes

We know from the traditional experiential learning literature that experience delivers decreasing marginal returns until eventually a plateau is reached. Does the level of experience at which that might happen differ across modes?[2]

Drawing on Levitt and March (1988), Argote and Todorova (2007) contended that a firm benefits from experience with an activity as long as it can extract meaningful new knowledge from the tasks it performs. It follows that the level of experience at which benefits for it level off hinges on the maximum number of potential opportunities for experiential learning offered by the activity. Let us consider an activity A, which consists of tasks that are a strict subset of the tasks that go into an activity B. All else being equal, activity A is likely to offer fewer opportunities to extract meaningful new knowledge and, thus, fewer potential opportunities for experiential learning than activity B. This means that a firm gathering experience while involved in activity A is likely to exhaust potential experience benefits more quickly than if gathering experience with activity B.

Research on the impact of the levels of task variation on learning outcomes allows us to go a step further. Schilling et al. (2003) showed that some degree of variation in the tasks of a given activity can afford opportunities for experiential learning arising from task synergy that do not exist when tasks are either too homogeneous or too heterogeneous (see also Narayanan et al. 2009). They wrote that "because the tasks are related, the learners develop a more abstract and complex knowledge structure that pertains to both types of tasks.… [T]he variation stimulates the learners to develop a deeper understanding of the tasks than they would if they had performed only one type of task over time" (Schilling et al. 2003, p. 52). It follows that a firm that gathers experience with an activity involving somewhat different but related tasks may not only gain specific knowledge about how to perform each of the tasks but may also benefit from the learning synergies between them, whereas all else being equal, there will be fewer potential opportunities for experiential learning if the activity involves only unrelated tasks. Experience benefits are therefore likely to level off at higher levels of experience when firms carry out activities involving higher levels of "related task variation" (Schilling et al. 2003, p. 40), because the presence of learning synergies between tasks provides more learning opportunities.[3]

These arguments provide important insights into the experience threshold of internal development, joint development, and licensing. A firm electing to bring a product to market on its own by internal development performs in-house technology development, prototype design, tooling development, manufacturing, and sales. According to the NPI literature, even though these tasks are quite different, they are nonetheless fundamentally

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related (Eisenhardt and Tabrizi 1995, Singh 1997; see also Brown and Eisenhardt 1995 for a review), and this means that there are potentially learning synergies. Licensees do not enjoy the same synergies as internal developers because they only perform a subset of the tasks performed by the latter. For instance, a firm choosing internal development may use its knowledge of the materials used in the product to improve the manufacturing process by customizing the tooling and machinery to the materials' characteristics. This potential benefit is by nature inaccessible to licensees. All else being equal, a licensee has thus fewer potential opportunities for experiential learning and so will exhaust the performance benefits of experience at a lower level of same-NPI-mode experience than an internal developer.

Again, joint development falls between the other two modes. Each partner is responsible for the conception and manufacture of only a subset of the complete array of product subsystems. Each partner thus undertakes the full range of new product introduction tasks. So although the potential opportunities for experiential learning are undoubtedly more numerous with internal development, the learning opportunities of a licensee will be much fewer because a licensee will only carry out manufacturing tasks. Hence, all else being equal, the performance benefits of same-NPI-mode experience garnered through internal development will plateau at a higher level than through joint development, and in turn, same-NPI-mode experience garnered through joint development will plateau at a higher level than through licensing, as shown in the following hypotheses.

Hypothesis 3A (H3A). *Experience benefits plateau at a higher level of same-NPI-mode experience in internal development than in either joint development or licensing.*

Hypothesis 3B (H3B). *Experience benefits plateau at a higher level of same-NPI-mode experience in joint development than in licensing.*

Reinforcing Impact of Technological Complexity on the Speed of Experiential Learning

As we said earlier, a clear understanding of cause–effect relationships is pivotal in realizing the speed of experiential learning. Are there situations where firms might enjoy a higher speed of learning?[4] Ahuja and Lampert (2001, p. 527) wrote that exposure to novel technologies is often conducive to organizational performance because "the novelties that new technologies draw attention to spark renewed examination of causes and effects, improve understanding and insight, and lead to breakthrough inventions." In the same vein, we reason that bringing to market through internal development, joint development, or licensing a new product of a high level of technological complexity allows a firm to enhance its awareness of the process cause–effect relationships involved in the chosen NPI mode. The speed of learning from same-NPI-mode experience will thus be increased.

The conceptualization and manufacture of technologically complex products often pose fundamental problems that call for a higher level of cognitive effort. However, firms generally attempt to address problems by tailoring existing ways of doing things rather than devising completely de novo solutions (Cyert and March 1963). Thus, especially when dealing with complex problems, firms tend to reexamine previous experience, applying what they can to the activity at hand, and the additional cognitive effort required by complex problems can provide valuable benefits. Specifically, it may allow firms to derive additional lessons about what worked, what did not, and why that might otherwise go unnoticed (Zollo and Winter 2002). As Zollo and Singh (2004, p. 1252) explained, "At increasing levels of complexity, the benefits of explicitly extracting lessons learned from previous experiences appear to exceed the costs connected to codification activities (e.g., investment in time, effort, and managerial attention)." It follows that a firm that brings to market a technologically complex product will meticulously revisit past same-NPI-mode experience, be it internal development, joint development, or licensing. In doing so, it often gains meaningful new knowledge about cause–effect relationships (Ahuja and Lampert 2001, Zollo and Winter 2002, Zollo and Singh 2004). We have hypothesized (in H2) that a greater awareness of cause–effect relationships increases the speed of experiential learning, in that it allows a firm to derive from its experience additional lessons about the factors driving the efficiency of the tasks required. We thus expect introducing new products that are technologically complex to enhance the speed of learning from same-NPI-mode experience, as shown in the following hypothesis.

Hypothesis 4 (H4). *The speed of learning from same-NPI-mode experience is positively related to the levels of technological complexity of the focal product.*

Empirical Analysis

Sample and Sources

The empirical context of this study is the global aircraft industry between 1944 and 2000.[5] Our sample includes 278 new aircraft introductions undertaken by 94 firms, all of which have had at least one previous product introduction experience in the relevant area of business.[6] There are 126 introductions of fighters, 51 introductions of helicopters, 42 introductions of jets (military and civil, passenger and cargo aircraft, as well as private business aircraft), and 59 introductions of turboprops. The number of introductions of the same type per firm ranges from 1 to 12, with a mean of 2.96. Of the firms in our sample, only 29% appear once, 28% twice,

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14% three times, 12% four times, and 18% five times or more. We drew our data from the Aerospace Systems Group Library (Forecast International/DMS 2000), a database that consists of individual reports on each aircraft project commercialized since World War II. The reports contain information on the aircraft manufacturers themselves (e.g., location and major shareholders) and give project details including major milestones (e.g., the dates of the maiden flight and initial deliveries), technical characteristics (e.g., maximum payload, range, and speed), and estimated unit price and production up to the year 2000. They also list major suppliers and customers and, if applicable, the firms sharing the prime contractor role, task sharing among prime contractors, and finally, the licensees.

NPI Modes in the Aircraft Industry

The Aerospace Systems Group Library (Forecast International/DMS 2000) provides the NPI modes used by manufacturers for each aircraft undertaken. Each report also lists under the "Contractor" heading the prime contractor or contractors of a project. When a project has been licensed to other manufacturers, the name of the licensee or licensees appears under the "Licensee" heading. We classified as internal developments all aircraft listing a single firm under the Contractor heading (Forecast International/DMS 2000). For example, we coded as internal developments all jet airliners introduced by Boeing. Note that a firm choosing internal development may outsource the manufacture of several subsystems to first-tier suppliers, possibly through risk-sharing agreements, but it is the prime contractor's engineering processes that are used.[7] For example, Boeing outsourced the production of all of the moving parts of the B-767 wing to the Italian firm Alenia (Forecast International/DMS 2000), but it remained nonetheless responsible for the performance of all parts of the aircraft (Hobday et al. 2005). Hence, we credit Boeing alone for developing the technologies and capabilities required for the conception of all of the subsystems as well as the tooling and techniques required for the manufacture of the B-767.

When at least two firms are listed under the Contractor heading, we classified the aircraft as a joint development. For example, we coded as a joint development the ATR 42/72 turboprop regional airliner because both the French firm Aerospatiale and the Italian firm Alenia are listed. We also classified as a joint development the V-22 Osprey rotorcraft because it was jointly developed by the U.S. firms Bell and Boeing. In these cases, as is generally true in other joint developments undertaken in the aircraft industry, each partner carried out the conception and production of several subsystems that were later integrated. For the ATR 42/72, Alenia produced the aircraft fuselage and tail sections, and Aerospatiale produced the wings and the nacelles. For the V-22, Boeing produced the fuselage, empennage, and wing fairings; Bell was responsible for the nacelles and the entire drive train. All of the partners involved in a joint development list the project in their product portfolios, and we credit each of them equally.

We coded as licensing when a firm acquired for a lump sum and royalties the right to manufacture and commercialize an aircraft that was initially developed by another manufacturer (Atuahene-Gima 1993, Schilling and Steensma 2002). In such cases, the name of the licensee or licensees appears under the Licensee heading in the Forecast International/DMS report. For example, we classified as licensing the introduction of the helicopter KV-107 undertaken by Kawasaki (Japan) as it was a license-built version of the helicopter H-46 initially produced by Boeing (the United States). Aircraft licensees generally do not perform tasks related to product conception but benefit from the manufacturing and tooling techniques developed by the licensor. Moreover, aircraft licensing agreements usually include contractual clauses enforcing specific territorial limitations.

Overall, the data include 169 introductions of internally developed aircraft, 56 introductions of jointly developed aircraft, and 53 introductions of licensed aircraft. We verified the NPI mode of each aircraft in the sample with *Jane's All the World's Aircraft* publications spanning 1944–2000.

Research Design

We adopted the research design used by Anand and Khanna (2000) to compare experience effects across varying types of joint ventures and that used by Sampson (2005) to compare equity and nonequity alliances. We divided our sample of 278 aircraft introductions according to the three NPI modes used; then regressed the performance of the aircraft against the firm's experience with internal development, joint development, or licensing; and compared the regression estimates of the experience variable across the models while accounting for the different sample sizes. Next, we entered in the models the interaction between the projects' technological complexity and the experience variable.

Dependent Variable

Our dependent variable is NPI performance, which we assessed by the cumulative *unit sales* of each aircraft (Forecast International/DMS 2000). Strictly speaking, the learning curve applies to costs rather than sales. Unfortunately, cost information is generally proprietary, in the case of both military aircraft and, to a lesser extent, commercial aircraft. Nonetheless, we believe that reliable estimates of experience benefits can be obtained from historical sales data. We expected firms with prior same-NPI-mode experience to carry out tasks more efficiently, thereby achieving cost economies. However, in

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industries with price-sensitive demand, the price-cost margins remain more or less constant as experiential learning proceeds (Lieberman 1984). The underlying logic is that firms lower their prices as they achieve cost economies to deter new entrants and increase sales volumes. This strategy allows firms to achieve scale economies and to go down the learning curve by permitting a rapid increase in cumulative output (Ghemawat 1985). Several studies of experience benefits have drawn on this notion to compensate for a lack of cost data. For instance, Lieberman (1984) argued that output price was a satisfactory surrogate for learning outcomes in the chemical industry. In a similar vein, McGee et al. (1995) examined experience effects in high-tech industries by analyzing whether marketing, production, and technical experiences affected sales growth. More recently, Nerkar and Roberts (2004) studied experience effects in the pharmaceutical industry by examining the impact of technological and product market experience on drug sales.

We expected aircraft manufacturers with same-NPI-mode experience to introduce products that better meet market demand in terms of technical specifications and/or price, and thus ultimately to achieve higher sales volumes (Zirger and Maidique 1990). Moreover, in the aircraft industry, where products are usually manufactured after orders are received, unit sales have long been the primary source of profits because of the high level of fixed costs required to initiate a project (Wright 1936). Sales volume is therefore a key measure of the performance of any fighter, helicopter, jet, or turboprop. Capturing learning outcomes by sales volumes is thus appropriate for our study of the benefits of accumulated same-NPI-mode experience.

Sixty-four of the aircraft included in our sample were still being produced in 2000. To avoid midprogram bias, we estimated the unit sales for these projects based on the production schedule of those projects whose production was terminated in 2000. Based on the reports in *Jane's All the World's Aircraft*, we found that, on average, aircraft projects reached 6% of their total production by the end of the 1st year, 13% by the end of the 2nd, 38% by the end of the 5th, 68% by the end of the 10th, and 86% by the end of the 15th year, with production falling after that. Using these trends, we were able to estimate the cumulative unit sales for the 64 aircraft projects still in production in 2000. Overall, cumulative unit sales range from 3 to 8,584, with a mean of 575. As a robustness check, we ran the models without the 64 cases for which total production is estimated rather than observed; the results remained substantially unchanged. The results were also robust to the removal of outliers.

We tested our predictions with linear regressions. However, there are multiple observations per firm, and hence these are not completely independent. To address this issue, we clustered our data by firms; there were 94 clusters in all. Such an approach provides a robust estimator when observations are assumed to be independent across firms but not within them. We also clustered the data by countries to address the impact of national policies on aircraft sales; this totaled 21 clusters.

Independent Variable

Our main independent variable is *same-NPI-mode experience*, which we captured by counting the number of times a firm has used a mode since its entry into a particular area of business (fighter, helicopter, jet, or turboprop). This measure corresponds to the traditional measure of experience based on cumulative output (Argote 1999). In our sample of 278 NPIs, 18% were undertaken by firms with no prior experience with the focal mode, 35% by firms with one prior experience, 21% by firms with two, 12% by firms with three, 7% by firms with four, and 7% by firms with five or more. Same-NPI-mode experience ranges from 0 to 9, with an average of 1.81. In robustness checks, we used several other measurements of same-NPI-mode experience, which we describe in more detail below.

Control Variables

We use several variables to control for alternative explanations. For instance, larger firms may enjoy greater sales regardless of the new aircraft. Thus, we included in the models a revenue proxy by area of business (fighter, helicopter, jet, or turboprop). First, we estimated the average annual production for a given aircraft by dividing the number of units sold over the entire life cycle by the number of years of production.[8] We then determined average annual sales by multiplying average annual production by price. We obtained our revenue proxy, by area of business and by year, by summing the average annual sales of all the aircraft that the firm manufactured that year in a given area of business. The *business unit size* variable is the logarithm of this figure in the year prior to each NPI. We estimated aircraft sales figures in this way because it was impossible to obtain the actual data for the entire 52-year period in all 21 countries.[9] We also added a dummy variable, *state-owned firm*, which is equal to 1 if the focal firm was owned by the state because we expected them to have privileged access to government contracts and thus achieve greater sales.

Sales volumes are also likely to be influenced by the size of the market to which a firm has privileged access. The *home market size* variable captures the logarithm of the gross domestic product (GDP)[10] of the focal firm's home country (Maddison 2003). We also introduce the date on which the first delivery of each project took place. This *NPI year* variable takes into account the steady decline in aircraft sales over the last 60 years. A *number of competitors* variable captures the number

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of firms that competed in the area of business in the year prior to each focal introduction. A large number of competitors may increase competitive pressure, thus reducing sales.

The technological complexity of an aircraft is likely to eventually affect sales volumes. As is common in studies of the aircraft industry (e.g., Frenken and Leydesdorff 2000, Garrette et al. 2009), we estimated an aircraft's *technological complexity* by the logarithm of its maximum speed, range, and takeoff weight. We also expected subfields of the industry to be of different sizes; thus we introduced a categorical variable that captures the product type (i.e., *fighter*, *helicopter* (omitted category), *jet*, or *turboprop*). We included a dummy variable, *military design*, equal to 1 if the focal aircraft were designed for military use, because sales of military aircraft are often restricted to specific countries for political reasons. In addition, commercial aircraft are less sensitive to functional obsolescence than military ones and can thus be produced over longer periods of time. Finally, high development costs often have a strong negative impact on sales volumes (Schoonhoven et al. 1990). We added development time as a proxy for development costs (Macher and Boerner 2006, Hoang and Rothaermel 2010). The *development time* variable is the number of years between the first flight of a prototype and the date of delivery of a production aircraft. For licensed aircraft, we set *development time* at 0 because the products are ready-made.[11]

Because NPI-mode choices may be determined by unobserved characteristics, we used a first-stage model to create a selection term that corrects for NPI-mode endogeneity in the performance models (Shaver 1998). Thus, we used an ordered probit to estimate the likelihood that a firm will choose to bring a product to market using internal development (coded 1), joint development (coded 2), or licensing (coded 3). The selection model includes all of the variables of the performance model with the exception of *development time*, which is, of course, unknown when the NPI mode is chosen.[12] We entered into the selection model an instrument that captures the economic climate in the firm's home country at the time of the NPI-mode decision. We estimated this by the average GDP growth of the firm's home country in the three years prior to each NPI (Maddison 2003). Park et al. (2002) found a positive impact of market growth on the use of external governance modes. However, the economic climate at the time of NPI-mode choice is unlikely to influence aircraft cumulative unit sales since they are usually spread out over several decades.[13] The selection model returned the inverse Mills ratio, which we entered into the performance models to correct for self-selection (Shaver 1998). We describe below additional analyses using other specifications to control for firm heterogeneity.

Results

In Table 1, we provide descriptive statistics and a correlation matrix. Although several variables exhibit significant levels of correlation, the overall pattern does not reveal a tendency toward multicollinearity among the measures. Indeed, the individual VIF measures are inferior to the generally accepted threshold of 10 with a mean of 1.38.

Table 2 reports the results of the multivariate analyses. Model 1 is the first stage of the model and analyzes the factors affecting NPI-mode decisions. The second-stage models 2a and 2b analyze the factors affecting unit sales across the full sample of 278 observations while accounting for the endogeneity of the NPI-mode choice. We determined the effect of each NPI mode on unit sales by capturing whether internal development, joint development (the omitted category), or licensing is used for the focal NPI. The second-stage models 3a and 3b, 4a and 4b, and 5a and 5b are restricted to internal development, joint development, and licensing, respectively. We entered in Models 2a, 3a, 4a, and 5a the main term of same-NPI-mode experience and in Models 2b, 3b, 4b, and 5b both the main and the squared terms for this variable.

The three models per NPI mode, which only include the main term for *same-NPI-mode experience* (Models 3a, 4a, and 5a), indicate that same-NPI-mode experience increases sales volumes for both internal development ($\beta = 0.206$, $p < 0.01$) and joint development ($\beta = 0.092$, $p < 0.05$) but not for licensing. When including both the main and squared terms for *same-NPI-mode experience* (Models 3b, 4b, and 5b), the main term is significant and positive and the squared term is significant and negative for both internal development ($\beta = 0.409$, $p < 0.01$ and $\beta = -0.032$, $p < 0.01$) and joint development ($\beta = 0.368$, $p < 0.05$ and $\beta = -0.107$, $p < 0.10$). Both coefficients are insignificant for licensing. It follows that same-NPI-mode experience is related to NPI performance in a curvilinear manner for both internal and joint development, but not for licensing. Thus H1a and H1b are supported but H1c is not.

We then examined whether the marginal performance benefits of experience differ between internal development and joint development. To do so, we used the suest command of the statistical package Stata 11. This command uses seemingly unrelated estimation to combine the results of different regression models into one parameter vector (StataCorp 2009). Hence, we can use this command to assess differences in the size of estimates of the same variable produced by different samples while controlling for different sample sizes. We thus combined Models 3a and 4a with the suest command and performed a Wald test on the regression coefficients for *same-NPI-mode experience*. This test significantly rejected the hypothesis that the marginal returns from same-NPI-mode experience are

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Table 1 Correlation Matrix and Descriptive Statistics ($N = 278$)

ID	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	*Unit sales* ('000)	1																	
2	*Business unit size* (log)	0.220*	1																
3	*State-owned firm*	−0.050	−0.19*	1															
4	*Home market size* (log)	0.210*	0.30*	−0.30*	1														
5	*NPI year*	−0.120	−0.22*	0.23*	0.31*	1													
6	*Number of competitors*	−0.180*	0.07	0.03	−0.22*	−0.05	1												
7	*Fighter*	−0.030	0.17*	−0.11	−0.30*	−0.40*	0.49*	1											
8	*Jet*	0.110	0.02	−0.12*	0.19*	0.17*	−0.44*	−0.38*	1										
9	*Turboprop*	−0.150*	−0.20*	0.05	0.05	0.17*	0.23*	−0.47*	−0.22*	1									
10	*Helicopter*	0.100	−0.02	0.20*	0.16*	0.17*	−0.46*	−0.43*	−0.20*	−0.25*	1								
11	*Military design*	−0.120	0.02	−0.01	−0.23*	−0.31*	0.27*	0.61*	−0.54*	−0.26*	0.00	1							
12	*Economic climate*	0.020	0.01	0.02	−0.22*	−0.41*	0.09	0.09	−0.02	−0.07	−0.01	0.14*	1						
13	*Technological complexity*	−0.010	0.11	−0.26*	0.04	−0.08	0.09	0.30*	0.48*	−0.19*	−0.64*	−0.01	0.02	1					
14	*Development time*	−0.020	0.05	0.05	0.16*	0.30*	−0.02	−0.02	−0.08	−0.11	0.21*	0.12*	−0.14*	−0.05	1				
15	*Internal development*	0.160*	0.30*	−0.32*	0.26*	−0.21*	−0.03	0.01	0.03	0.07	−0.11	−0.04	−0.05	0.01	0.17*	1			
16	*Joint development*	0.010	−0.12	0.21*	0.10	0.40*	−0.09	−0.19*	0.16*	0.00	0.09	−0.17*	−0.11	0.08	0.32*	−0.63*	1		
17	*Licensing*	−0.210*	−0.25*	0.19*	−0.43*	−0.14*	0.13*	0.18*	−0.20*	−0.10	0.05	0.23*	0.17*	−0.10	−0.54*	−0.60*	−0.24*	1	
18	*Same-NPI-mode experience*	0.080	0.32*	−0.18*	0.15*	0.10	0.10	0.21*	0.00	−0.19*	−0.06	0.05	−0.07	0.21*	0.03	0.27*	−0.30*	−0.03	1
	Min	0.003	0	0	−4.09	1,948	1	0	0	0	0	0	−0.05	2.26	0	0	0	0	0
	Mean	0.575	0.26	0.29	−0.18	1,974	21	0.45	0.15	0.21	0.18	0.69	0.04	4.38	2.55	0.61	0.20	0.19	1.81
	Max	8.584	1.76	1	2.07	2,000	34	1	1	1	1	1	0.06	6.60	12.26	1	1	1	9
	SD	0.920	0.33	0.46	1.20	13.80	7.73	0.50	0.36	0.41	0.39	0.46	0.01	1.01	2.30	0.49	0.40	0.39	1.62
	Mean VIF = 1.38	1.160	1.48	1.38	1.70	2.12	1.20	—	—	—	—	1.33	1.23	1.120	1.2	—	—	—	1.26

*$p < 0.05$.

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Table 2 The Performance Impact of Same-NPI-Mode Experience for Internal Development, Joint Development, and Licensing

Variable	Model 1 NPI mode	Model 2a Unit sales	Model 2b Unit sales	Model 3a Unit sales	Model 3b Unit sales	Model 4a Unit sales	Model 4b Unit sales	Model 5a Unit sales	Model 5b Unit sales
Business unit size	−1.428***	0.374*	0.348*	0.030	0.030	0.020	0.287	0.835***	0.871**
	(0.341)	(0.208)	(0.192)	(0.275)	(0.244)	(0.538)	(0.627)	(0.322)	(0.345)
State-owned firm	0.326	0.014	0.009	0.267	0.253	−0.111	−0.189	−0.196**	−0.202**
	(0.219)	(0.155)	(0.156)	(0.280)	(0.284)	(0.174)	(0.226)	(0.085)	(0.086)
Home market size	−0.352**	0.240***	0.234***	0.184*	0.181*	0.166	0.165	0.083	0.085
	(0.141)	(0.077)	(0.070)	(0.107)	(0.097)	(0.175)	(0.192)	(0.057)	(0.054)
NPI year	0.022**	−0.021***	−0.020***	−0.023***	−0.020***	−0.012*	−0.011*	−0.006***	−0.006**
	(0.009)	(0.005)	(0.004)	(0.007)	(0.008)	(0.006)	(0.006)	(0.002)	(0.002)
Number of competitors	0.022	−0.005	−0.006	0.001	−0.006	0.000	−0.001	0.006**	0.005*
	(0.017)	(0.004)	(0.004)	(0.005)	(0.006)	(0.016)	(0.013)	(0.003)	(0.003)
Technological complexity	0.248*	−0.172**	−0.177**	−0.203	−0.217*	−0.017	−0.003	−0.116*	−0.121*
	(0.148)	(0.084)	(0.082)	(0.125)	(0.122)	(0.130)	(0.110)	(0.063)	(0.069)
Fighter vs. helicopter	−0.835*	0.195	0.236	0.098	0.271	−0.241	−0.242	−0.002	0.020
	(0.433)	(0.276)	(0.262)	(0.477)	(0.421)	(0.340)	(0.316)	(0.142)	(0.148)
Jet vs. helicopter[a]	−1.231**	0.326	0.331	0.172	0.222	0.058	−0.011		
	(0.502)	(0.285)	(0.276)	(0.524)	(0.519)	(0.549)	(0.478)		
Turboprop vs. helicopter	−1.235***	0.006	0.040	−0.260	−0.143	−0.468	−0.441	0.075	0.109
	(0.410)	(0.121)	(0.096)	(0.254)	(0.223)	(0.477)	(0.466)	(0.176)	(0.214)
Military design	−0.075	−0.151	−0.140	−0.258**	−0.224	0.299	0.231	−0.152	−0.142
	(0.263)	(0.110)	(0.119)	(0.114)	(0.144)	(0.223)	(0.220)	(0.253)	(0.270)
Economic climate	18.474**								
	(7.474)								
Development time[b]		−0.054***	−0.047***	−0.089***	−0.074***	−0.079***	−0.084**		
		(0.017)	(0.014)	(0.024)	(0.019)	(0.031)	(0.035)		
Internal development vs. joint development		−0.826***	−0.831***						
		(0.239)	(0.229)						
Licensing vs. joint development		−0.364***	−0.411***						
		(0.120)	(0.118)						
Same-NPI-mode exp.		0.158***	0.272***	0.206***	0.409***	0.092**	0.368**	0.015	0.046
		(0.030)	(0.054)	(0.041)	(0.060)	(0.044)	(0.173)	(0.041)	(0.104)
Same-NPI-mode exp.^{2}			−0.019***		−0.032***		−0.112*		−0.007
			(0.005)		(0.007)		(0.064)		(0.019)
Mills ratio		0.510***	0.493***	0.024	0.077	0.513	0.623	0.458*	0.473**
		(0.134)	(0.130)	(0.262)	(0.259)	(0.400)	(0.489)	(0.247)	(0.241)
Constant	44.592**	43.226***	42.029***	47.553***	41.591***	25.028**	23.078*	13.270***	12.872***
	(17.572)	(9.374)	(8.718)	(14.598)	(15.424)	(12.769)	(11.780)	(4.387)	(4.847)
Number of observations	278	278	278	169	169	56	56	53	53
		All NPIs		Only internal development		Only joint development		Only licensing	
Number of businesses	94	94	94	71	71	30	30	27	27
Number of countries	—	21	21	15	15	11	11	17	17
F	78.030***	13.530***	13.550***	8.470***	10.530***	11.600***	11.970***	6.770***	6.140***
R^2	0.177	0.226	0.231	0.196	0.207	0.322	0.360	0.297	0.299

Notes. Robust standard errors appear in parentheses below coefficients. For the first-stage selection model (Model 1), ordered probit regression is clustered by firm. Two-way clustering is not available for ordered probit regressions. *NPI mode* is coded 1 for internal development, 2 for joint development, and 3 for licensing. A positive coefficient indicates that the firm is more likely to license. For the second-stage performance models (Models 2–5), linear regressions are clustered by both firm and country to address firm-level commonalities across business domains and the impact of common national policies. Random-effect regressions yield substantially similar results. Model 2 uses the full sample of 278 observations. Models 3–5 are restricted to internal development, joint development, and licensing, respectively.

[a]Data do not include any licensed jet aircraft.

[b]Development time is set to zero for all licensed products.

*$p < 10\%$; **$p < 5\%$; ***$p < 1\%$ (two-tailed tests).

the same for internal development and joint development ($F = 4.10$, $p = 0.081$). This means that the marginal performance benefits of experience are higher for internal development than in joint development. Thus H2A is supported; H2B is also supported because experience does not increase performance in licensing.

Furthermore, the inflexion point for the experience-performance curve is 6.47 in internal development and 1.64 in joint development. We combined Models 3b and 4b with the suest command and performed a Wald test to assess whether the inflexion points are statistically different. This test significantly rejected the hypothesis

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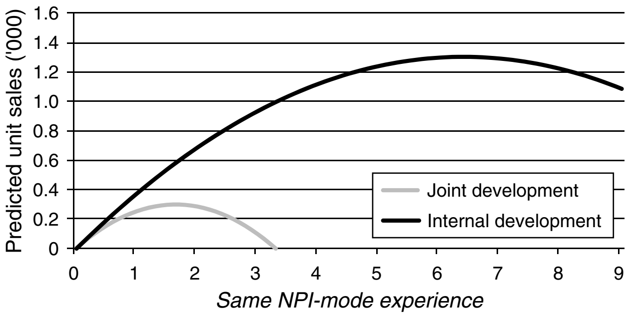
Figure 1 The Performance Impact of Same-NPI-Mode Experience for Internal Development and Joint Development



Note. Using coefficients from Models 3b and 4b.

that they are equal ($F = 4.14, p = 0.044$). Thus, the level of experience at which benefits for it level off is higher in internal development than in joint development, thereby supporting H3A. We also found support for H3B because no experience benefits were found in licensing. It is worth noting that the inflexion points are within the range of possible values of *same-NPI-mode experience*.[14] This implies an inverted U-shaped experience–performance relationship in both internal development and joint development (see Figure 1). This result goes beyond the traditional competency trap perspective according to which the marginal performance benefits of experience decrease until a plateau is reached (Levitt and March 1988, Argote 1999). Yet it supports several studies that have found that high levels of experience may actually harm performance when changes in the technological and competitive environment require swift implementation of new processes (Leonard-Barton 1992, Ingram and Baum 1997). Aircraft manufacturers with previous same-NPI-mode experience generally use the same technical choices and management processes as used in the past. However, the requirements for success have changed considerably in the aircraft industry. Cuts in defense budgets and increased fuel costs are just two environmental factors that have led buyers to be more price conscious. At the same time, firms using novel production techniques such as computer-aided design, outsourcing of design work to risk-sharing suppliers, and implementation of the system integration mode of production have successfully entered the industry (e.g., Bombardier and Embraer). The experience benefits of same-NPI-mode experience are now more than counterbalanced by the cost of sticking with an old production process rather than experimenting with a new one.

We tested our Hypothesis H4 by entering the interaction between *same NPI mode experience* and *technological complexity* for each mode (see Table 3). Models 3c, 4c, and 5c include the interaction between *technological complexity* and the main term of *same-NPI-mode experience*, whereas Models 3d, 4d, and 5d include the interactions between *technological complexity* and both the main and the squared terms for this variable (Barkema and Vermeulen 1998). Models 3c and 3d, 4c and 4d, and 5c and 5d are restricted to internal development, joint development, and licensing, respectively. The interactions are never jointly significant when both the main and squared terms are entered. However, the interaction with the main term of *same-NPI-mode experience* is only significant and positive in Model 3c (for internal development) ($\beta = 0.051$, $p < 0.01$). Thus, in internal development, technological complexity increases the marginal performance benefits of experience, whereas in both joint development and licensing, it does not affect the speed of experiential learning. Thus H4 is supported for internal development only.

To improve our understanding of how aircraft technological complexity affects benefits from internal development experience, we used the regression estimates of Models 3d to plot the relationship between experience and performance for various levels of technological complexity,[15] holding all other covariates in the regression at their mean (see Figure 2). Several results stand out. First, inexperienced firms achieve greater commercial success with low-tech products than with high-tech products (see also Model 3b). As firms gather experience, they learn how to address the challenges associated with the introduction of high-tech products. They may eventually develop capabilities that allow them to launch high-tech products that achieve a better quality-to-price ratio than low-tech ones. It is noteworthy that whatever the technological complexity of their new products, firms must still undertake in-house all of the tasks associated with product expansion; the levels of related task variation are thus likely to remain unchanged. Figure 2 supports this in that it suggests that while technological complexity increases the speed of experiential learning, it does not affect the experience threshold. It follows that product technological complexity ultimately enhances the potential for improved performance through experiential learning. Finally, in our empirical setting, experience eventually harms sales volumes whatever the levels of product technological complexity. However, excessive experience is more detrimental to the performance of high-tech products than to low-tech ones. It is indeed plausible that once aircraft manufacturers settle into sustained competency traps, they have more difficulty finding in prior experiences solutions to sophisticated technical problems than to more basic ones.

Model 2a analyzes the effect of the controls on sales volumes. *Business unit size* and *home market size* increased *unit sales* whereas *technological complexity*, *NPI year*, and *development time* decreased it. The inverse Mills ratio is significant, confirming the endogeneity of the NPI-mode choice. Joint development achieves higher sales than both internal development and licensing, possibly because joint aircraft projects

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Table 3 The Impact of Technological Complexity on Experience Effects

Variable	Model 3c Unit sales	Model 3d Unit sales	Model 4c Unit sales	Model 4d Unit sales	Model 5c Unit sales	Model 5d Unit sales
Business unit size	0.004	−0.010	0.225	0.599	0.848**	0.875**
	(0.283)	(0.249)	(0.764)	(1.006)	(0.330)	(0.348)
State-owned firm	0.278	0.269	−0.146	−0.252	−0.188**	−0.193**
	(0.274)	(0.274)	(0.201)	(0.285)	(0.083)	(0.085)
Home market size	0.167	0.157	0.207	0.202	0.078	0.080*
	(0.108)	(0.100)	(0.229)	(0.263)	(0.052)	(0.048)
NPI year	−0.024***	−0.021***	−0.015	−0.011	−0.007***	−0.006**
	(0.007)	(0.008)	(0.010)	(0.010)	(0.003)	(0.003)
Number of competitors	0.002	−0.008	0.000	−0.002	0.007***	0.007*
	(0.005)	(0.007)	(0.016)	(0.013)	(0.003)	(0.004)
Technological complexity	−0.306**	−0.470**	−0.085	−0.052	−0.147	−0.193
	(0.138)	(0.197)	(0.223)	(0.208)	(0.091)	(0.146)
Fighter vs. helicopter	0.073	0.322	−0.138	−0.078	−0.046	−0.042
	(0.486)	(0.425)	(0.421)	(0.409)	(0.120)	(0.158)
Jet vs. helicopter[a]	0.122	0.138	0.210	0.169		
	(0.553)	(0.559)	(0.718)	(0.662)		
Turboprop vs. helicopter	−0.297	−0.127	−0.324	−0.241	0.046	0.055
	(0.269)	(0.239)	(0.613)	(0.629)	(0.191)	(0.269)
Military design	−0.302***	−0.324***	0.292	0.112	−0.140	−0.143
	(0.085)	(0.123)	(0.207)	(0.218)	(0.222)	(0.256)
Development time[b]	−0.098***	−0.077***	−0.074***	−0.069**		
	(0.023)	(0.019)	(0.025)	(0.030)		
Same-NPI-mode exp.	−0.029	−0.313	−0.046	1.052***	−0.069	−0.311
	(0.067)	(0.315)	(0.239)	(0.359)	(0.178)	(0.745)
Same-NPI-mode exp.^{2}		0.027		−0.434***		0.053
		(0.053)		(0.114)		(0.124)
Same-NPI-mode exp. × Technological complexity	0.051***	0.175**	0.033	−0.140	0.021	0.081
	(0.011)	(0.074)	(0.056)	(0.086)	(0.035)	(0.149)
Same-NPI-mode exp.^{2} × Technological complexity		−0.015		0.065***		−0.013
		(0.011)		(0.019)		(0.025)
Mills ratio	−0.025	0.028	0.635	0.803	0.444*	0.458**
	(0.274)	(0.283)	(0.564)	(0.725)	(0.238)	(0.230)
Constant	49.535***	44.039***	30.336	23.300	14.339***	14.194**
	(14.560)	(15.827)	(20.159)	(20.134)	(5.447)	(6.207)
Number of observations	169	169	56	56	53	53
	Only internal development		Only joint development		Only licensing	
Number of businesses	71	71	30	30	27	27
Number of countries	15	15	11	11	17	17
R^2	0.201	0.222	0.327	0.387	0.304	0.308

Notes. Robust standard appear in parentheses below coefficients. The first-stage selection used is Model 1 (see Table 2). Linear regressions clustered by both firm and country to address firm-level commonalities across business domains and impact of common national policies. Random-effect regressions yield substantially similar results. Models 3–5 are restricted to internal development, joint development, and licensing, respectively.

[a]Data do not include any licensed jet aircraft.

[b]Development time is set to zero for all licensed products.

*$p < 10\%$; **$p < 5\%$; ***$p < 1\%$ (two-tailed tests).

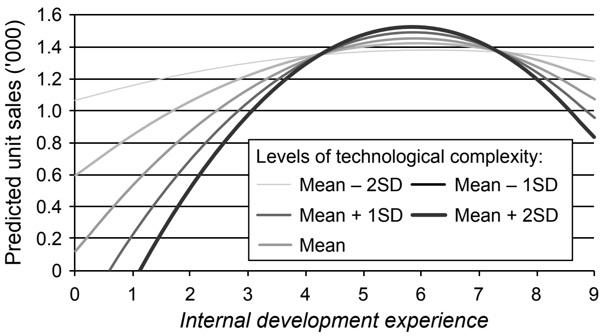
are introduced for the most part by firms from different countries working together and project partners have privileged access to their own domestic markets (e.g., Airbus aircraft). *Military design, product type, state-owned firm*, and *number of competitors* did not affect sales volumes.

Finally, several results stand out from the selection model (Model 1). Smaller firms, firms from smaller countries, helicopter manufacturers, and firms introducing high-tech products are all more likely than other firms to opt for licensing. Further, a favorable economic climate positively affects the choice of licensing (Park et al. 2002), whereas the internal development of new aircraft has decreased over time. *State-owned firm, military design*, and *number of competitors* had no significant influence on NPI-mode choices.

Eliminating Alternative Explanations

First, although we have stressed learning from subsequent experience with the same NPI mode, firms might also benefit from technological and market experience (Nerkar and Roberts 2004), learning more about the product market from internal development than from

Figure 2 The Impact of Technological Complexity on Experience Effects (*Internal Development Only*)



Note. Using coefficients from Model 3d.

licensing and with joint development falling between the two. If this is true, then licensees should benefit more from any experience with internal development or joint development than from any licensing experience. Similarly, alliance partners should enjoy higher benefits from internal development experience than from joint development experience. We thus regressed the sales of joint aircraft against *internal development experience* and the sales of licensed aircraft against *internal development experience* and *joint development experience*. None of the variables had a significant positive impact.[16]

Second, according to the learning literature similarity across successive endeavors is a primary source of experience benefits (Tversky 1977). However, firms that have introduced a product using internal development might introduce similar products over time, whereas licensees and alliance partners may launch products that differ radically from their earlier ones. We ruled out this explanation by replacing technological complexity by a variable that compares the technological complexity of the focal project to that of the firm's most recent aircraft of the same type introduced using the same mode. The experience effects for the three NPI modes and the impact of the levels of technological complexity on experience effects remained virtually the same. The results also remained unchanged when we used the most complex aircraft that the firm ever launched in the same mode.

Sensitivity Analyses

We performed several sensitivity analyses. First, we used alternative measures. The results remained qualitatively the same when we log-transformed *same-NPI-mode experience* or when we discounted it by a factor based on the time interval between NPIs. We also replaced *NPI year* by time periods corresponding to different conditions (e.g., war versus peace) and estimated the intensity of competition by the number of competing products and the home market size by military budgets. The results remained unchanged. We next accounted for the mergers and acquisitions that have occurred in the aircraft industry recording whether a firm had undertaken acquisitions in the past, using windows of 3, 5, and 10 years. This did not influence the results.

We also ran alternative models. The limited number of observations for both joint development (56 observations) and licensing (53 observations) relative to the number of predictors in the models may bias the results. We ruled out this potential risk of overfit by excluding from the treatment effect model all of the controls that were insignificant in the full performance model (Model 2a)—namely, *number of competitors, state owned firm, military design*, and *product type*. The results were virtually the same. We also used a multinomial probit in the selection model. The findings remained unchanged. Finally, the clustering procedure used in the study controlled for unobserved heterogeneity across firms and countries. However, by definition, joint projects involve at least two firms. A firm might also out-license the same aircraft to several licensees. Hence, unobserved heterogeneity across projects might bias the results. We controlled for this effect by clustering our data by firm and project. The findings remained unchanged. The results might also be biased by firm-specific heterogeneity not captured by the clustering specification used. However, neither ordered nor multinomial probit regressions support firm fixed-effects specifications (StataCorp 2009, p. 410). We thus carried out random-effect regressions. The results remained unaffected, except that the levels of significance suffered somewhat because of the reduced degrees of freedom.

Discussion

Our study sheds light on several important aspects of experiential learning. We begin with the notion that experience-driven routinization eventually creates competency traps that lead firms to endlessly refine existing processes (Levitt and March 1988). Hence, experience exhibits decreasing marginal performance benefits that eventually level off (Argote 1999). By logical extension, we argue that the speed of learning, defined as the magnitude of the marginal experience benefits, is higher in activities that allow for a better awareness of cause–effect relationships, whereas the experience threshold, the level at which the experience benefits plateau, is higher in activities that involve higher levels of related task variation. We also contend that firms facing novel technical problems in the execution of an activity often revisit past experiences with the activity. Doing so may lead to a better understanding of process cause–effect relationships, which, in turn, serves as a check on excessive routinization, breaks knowledge ossification, and ultimately increases the speed of learning.

For the sake of simplicity, we restricted our attention in this study to three NPI modes. We argue that the gains of using the same NPI mode as used previously will vary depending on whether the mode used

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is internal development, joint development, or licensing. We predict that the speed of learning as well as the experience threshold are higher in internal development than in joint development and, in turn, higher in joint development than in licensing. We also predict that the introduction of new products of a high level of technological complexity increases the speed of learning from same-NPI-mode experience regardless of whether internal development, joint development, or licensing is the chosen mode. We test our hypotheses on 278 introductions of new aircraft carried out between 1948 and 2000 by 94 firms. We find that whereas same-NPI-mode experience has an inverted U-shaped relationship to NPI performance in internal and joint developments, both the speed of learning and the experience threshold are higher for internal development than for joint development. Our analyses also indicate that experience does not affect performance in aircraft licensing. Hence, the potential for improvement through experiential learning is greatest in internal development, moderate in joint development, and limited—if not entirely nonexistent—in licensing. Finally, we find that firms launching high-tech products enjoy a higher speed of learning from same-NPI-mode experience than firms launching low-tech products, but only if they do so using internal development.

The specificities of the aircraft industry may be behind our finding of an absence of experience benefits in licensing. Aircraft manufacturing is extremely difficult. Each airframe component must be accurately machined from advanced raw material, and licensors generally agree to allow licensees to use the machines, software, and processes they have developed. This means that causal ambiguity is a major concern for aircraft licensees not only for tasks related to aircraft conception but also for those related to manufacturing. Therefore, experienced licensees do not have the same opportunities to draw on experience to refine current tasks, or at least manufacturing tasks, as do firms using one of the other two modes. Hence, it is consistent with our argument that aircraft licensees gain only limited benefits from past licensing experience. We also found that firms launching high-tech products enjoy a higher speed of learning from same-NPI-mode experience than firms launching low-tech products, but only when those products are internally developed. This unexpected finding may again be due to the specificities of the aircraft industry. Aircraft licensing is characterized by extremely high levels of causal ambiguity, so ex post deliberate reexaminations of process cause–effect relationships are likely to be in vain. In the case of joint aircraft development, additional costs associated with the need to increase interfirm coordination because of technological complexity (Singh 1997) might just cancel out any increase in performance benefits from collaborative experience. One need only look at what happened with the Airbus A380. The development of that project was a well-documented example of a rather hectic process as a result of coordination problems between partners, despite the fact that all of them had collaborative experience.

Our study contributes to extant research in several ways. First, we extend the organizational learning literature by demonstrating that the potential for learning through experience is greater with some organizational activities than with others, and we explain why. We show that the speed of experiential learning is higher when there is a better understanding of the causal links between tasks and outcomes, and we also show that experience effects plateau later when there are higher levels of related task variation. These are important insights into how firms may benefit from previous experience and they contribute to our understanding of the factors driving two core facets of organizational learning processes: the *speed of experiential learning* and the *experience threshold*. Even more striking are our findings that firms enjoy a higher speed of learning when they undertake activities involving high levels of technological complexity. The underlying idea is that firms often solve novel problems by applying additional cognitive effort and resources to past experiences. In doing so, they may develop a better awareness of cause–effect relationships, which, in turn, allows them to increase the benefits they may derive from experience. Our view echoes work by Zollo and Winter (2002, p. 341), who noted that "competence improves as members of an organization become more aware of the overall performance implications of their actions, and is the direct consequence of a cognitive effort more or less explicitly directed at enhancing their understanding of these causal links."

Our argument that the speed of learning is driven by firm awareness of cause–effect relationships also contributes to research that compares learning curves across industry environments. Balasubramanian and Lieberman (2010, p. 393) wrote that the speed of learning is higher in high-tech industries than in more mature industries, using as examples the making of leather goods and yarns, where the production process can be readily observed. They go on to explain that newcomers in such mature industries often replicate the production processes used by incumbents by merely observing them. Although replicating can provide a jump-start, it does not generally allow for a clear awareness of cause–effect relationships (Winter and Szulanski 2001). Our view is that new entrants in traditional industries face difficulties in effectively using experience to refine their production process; hence the speed of learning is likely to be somewhat lower. In contrast, firms that enter high-tech environments by necessity develop the required production process on a stand-alone basis, through experimentation and direct experience, simply because they cannot replicate already existing processes. This requires a large

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investment but often provides a clearer understanding of cause–effect relationships (Mosakowski 1997). Our view suggests that when these firms can draw valuable inferences about the efficiency of their actions, the speed of learning is likely to be higher.

Our study also contributes to the stream of the corporate strategy literature that examines the experience effects of different governance modes. It is among the first to examine whether the potential for improvement through experiential learning differs across expansion modes. Several studies have examined how same-mode experience affects performance in collaborations and corporate acquisitions (see Barkema and Schijven 2008 for a review), and others have analyzed the impact of collaborative experience on later acquisition performance (Villalonga and McGahan 2005, Agarwal et al. 2006, Nadolska and Barkema 2007, Zaheer et al. 2010, Zollo and Reuer 2010), but to the best of our knowledge, no previous work has compared experiential learning processes across internal growth, collaboration, and external sourcing. Our study is an initial step toward filling this gap. We suggest that both the speed of experiential learning and the experience threshold are higher in internal endeavors than in expansions carried out through external sourcing, with collaborative ventures falling between the two. The potential for experiential learning is thus greatest in internal endeavors, moderate in collaborations, and rather limited in expansions carried out through external sourcing.

Although we have concentrated on the introduction of new products, we believe that our arguments also apply to other corporate activities such as vertical and horizontal diversification and international expansion. Indeed, the degree of understanding of cause–effect relationships and the level of related task variation are likely to differ across governance modes available to firms for any of the activities mentioned above. Zollo (2009) highlighted that firms expanding through corporate acquisitions often poorly understand the reasons for their success or failure. Thus, they have difficulty drawing viable inferences useful in subsequent acquisitions. Conversely, we can expect firms entering new markets through greenfields to enjoy accurate performance feedback that can be valuable for similar subsequent endeavors. In parallel, Zollo (2009) indicated that the tasks involved in making acquisitions (target search, bidding, and post-merger integration) are likely to have limited potential for learning synergies. We thus expect that experience benefits will plateau sooner for acquisitions than for greenfields, where tasks are more closely related. Further, some research emphasizes that collaboration lies within a continuum that goes from internal growth to corporate acquisitions (Barkema and Vermeulen 1998). This leads us to suggest that the potential for experiential learning is likely to be greatest in internal endeavors, moderate in collaborative ventures, and somewhat limited in corporate acquisitions.

This study also makes a contribution to managerial practice. We established a link between the awareness of cause–effect relationships and the speed of experiential learning, as well as a link between the level of related task variation and the experience threshold. Our results can thus be of value to managers who seek to understand—indeed, forecast—the potential for improved performance through experiential learning. We also showed that the speed of learning is highest when firms face novel technological challenges. We thus provide important insights on how managers can maximize the performance of their product expansions. Specifically, managers of firms in industries with price-sensitive demand might conclude that it is the most experienced firms that can best compensate for the negative impact of technological complexity on sales volumes as they can draw on higher experience benefits (see Figure 2).

Limitations and Future Research

As with any study, this one has limitations that suggest future research directions. First, the data we use come from an industry that is unarguably affected by politics. With this in mind, we have corrected the regression estimates by clustering our data by firms and countries, thereby accounting for the performance impact of firm-specific and country-specific factors. This leads us to believe that industry specificities do not drive our findings. Second, we measured NPI performance with sales volumes. We did so due to a lack of cost data. In line with the traditional learning-curve view, future research might examine more specifically the impact of same-NPI-mode experience on cost efficiency. Third, we suggest that the nature of the tasks a firm performs, given the mode it has chosen, drives its understanding of cause–effect relationship and the level of related task variation. Future research might attempt to test more directly how both affect experience effects.

Future research might investigate the boundary conditions of our results. For example, Tversky (1977) suggested that the degree of similarity between sequential tasks is a prime driver of experience benefits. Future research could examine whether similarity yields the same levels of benefits in internal ventures, collaborative endeavors, and expansions carried out through external sourcing. In a similar vein, Cyert and March (1963) argued that firms learn more from failure than from success because behavioral adjustments primarily occur when aspiration levels are not met. Thus, whatever the mode used, the benefits of same-NPI-mode experience are likely to be higher for firms that had low sales volumes in the past and for firms with projects that were cancelled at the prototype stage. Future research might examine whether the impact of prior failure on

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experience benefits remains the same across different governance modes. Furthermore, we focused on the experience of a focal firm. However, joint development involves two or more firms, and licensing ties together a licensee and licensor. Future research might take into account experience gathered by other firms involved in a project. Researchers might also examine whether partner-specific experience (Zollo et al. 2002, Gulati et al. 2009) has a similar performance impact when a product is brought to market as a joint development, as when it is introduced via licensing.

We found an inverted U-shaped relationship between experience and performance in internal and joint developments. Several other scholars have found a U-shaped experience–performance relationship in corporate acquisitions (Haleblian and Finkelstein 1999, Finkelstein and Haleblian 2002, Nadolska and Barkema 2007). This discrepancy in findings might be due to the specificities of acquisitions. Acquisitions involve high levels of outcome ambiguity (Zollo 2009). They are also heterogeneous because they are made for a variety of reasons (Zollo and Reuer 2010). Limited acquisition experience is thus often conducive to superstitious learning and overconfidence (Zollo and Reuer 2010). The aforementioned scholars acknowledge that firms learn how to make appropriate generalizations as they reach certain levels of experience, but extensive experience may still create core rigidities. Future research could investigate whether an experience–performance relationship is likely to be S-shaped in acquisitions, whereas experience increases performance first decreases and then increases before decreasing again.

Finally, we used an organizational learning approach to examine the relationship between experience and performance. However, firms are likely to choose activities for which they have the most valuable skills. Thus, the positive effect of experience on performance may not be caused by experiential learning but rather driven by astute self-selection. As Felin and Foss (2011, p. 239) highlighted, "There is also a serious problem of survivor bias and endogeneity in specifying the experiences themselves as the cause or origin of learning and behavior." Future research could examine in further detail the respective roles of learning and endogeneity in experience–performance relationships.

Conclusion

Overall, we have shown that the speed of learning is higher when firms carry out activities that allow for a clearer understanding of cause–effect relationships, whereas the experience threshold is higher when firms are in activities involving higher levels of related task variation. Drawing on this view, we have shown that the potential for improved performance through experiential learning is greater with some NPI modes than with others. As our study sheds light on several important aspects of experiential learning, it brings valuable insights to the organizational learning literature.

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Endnotes

[1]One may consider two types of governance mode learning: (a) learning about managing modes and (b) what might be learned from other firms through knowledge transfer, for example (Simonin 1997). In line with research on experiential learning in governance modes (Anand and Khanna 2000, Hoang and Rothaermel 2005, Sampson 2005, Gulati et al. 2009), we focus exclusively on the former.

[2]I am grateful to an anonymous reviewer for suggesting this line of thought.

[3]The number of tasks involved in an activity also affects the potential for learning synergies. Let us return to the aforementioned activities A and B. The potential for learning synergies is less for activity A than B, simply because the activity A tasks are a strict subset of those of B. A scope economies parallel can be drawn. If firm 1 has three product lines (X, Y, and Z) and firm 2 has two (X and Y), firm 1 has a greater potential for scope economies than firm 2.

[4]I am grateful to an anonymous reviewer for suggesting this line of thought.

[5]Joint aircraft projects typically have a modular product architecture (Schilling 2000). Thus, each partner produces distinct subsystems, which are later integrated. Research indicates that this mode of production provides limited interfirm learning because each partner works independently on different subsystems (Sobrero and Roberts 2001, Gerwin and Ferris 2004). Research also highlights that interfirm learning is limited in product licensing (Mowery et al. 1996, Schilling and Steensma 2002). Thus, any benefits that aircraft producers may enjoy from experience in joint development or licensing is likely to come from greater efficiency of the necessary in-house NPI tasks rather than an improvement of interfirm learning capabilities.

[6]Research suggests that the initial investments made by a firm in a given locale or area of business do not follow the same rationale as those made subsequently, thus we would expect different impacts on performance (Chang and Rosenzweig 2001). For this reason, we limited our analysis to NPIs carried out by incumbent firms.

[7]Aircraft manufacturers developed this mode of production to minimize the risk of their knowledge leaking out or being misappropriated (Mowery 1990). The relationship between the prime contractors of aircraft and their suppliers has changed recently with the development of the systems-integration mode of production. In the case of the B-787, Alenia and Mitsubishi are building sophisticated subsystems that are already tested and ready for assembly. They also have full control over the selection and monitoring of second and third-tier suppliers.

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This is a first, and it represents a turning point in aircraft production history (McPherson and Pritchard 2007). Until the B-787, all risk-sharing partnerships between prime contractors and suppliers entailed basic manufacturing subcontracting relationships devoid of any development responsibilities. Our data set does not include an aircraft project that uses this new mode of production (e.g., Boeing B-787, Airbus A350, Bombardier CSeries, Embraer E-jets) because our data collection period ends in 2000.

[8]For our 278 projects, the production runs range from 1 to 38 years with a mean of 13.

[9]The number of observations per country are as follows: Argentina (1), Australia (5), Belgium (4), Brazil (5), Canada (11), China (1), France (34), Germany (8), India (7), Indonesia (4), Israel (2), Italy (21), Japan (16), the Netherlands (4), South Africa (2), Spain (5), Sweden (6), Switzerland (7), Taiwan (2), the United Kingdom (44), and the United States (89).

[10]For 2000 (the only year for which both sets of data were available), regressing the GDP of a country against its military budget and the aircraft inventories of the airlines based in that country yielded an R-squared of 92%, with both variables having a highly significant positive effect.

[11]We could not use *development time* as a dependent variable because this measure is not relevant in licensing.

[12]Including *development time* in both stages of the treatment models did not change the results, except that it loses its significance in the performance models.

[13]We verified that *economic climate* was insignificant when included in the performance model. Hence the instrument satisfies the conditions of affecting the first-stage decision and not affecting the second-stage outcomes.

[14]*Internal development experience* ranges from 0 to 9, with an average of 2.15. *Joint development experience* ranges from 0 to 3, with an average of 0.85.

[15]I thank an anonymous reviewer for suggesting this graph.

[16]We also regressed the performance of the three types of NPIs against the three experience variables: *internal development experience, joint development experience*, and *licensing experience*. Our core findings remained substantially unchanged. However, whereas neither licensed nor joint products enjoy any experience spillovers, both licensing and joint development experiences harm the performance of internally developed products. This echoes work on how external sourcing modes, such as corporate acquisitions and licensing, often produce superstitious learning and overconfidence (e.g., Zollo 2009, Mulotte et al. 2013).

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