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FAST AND EXPENSIVE: THE DIFFUSION OF A DISAPPOINTING INNOVATION

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Firms seek to imitate innovations that yield competitive advantage, but imitation can presage disappointment when the innovation value is below expectations. Empirical research has only rarely examined the diffusion of such disappointing innovations, and it is not known whether negative information from past adopters will halt the diffusion process. Likewise, the effect of heterogeneity in the innovation value on its spread has not been systematically investigated. Here, a unique dataset on a disappointing innovation is used to examine how adoption decisions are imitated, but actual use and subsequent abandonment can yield information that reduces the likelihood that others will adopt. The findings show imitation of the adoptions of other firms, but avoidance of the innovation once these firms start using the innovation or abandon it. Copyright © 2011 John Wiley & Sons, Ltd.

INTRODUCTION

For researchers with an interest in the acquisition of strategic capabilities to gain competitive advantage, the effect of innovations is a disputed topic (Barney, 1986; Zander and Kogut, 1995). Many accept the view that homogeneously valuable innovations spread rapidly, and thus only give temporary competitive advantage (Barney, 1986). Others argue that innovations often have heterogeneous value once they are matched with firm routines and capabilities, and hence also yield enduring competitive advantage (Helfat, 1997; Zollo and Winter, 2002). Yet others argue that uncertainty delays the diffusion of valuable innovations, giving early adopters competitive advantage over longer periods than the temporary-advantage view admits (Greve, 2009). Points of contention among these views are how easily firms can discover the value of innovations and how variable this value is across firms.

Similar points of contention exist in diffusion research. In his classical review, Rogers (1995: 100) criticized the literature for a 'pro-innovation bias' reflected in the implicit assumption that innovations were beneficial, and that gradual diffusion was to be explained by problems in understanding them or accepting the need for change. It is no longer true that this bias is shared across all diffusion studies, but there is still a large pro-innovation stream of work where the innovation is assumed to be beneficial for all adopters, and much of the theoretical and empirical effort is spent showing how features of the adopters and the social structure delay discovery of its value (Rogers, 1995). An important conclusion from this research is that knowledge about the benefits of the innovation is spread through contact with prior adopters, so network

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ties with prior adopters predict adoption by the focal organization.

Diffusion research also has a social-construction stream where the innovation is assumed to have ambiguous value for the adopter, and much of the theoretical and empirical effort is spent showing how features of adopters and the social structure shape the social construction of its value (DiMaggio and Powell, 1983). An important conclusion from this research is that judgments about the benefit of the innovation are made through observation of prior adopters, so measures of the visibility of prior adoptions predict adoption by the focal organization (Strang and Soule, 1998). Together these streams argue that a social process of evaluating the innovation determines the adoption, and that this process can spread innovations with either positive or ambiguous value.

A natural follow-up question would be what happens if an innovation has heterogeneous value across adopters, including negative value for most adopters. Will it still spread through observation of prior adoptions by firms? Will information about the negative outcomes eventually outweigh the observation of adoptions, and thus slow its spread? These questions have been raised only rarely in the literature on the diffusion of innovations (Strang and Soule, 1998). For a variety of reasons, they are difficult to answer. A conceptual problem is that they address key assumptions in each research stream. The pro-innovation stream has focused on positively valued innovations and a theory of risk-averse adopters, and thus cannot easily accept the possibility that negatively valued innovations will spread (Rogers, 1995). The social construction stream has focused on innovations with ambiguous value, and cannot easily accept that a true value exists and is observable (Meyer and Rowan, 1977). A methodological problem is that researchers discover and analyze innovations when they have reached a high adoption rate, and rarely study innovations that obtained limited spread because they had negative value for many adopters (Soule, 1999).

In the following, I define a disappointing innovation as an innovation that has heterogeneous value and negative value for the majority of adopters. The heterogeneous value is part of the definition because it means that the innovation produces some successes, which makes it harder to discover that the value is negative for many adopters,[1] but it is important for the definition that the use of the innovation generates more bad news than good.

Study of the diffusion of disappointing innovations has important benefits. For the debate on the effects of innovations on competitive advantage, evidence on the diffusion of a disappointing innovation would strengthen the view that innovations are consequential because their value is highly uncertain (Greve, 2009). For researchers with an interest in strategic decision making (Eisenhardt and Zbaracki, 1992; Cyert and Williams, 1993; Hitt and Tyler, 1991; Nutt, 2001), disappointing innovations give opportunities to examine the integration of divergent information. In order to understand how decision makers weight different information sources and information content, it helps to have the mix of positive and negative information that is typical of disappointing innovations.

Some studies have found that disappointing innovations do spread widely but temporarily. A new variety of hybrid corn spread to more than one-half of a population of seed growers, but then fell back to zero as a result of its bad taste (Apodaca, 1952). Wooden plank toll roads spread rapidly until it was discovered that the life span was much shorter than expected (Bikhchandani, Hirshleifer, and Welch, 1998). Stock analysts were more likely to adopt coverage of a firm if others had recently done so, but were also more likely to overestimate the performance of the firm and later abandon coverage (Rao, Greve, and Davis, 2001). The matrix organizational form was adopted by many hospitals but subsequently abandoned (Burns and Wholey, 1993). In these cases, the information needed to stop the diffusion of the innovation became available, though its timing and accuracy differed, leading to abandonment. While these studies suggest that disappointing innovations can spread, they focused on how disappointment led the focal adopter to abandon the innovation and did not show an effect on the actions of others.[2] The theory developed here

[1] Homogeneous and negative value is a theoretically possible case that is empirically less interesting because it makes diffusion unlikely.

[2] Rao *et al*. (2001) entered abandonment into the adoption analysis as a control variable, but found no effect on organizational adoption. However, that analysis examined rapid diffusion processes that left potential adopters with little time to react to abandonments.

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predicts that news on a disappointing innovation also become known to other firms than the original adopter, and reduces the likelihood that they will adopt it.

In the following, I extend the theory of adoption decisions from its current focus on imitation of past adopters to also include information gained from past adopters as they use the innovation or abandon it. This theoretical extension is important when the innovation has negative value for many adopters. While a successful innovation yields positive information from all information sources, a disappointing innovation forces a decision maker to decide between the positive information suggested by observation of adoption actions and the negative information that emanates from adopters as they discover the true value of the innovation through using it. This tension has been unexplored in past research, and offers an opportunity to examine how the diffusion of disappointing innovations can slow down.

The theory is tested on data on a disappointing innovation in passenger shipping. Fast passenger ferries obtained speeds that were multiples of conventional ferries. They could compete with air travel on short routes and thus gain high load factors and a price premium over conventional ferries. Oil was inexpensive when they were developed, and few paid attention to their poor fuel efficiency. Then the oil price greatly increased, reducing the profitability of fast ferries, and technical problems also appeared. In spite of these problems, they continued to hold appeal for some firms because the importance of fuel costs for the profitability differed significantly across routes and operators, as did the technical problems. This left potential adopters with the problem of judging the value of fast ferries in the face of high uncertainty, and with some information coming from firms that had different cost/benefit calculations than them.

DIFFUSION AND DISAPPOINTMENT

The standard theory of the diffusion of innovations considers adopter characteristics that make the firm more or less likely to adopt and environmental characteristics that constitute external pressure toward adoption (Strang and Tuma, 1993; Rogers, 1995). Some innovations have a normative nature because they provide a public good such as fair employment practices (Dobbin *et al*., 1993) or good governance principles (Fiss and Zajac, 2004), and for such innovations the normative pressures are central in the explanation (Meyer and Rowan, 1977). Other innovations are competitive weapons that the firm uses to increase efficiency and gain competitive advantage (Dewar and Dutton, 1986; Greve and Taylor, 2000; McKendrick, 2001), and for such innovations the ability of the firm's managers to interpret information that predicts the value of the innovation is central in the explanation.

Decision makers can gain information about the *actions* of past adopters and the *information* that motivated their actions, and these actions and information can either be *pre adoption* or *post adoption*. Although either of these categories of information could influence a decision maker who is trying to judge the value of an innovation, diffusion research has tended to focus on just the action of adopting the innovation, which is taken as a result of pre-adoption information held by the focal adopter. Studies that count prior adopters or weight them by social proximity follow this approach, and have produced findings on how decision makers notice and react to the adoption decisions of others (e.g., Czepiel, 1975; Kraatz, 1998; Strang and Soule, 1998; Lee and Pennings, 2002).

The focus on adoption as the action of interest leads to a paradox. Because it is based on pre-adoption information, the firm that adopts is not necessarily better informed than the focal firm that has not yet adopted. Instead, it may just have a different risk preference (Mansfield, 1961) or a different (but not better informed) estimate of the value than the focal firm (Bikhchandani, Hirshleifer, and Welch, 1992). When many firms examine the same uncertain decision alternative, the most optimistic one is likely to act first, suggesting a positive bias in this information (Harrison and March, 1984). But if the focal firm knows as much as the prior adopter, why should it imitate the prior adopter? The answer is that the weight of evidence from *multiple* adopters may convince decision makers, but even this conviction is not strong because decision makers may guess that some prior adopters imitated others. Hence there is limited information in adoption actions, and the diffusion process can be reversed by more reliable contradictory information (Bikhchandani *et al*., 1992).

Abandonments are interesting because they are an action that can influence adopter decisions, just

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		Information timing	
		Pre adoption	Post adoption
Information type	Action	Adoption decision	Expansion Abandonment
	Value	Value estimate	Value knowledge
	Routines	Implementation plan	Implementation experience

Figure 1. Information for adoption decisions

as adoptions can. Because it is generally assumed that innovations are successful, the potential negative influence of abandonments on adoptions has not been systematically investigated.[3] Indeed, the implicit assumption that innovations are valuable has prevented analysis of potentially discrediting information more generally, leaving a void in research on innovation adoption. This is a serious shortcoming because adoptions and abandonments of innovations are not the only information that influences decision makers; other forms of information also matter.

The inattention to discrediting information in research on the innovation diffusion is especially stark because other areas of research have started to examine the relation from adverse outcomes to subsequent actions. Organizational failures (such as bankruptcy) and near-failures have been shown to produce learning in geographically proximate organizations (Baum and Ingram, 1998; Kim and Miner, 2007). An important mechanism behind the effect is avoidance of actions associated with failure (Miner *et al*., 1999), and conversely, repetition of actions that are associated with successful outcomes (Haunschild and Miner, 1997; Haleblian, Kim, and Rajagopalan, 2006). It is time to bring these insights to research on interfirm diffusion of innovations.

Figure 1 gives an overview of different types of information that may influence a potential adopter of an innovation. The information is organized by whether it is generated pre or post adoption, and by what type of information it is. Starting at the top, innovation studies have nearly exclusively focused on the action of adopting. Conversely, we may predict that the action of abandonment can reduce imitation of adoption. However, adoption and abandonment decisions are influential because they allow the decision maker to make inferences about the value estimate, so it is reasonable to ask whether the decision maker might also be influenced by direct access to the value estimate. Such access would occur if potential adopters share the information they have before the adoption, or if an adopter voluntarily shares or inadvertently leaks its value estimate. Because value estimates are an important driver of adoption decisions, they could have a strong influence on potential adopters. Finally, one source of uncertainty about innovations is the lack of knowledge on how to implement them. Any knowledge that either facilitates implementation or reveals implementation difficulties could potentially affect adoption decisions, especially if they were post adoption and hence based on direct experience.

Pooling of pre-adoption value estimates and implementation knowledge is unlikely when firms are seeking to adopt an innovation in order to gain competitive advantage. With such sharing, everyone would be able to form a better value estimate, so it would be very difficult for innovations with negative value to spread, but it would also be difficult to gain any advantage over competitors. Hence the information of primary interest in strategic management is (leaked) post-adoption knowledge and post-adoption actions.

Value information

Because firms adopt innovations under great uncertainty, the information they gain after adoption can lead to significant shifts in their estimate of the value of the innovation. The post-adoption

[3] The use of abandonment as a control variable in one study has already been noted (Rao *et al*., 2001), and the effect of abandonments on the abandonments of others has also been investigated previously (e.g., Burns and Wholey, 1993; Greve, 1995).

value knowledge is more informed than the pre-adoption estimate that led to the adoption, so it would be more persuasive to a potential adopter than observation of the adoption action if it could be observed accurately. Because it is based on observation of outcomes, unlike the pre-adoption value estimate, the post-adoption value knowledge may affect the likelihood of adoption even if it is observed only imprecisely. This matters because firms are unlikely to have direct access to the revealed value of an innovation adopted by another firm. Such information is proprietary, especially when it concerns a technology with a strong effect on costs.

In spite of the secrecy that often surrounds innovations, post-adoption information spreads through interpersonal networks that cross firms. These interpersonal networks, in turn, are best developed among proximate firms. The interlock network between boards of directors is the focus of much research precisely because directors bring to bear expertise gained from other firms when relevant to a decision at a focal firm (Davis, 1991; Davis and Greve, 1997). Similarly, local spread of knowledge is a well-established finding in the literature on technological diffusion in general (Jaffe, Trajtenberg, and Henderson, 1993; Pouder and St. John, 1996; Audretsch and Feldman, 1996; Singh, 2005), as well as diffusion in specific industries such as biotechnology (Powell, Koput, and Smith-Doerr, 1996; Owen-Smith and Powell, 2004). These findings suggest that post-adoption information about the value of the innovation to the adopter and its implementation spreads to proximate firms even when this information has proprietary value. However, the fidelity of information transmission across such informal networks is necessarily open to question, so the decision maker needs to judge the value of such information against the possible distortion in the transmission process.

Moreover, an innovation is used as a part of a production system, with a value that may depend on the other parts, so two firms with different production systems may have different revealed value of an innovation. As a result, there are two sources of noise for a decision maker seeking to infer the value of the innovation from a prior adopter. First, observation of the value will only be indirect through hearsay, possibly with some error. Second, the relevance of the information is uncertain because of the heterogeneous value of the innovation across firms, which adds additional error. If the relevance of the information can be judged through some signal such as a characteristic of the adopter firm, better inferences can be made (Terlaak and King, 2007; Terlaak and Gong, 2008). However, it may be difficult to judge which adopter characteristics best predict the value of the innovation.

In spite of this noise, the low threshold for halting imitation (e.g., Bikhchandani *et al*., 1992) means that use of an innovation by other firms reveals the negative value sufficiently well that a firm that already is at the brink of not adopting because its own value estimate is low will decide against adopting. Thus, even a noisy signal of the value of an innovation leads to non-adoption by a firm that is made skeptical by the observation of a negative own estimate of its value. Likewise, information about the implementation experience of others can lead to non-adoption if they suggest limited fit with the focal firm. Value signals and implementation experience are both more likely to spread to proximate firms, and seem difficult to distinguish from each other, so the prediction is that use of the innovation by proximate firms reduces the likelihood that a focal firm will adopt the innovation. Hence the hypothesis is:

> *Hypothesis 1: Firms are less likely to adopt a disappointing innovation when proximate firms have started using it.*

Action information

Post-adoption actions influence the adoption likelihood when firms use them to infer the value of adoption. For the firm that is considering an innovation, the advantage of adopter actions is that that they may be easier to learn than the internal value information held by the adopter. The disadvantage is that actions can have multiple interpretations. The clearest negative signal is abandonment of the innovation (Burns and Wholey, 1993; Greve, 1995; Rao *et al*., 2001), but even this signal needs interpretation. If the firm had simply stopped using the innovation and disposed of it at some cost, it would have been clear that it had negative value. However, production equipment innovations have a nonzero resale value, so abandonment is likely to be in the form of a sale rather than scrapping. While a sale could be a negative signal, it could also mean that, because of heterogeneity in the

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value, another firm assigned a higher value to the innovation than the original adopter, and made a successful bid for it. Thus, sale of an innovative technology is a noisy signal of value. Information about the sale price would help interpret the meaning because sales at a loss would signal negative value just as scrapping does, but such information is usually not disclosed. Hence, mere observation of the sale may not be enough to infer a negative value of the innovation, but managers of a firm that is proximate to the selling firm may be able to get the additional information needed to make this inference.

A potentially more powerful signal would be if the adopter completely abandoned the innovation by selling all units on stock. However, the same caveat applies, because a firm that experiences a positive value of an innovative technology but receives a bid to sell it for a higher value would be likely to sell all units rather than just some. Even when the abandonment clearly is caused by inefficiency of the technology, heterogeneous value of the innovation across firms may imply that an innovation that had negative value for one firm observed to abandon it might actually have a positive value for the focal firm. Thus, the link from the actions of other firms to the value of the innovation for them is uncertain, and the link from there to the value of the innovation for the focal firm is even more uncertain. Again the key may be proximity to the adopter so that information about the reason for the abandonment can be obtained. Thus I hypothesize:

> *Hypothesis 2: Firms are less likely to adopt a disappointing innovation when proximate firms have sold or abandoned it.*

Comparing information types

The next step is to consider whether there is a difference in the impact of these types of information on the focal firm's decision. To do so, consider what type of information will cause a decision maker to update the estimated value of the innovation, and by how much. First, an order is a pre-adoption behavior and thus signals a positive internal value estimate or that the firm has been convinced by the orders of others that the innovation has positive value (Bikhchandani *et al*., 1992). Thus it weakly increases the likelihood of adoption. Delivery to a proximate firm can trigger information about its post-adoption outcomes, which are highly diagnostic of the value, and will thus be given high weight in the decision making. However, the revealed value is heterogeneous, and thus either positive or negative, and it arrives with some noise. For a disappointing innovation, the information will tend to be negative, as predicted in Hypothesis 2, but the heterogeneity and uncertainty does not permit the conclusion that it will be a strong enough signal to outweigh the effect of the adoption information. Hence, the heterogeneity means that we cannot make a prediction on the relation of the order information and the delivery information even though the delivery information is post adoption and thus is given a high weight by the decision maker.

When a firm sells or abandons an innovation, the reason could be that their post-adoption valuation was negative or that they received a higher bid. Firms that are proximate to the selling firm should be able to discover the reason through social connections either directly to the firm or through third parties, and can infer the post-adoption value of the innovation from the sale or abandonment action. Because it is a post-adoption value signal and thus informed by actual use, unlike orders which are pre-adoption information, it will be given a higher weight by the decision maker than an order. Because it is caused by negative value, a sale or abandonment does not have the heterogeneity problem that prevented a prediction in the case of delivery. Hence I hypothesize:

> *Hypothesis 3: The reduction in adoption likelihood from sale or abandonment by a proximate firm is high enough to outweigh the positive effect of adoption of a disappointing innovation.*

DATA AND METHODOLOGY

Fast ferries

While normal ferries have service speeds of around 12 knots, fast ferries have at least double the service speed, and speeds over 40 knots are not uncommon. Typical route lengths are on the order of one to a few hours, as the higher speed is less valuable in short routes, and air traffic is a greater competition in longer routes. As a rule of thumb, fuel consumption in ships is proportional to the

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square of the speed, so fast ferries need to employ a variety of advanced design features to control the fuel consumption. Different hull designs have been developed to fit the needs of fast ferries, each with its own solution to the problems of reducing drag, giving stability and safety, and yielding a practical shape for transporting passengers and cars. Even with these designs, fast ferries have much higher fuel consumption than regular ferries. While dedicated passenger boats can obtain high speeds relatively inexpensively through low weight, a ferry transports cars as well as people, which adds to its weight.

Fast ferries are made as sea-skimming monohull or multihull structures (two or three-hull catamarans), wave-piercing multihulls, and hovercrafts. Multiple engines are the rule, and catamaran designs often have four engines, two in each hull. The propulsion can be propellers with a gearbox and drive shaft, or a waterjet. Aluminum hulls are used to save weight, though composite hulls have also been built. These materials, parts, and building techniques are costly, so fast ferries are substantially more expensive than conventional ferries with the same capacity. The technological differences also affect the operation and maintenance of fast ferries, so a firm that has only operated conventional ferries has much to learn when adopting a fast ferry.

The value of fast ferries

Fast ferries were a late-1980s invention that started spreading in the early 1990s, and were thought to be a highly valuable innovation. A retrospective article on the fast ferry market noted, 'Speed which in some cases can cut a journey time in half, has always had a great appeal for passengers who are prepared to pay a premium for it, especially on journeys of a couple of hours, or so, when fast ferries are at their most effective' (*Lloyds List*, 2001a). Early 1990's forecasts were that in the developed world, conventional ferries would become freight specialists, with most passenger and car traffic going on fast ferries. These market estimates were cut significantly in the next decade, and the same article noted, 'a number of major companies (...) have not been convinced by the economic case of operating these vessels in conjunction with the conventional combination ships. Some of these companies have since started to operate fast ferries, but not as an integral part of their business: rather as a summer add-on' (*Lloyd's List*, 2001a). However, market growth estimates remained at 20 percent for Europe, while a breakthrough for the North American market was predicted to come soon (*Lloyd's List,* 2001b). Instead, more disappointments were to follow.

The disappointments with fast ferries had two sources. First, the overall profitability of fast ferries took a sharp downward shift as a result of the increase in oil prices. In the early 1990s, the oil price was below $20 per barrel, but by mid 2005 it was more than $50 per barrel. The increased oil price negatively affects the profitability of any vessel, but fast ferries had so much higher fuel consumption than conventional ferries that the effect on their total costs was much greater. There was little public discussion of this problem, possibly because the firms that were stuck with unprofitable ferries preferred to sell them without too steep a discount in the price. However, in a personal interview conducted in August of 2005, an official of a public agency that had helped a shipping firm adopt a fast ferry in order to improve infrastructure and support the use of innovative technologies commented on the outcome:

> Currently there is a good demonstration of the risk in the [fast ferry] project. This ship is now unprofitable because the rising fuel costs have made its operations too expensive. It consumes five times as much fuel as an alternative ship, so it loses money, and the shipping operator would prefer to stop using it.

As of October 2009 this ferry is idle because of its high operating costs.

Second, the technological differences of fast ferries and regular ferries affect their use and maintenance. Many ferry operators were not ready for these differences, and discovered poor fit between the fast ferry technology and their requirements. For example, the three FastCat ferries that were built for operation in British Columbia between 1997 and 2000 proved susceptible to engine breakdowns and damage from flotsam, and were judged unsuitable for the intended route (*National Post*, 2003). They were auctioned off for $19.4 million (original price $450 million) in 2003, and were idle until they were resold for use in the United Arab Emirates in 2009 (*TradeWinds*, 2009). Similarly, the two Hawaii Superferries acquired in 2004

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were forced to stop operations because of unanticipated environmental problems, including a public uproar over the risk of ramming whales. They were repossessed in 2009 and subsequently acquired by the U.S. Maritime Administration, which was a loan guarantor, after their operating firm filed for bankruptcy (*The Virginian-Pilot,* 2010). *Spirit of Ontario* was ordered in 2003 for traffic on the Great Lakes, but experienced a series of technical and commercial problems. Its operator went bankrupt in 2005 and the vessel was seized by the receivers and sold to a corporation controlled by the city of Rochester for US$32 million. The original price is not publicly known, but its size (86 meters) suggests it would be near US$100 million. Despite the low resale price its operations were unprofitable and were halted in 2006, and it was resold to be used between Spain and Morocco (*New York Times*, 2007).

The sale prices of the ferries in these examples are known because they were acquired with public support or guarantees, but it is more common for fast ferry acquisitions to be fully private; the potential losses from selling or idling them are usually not made public. Likewise, technical problems are not widely reported out of fear that they may influence the resale price. However, fast ferries are specialized and call for matching investments on land (e.g., loading ports that fit), which makes them so difficult to sell that some ferries with known problems are kept in service. For example, the Danish ferry *Villum Clausen* has proven difficult to steer under the high winds that sometimes occur in its route, and its record of accidents and near-accidents has caused the government to bar it from docking during unfavorable wind conditions (*Ingeniøren*, 2008). In its most recent mishap, the hull was punctured in two places in a 3 October 2009 collision with the dock. It remains in use while the operator awaits delivery of a replacement, which will also be a fast ferry because the market potential of the route is thought to be sufficient for it to be profitable when operated by a reliable vessel (*Austal*, 2011).

Because of the potential losses from acquiring fast ferries and selling them quickly, it is a clear signal of disappointment that many ferries were sold after short periods of operation. Tabulation of the Kaplan-Meyer survivor function of first-time ferry acquisitions shows that 13 percent of the ferries were sold after two years and 39 percent after five years. For ferries delivered in 1999 or later, when oil prices started climbing, the statistics are worse: 17 percent were sold after two years, and it only took four years to reach 43 percent sold. These statistics are based on realized sales, and hence do not take into account that some ferries are made idle or put into receivership before the sale, as in the examples above. On the other hand, some of the first-time acquisitions were followed by reorders rather than sales. Although, as suggested in the case of *Villum Clausen*, not all reorders are success stories, some operators appear content to operate routes with fast ferries and to even expand their capacity. These actions suggest that some adopters found the fast ferries to be a good fit for their routes, even with the high operating expenses, while others were not able to operate them profitably.

Perhaps as a result of this value distribution, the diffusion of fast ferries does not show the typical shape of a diffusion curve. Figure 2 shows the cumulative number of fast ferries ordered per year. The curve has the usual upswing seen in diffusion curves, which can be dated to about 1993, but in 2000 it breaks downward again. This coincides with the recovery from the Asian crisis, which saw a rapid rise of oil prices from US$16 to US$30 (nominal prices). The oil price fell again soon after, so this peak alone cannot have been decisive for the change in the diffusion process. In the same period a number of shipping firms gained experience with fast ferries, however, and some ferries were sold by the original adopters. There was no spike in the sales of ferries in 1999 or 2000, but rather a steady pace of four to five sales per year, except for 1997, which had 12. To get a better idea of the causes of the decline, event-history analysis with variables on orders, new ship deliveries, secondhand deliveries, and sales will be used. Figure 2 also shows the cumulative number of fast ferries built per year. This curve is lagged as a result of construction times and preorders of ferries in series, and it is this lag that gives the opportunity to examine the difference of the effect of the adoption decision and the actual use on the subsequent spread of fast ferries.

Figure 3 shows the smoothed estimate of the hazard rate of first adoption of a fast ferry on a scale of months after the start of the diffusion process. The hazard rate increases greatly until it reaches a maximum in 1996. Thus the peak in adoptions is sooner and the falloff is sharper than that seen in the diffusion curve in Figure 2. This

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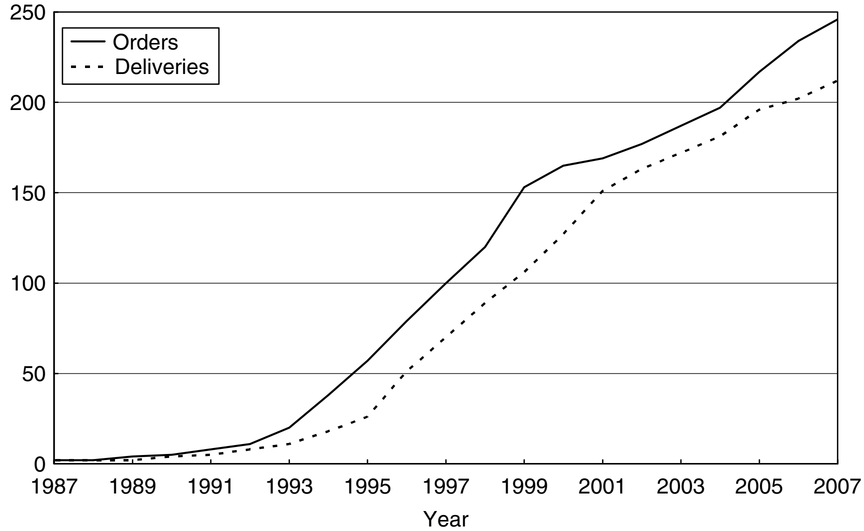

Figure 2. Orders and deliveries of fast ferries

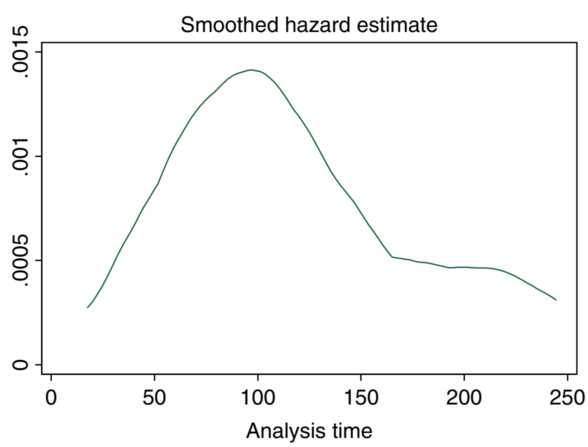

Figure 3. First orders of fast ferries.
This figure is available in color online at Wiley Online Library (wileyonlinelibrary.com)

is to be expected, as Figure 2 has all orders of fast ferries and includes reorders as well as first adoptions, while Figure 3 shows the hazard rate of first adoptions only.

Data sources and sample

Data on ships and shipping firms were obtained from the Lloyd's Fairplay Enhanced Registry of Ships CD-ROM and a specially ordered download of the Lloyd's Fairplay historical ownership data of ships. Lloyd's Fairplay keeps track of all ships that have or will get an IMO number (issued by the International Maritime Organization, and the equivalent of the license plate of a car), and has data on ownership, management, shipbuilder, ship construction, and capabilities. Shipping corporations have complex structures that often include separate ship-owning corporations for tax or financing reasons, and also split the commercial control from the daily management. Accordingly, the Lloyds data on fleet ownership and control was used to identify the firms controlling the ships.

Because the top speed of ferries varies continuously, a threshold for defining a fast ferry is needed. Here it is set at 25 knots, which means that all the ferries in the data are faster than a

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conventional ferry, but ferries that would be on the threshold of being defined as fast (e.g., 20–25 knots) are defined as conventional. Thus, the operational definition of a fast ferry is a vessel that transports passengers and cars (roll on, roll off) with a top speed in excess of 25 knots. The population at risk has 779 firms in total and is defined as all firms owning a non-cruise passenger ship.

Dependent variable and model

The dependent variable in the main analysis is the event of placing a first-time order for a fast ferry. The data report order and building dates to the nearest month. The event times in the analysis are given with a month's precision, just as in the data. The firm observations are split annually to update covariates, and are split again within the year whenever needed to update the diffusion covariates. A firm remains at risk of adoption until it orders a fast ferry or no longer owns other passenger ships.

The data were analyzed by the Cox model, which is a continuous-time hazard rate model with a flexible functional form for the time dependence. The model contains covariates that take into account effects of prior adoptions on the hazard rate. For each potential adopter n and past adopter s, the hazard rate is given as a function of objective variables that affect adoption V_n and the influence of past adoptions by others. The set of past adoptions is $S(t)$, and each adoption by others has a set of characteristics that determine the proximity to the potential adopter, W_{ns}. Coefficient vectors for each objective variable (β) and each proximity characteristic (δ) are estimated. The model is specified as follows:

$$r_n(t) = \exp\{\beta' V_n + \delta' W_{ns}\} r_0(t)$$

This term $r_0(t)$ specifies the time dependence in the rate of adoption, and in the Cox model its value is fit separately for each inter-event interval. As a result, variables that vary over time but not across firms are not entered as their effects are fully controlled by the model. Controls for world economic conditions are, thus, not needed. Also, because the sum of proximate and non-proximate adoptions adds up to all adoptions worldwide, which are controlled for through the time dependence, variables for all adoptions or all non-proximate adoptions cannot be added to these models. The control for time dependence means that the coefficients of the local adoption variables should be interpreted as showing how much greater the effect of a proximate adoption is compared to that of a non-proximate adoption. The time axis is set to the duration since January 1987, and the analysis uses data collected from 1987 (the start of the fast ferry diffusion process) through 2008.

Independent variables

For analyzing the information effect of past adoptions, I take advantage of a special feature of the ship purchase process. There is a time lag between placing an order and finishing of a ship in order to allow time for final design, acquisition of parts, scheduling of shipyard capacity, and actual production. When the shipyards are busy or the shipping firm orders a series of ships with phased delivery, the duration from order to delivery can be a few years. The information that a firm has ordered a fast ferry reveals its decision, and hence can influence the diffusion process. Delivery allows the firm to operate the ship and learn its true value, and potentially this information leaks to other firms as well. Thus, the difference between order and delivery dates allows distinction between the effects of the information about the firm's action and information about its outcomes.

I restrict the diffusion variables to the focal nation to take into account the stronger effect of information on proximate actions. Thus, they are cumulative counts of orders and deliveries within each nation. The nation data are based on the firm headquarter, which may be different from the location of the ship. Unfortunately, I am unable to track the latter, but ferry routes tend to be operated domestically or between nearby nations, usually by firms with a local headquarter. As an alternative specification of the effect of deliveries, I also examine the effect of secondhand sales into the nation. Although such sales are less common than new sales and are likely to be at a price discount, they may also prove informative for other shipping firms.

I examine sales of ships by the original buyer (from a shipyard) because such sales are likely to involve the greatest economic losses. When a firm sells its last fast ferry, I term that an abandonment. Abandonments are less common than sales, but may be a stronger signal of disappointment and, hence, have greater influence over other firms. In some cases, abandonment is preceded by sales of other fast ferries owned by the same firm. It is possible that all ships were put up for sale at once but only successfully sold in sequence, but this cannot be checked because the data record only actual sales, not offers to sell. When a firm is recorded as selling its last fast ferry and not owning any other vessel subsequently, I do not record an abandonment event because the firm may have failed rather than voluntarily sold the vessel. Regrettably, it is not feasible to check what happened to each firm because they are so geographically spread, and many are small. A firm can continue operating without registered ownership of any vessels if it uses leased vessels.

Control variables

Because the Cox model controls for all time-related influences that affect all firms equally, world-level variables cannot be entered (the effects are not identified). However, a separate analysis with a parametric specification of the hazard rate was used to verify that the oil price has a negative effect on orders, as it should have given the importance of fuel costs. I entered the following variables that vary by nation and year. The logarithm of gross domestic product (GDP) per capita and the annual growth in GDP per capita are from the World Bank. Same-nation economic conditions are likely to be influential because fast ferries gain an advantage over regular ferries when the customers assign a higher value to their time.

The following variables vary by firm and year, and are obtained from Lloyd's Fairplay. Firm age is the number of years since firm founding, and firm size is the logarithm of the firm's fleet of ships. Average ship size is the logarithm of the average ship size owned by the focal firm. Firm proportion of passenger ships is based on the total ship size of this category, and measures the specialization in passenger shipping. Ship type Herfindahl is the Herfindahl index of ship types owned by the focal firm, which measures concentration in ship types. It equals the sum of squared proportions of all ship types owned by the firm. The ship classification is based on the Lloyd's Fairplay ship types and has the nine categories: bulk, container, cruise, general cargo, offshore, passenger, tanker, vehicle carrier, and others. All variables on ship size use deadweight tons as the unit.

The descriptive statistics and correlations for the data are given in Table 1. Although new deliveries, secondhand deliveries, sales, and abandonments lag behind orders, they are sufficiently correlated to give potential multicolinearity problems when entered in the same model and omitted-variable bias if only one is entered but multiple have effects. The analysis will proceed by entering variables individually before entering them jointly.

FINDINGS

The analysis starts with an ordinary diffusion model where past adoptions in the same nation influence the decision. Next, variables are added to incorporate the effect of deliveries of new ships or secondhand ships, and then sales and abandonments of delivered ships. These analyses aim to discover how information about disappointments in the value of the innovation slows its diffusion. Finally, in order to examine the effect of the oil price increase, a set of analyses test whether the post–1999 deliveries affect adoptions differently.

Delivery effects

Table 2 contains analyses that test Hypothesis 1. Model 1 has only control variables and gives a set of results that are also stable in later specifications. There is a positive effect of GDP per capita, as expected. The positive effect of firm size was not predicted, but is reasonable considering that fast ferries are technologically more complex than regular ferries, which favors large firms with their greater technological capabilities. The ship type Herfindahl shows that concentrated fleets predict adoption, which suggests that specialist ferry operators are most likely to adopt fast ferries. The negative effect of average ship size may indicate operational similarity, as fast ferries have smaller car loading capacity than the mega-ferries that are used in high traffic routes. The estimate of orders within the same nation is positive and significant, showing the positive influence from prior adopters predicted by standard diffusion models. Thus, firms imitate the adoption decision of other firms in the same nation. Before the variables for deliveries and sales are entered, this looks like a normal diffusion process with imitation of proximate adoptions.

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Table 1. Correlation coefficients

	Mean	Std. dev.	1	2	3	4	5	6	7	8	9	10	11	12
1 Ln GDP/cap	9.010	1.41	1											
2 Growth GDP/cap	2.687	3.73	−0.20	1										
3 Firm age	18.806	25.301	0.19	−0.06	1									
4 Firm size	7.333	3.466	−0.16	0.04	0.19	1								
5 Ship size	6.513	2.830	−0.14	0.04	0.14	0.97	1							
6 Proportion passenger	0.670	0.437	0.09	−0.06	−0.02	0.00	0.13	1						
7 Ship type Herfindahl	0.894	0.199	0.19	−0.04	−0.15	−0.53	−0.40	0.51	1					
8 Same nation orders	4.623	8.126	0.31	−0.03	0.06	0.03	0.05	0.11	0.03	1				
9 Same nation deliveries	3.839	7.667	0.28	−0.03	0.05	0.03	0.05	0.11	0.03	0.89	1			
10 Same nation second-hand	0.441	1.141	0.18	−0.00	0.05	0.02	0.03	0.08	0.02	0.63	0.74	1		
11 Same nation sales	1.189	2.445	0.26	−0.06	0.06	0.04	0.05	0.10	0.03	0.83	0.87	0.82	1	
12 Same nation abandonments	0.175	0.574	0.16	−0.03	0.02	0.02	0.03	0.05	0.01	0.51	0.59	0.78	0.65	1

10,379 time-segment observations, representing 739 subjects with 96 events.

Model 2 adds deliveries, and shows that orders continue to have the expected positive effect, while deliveries have the expected negative effect. The coefficient of deliveries is significant, so Hypothesis 1 is supported. The deliveries coefficient estimate is approximately the same magnitude as the orders estimate, so the model predicts a slowdown of the diffusion. The similarity of magnitude of the two coefficients is a coincidence, but shows how outcome information containing a mix of successes and failures can produce a negative net effect that exactly balances the positive effect of observing adoptions.

Model 3 replaces the delivery variable with the variable for secondhand ships received, and gives a finding that corresponds to that of the delivery model. The coefficient of secondhand receipts is significant and negative, and the effect is much stronger than that of deliveries. Indeed, it seems unrealistically large, so we may suspect that the estimate has been inflated by the omission of the (correlated) deliveries variable. Model 4 enters the two variables simultaneously. This gives an inconclusive result, as only sales is significant, and only at the 10 percent significance level. The colinearity prevents accurate attribution of the effect to each of these variables, though each shows a strong effect on its own.

Model 5 replicates Model 4 with recalculated diffusion variables. Instead of being counts of all orders, deliveries, and secondhand sales, the adoptions are weighted by a decay function that multiplies them with a constant discount factor for each year since the most recent year. Thus, temporally distant adoptions are treated as less salient than recent ones, as in research on vicarious learning from other firms (e.g., Baum and Ingram, 1998). Different discount factors were tried, and 0.9 proved to have the best fit and greater improvement in fit than no decay, as seen in the likelihood ratio test below the model. This model shows results that support Hypothesis 1 through a highly significant negative effect of deliveries, while secondhand sales do not have a significant effect. The same reservation about the difficulty of showing both effects at the same time due to colinearity applies to this model.

Sales effects

The effects of sales and abandonments are analyzed in Table 3. Model 6 enters sales and shows

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Table 2. Diffusion of fast ferries, models with new deliveries and second-hand ships

	Model 1	Model 2	Model 3	Model 4	Model 5
Ln GDP per capita	0.310**	0.338**	0.278*	0.308**	0.258*
	(0.112)	(0.113)	(0.110)	(0.113)	(0.114)
Growth in GDP per capita	0.004	−0.008	−0.001	−0.006	−0.003
	(0.040)	(0.041)	(0.040)	(0.041)	(0.042)
Firm age	−0.003	−0.003	−0.003	−0.003	−0.004
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Firm size	0.612**	0.617**	0.622**	0.622**	0.606**
	(0.145)	(0.144)	(0.145)	(0.145)	(0.145)
Ln average ship size	−0.806**	−0.814**	−0.820**	−0.820**	−0.802**
	(0.172)	(0.171)	(0.173)	(0.172)	(0.172)
Proportion passenger ships	−0.578*	−0.590*	−0.569^{+}	−0.578*	−0.577^{+}
	(0.295)	(0.293)	(0.296)	(0.295)	(0.296)
Ship type Herfindahl	1.736^{+}	1.770^{+}	1.820^{+}	1.811^{+}	1.741^{+}
	(0.933)	(0.930)	(0.933)	(0.931)	(0.935)
Same-nation orders	0.050**	0.097**	0.075**	0.090**	0.205**
	(0.012)	(0.018)	(0.014)	(0.018)	(0.033)
Same-nation deliveries		−0.099**		−0.053	−0.165**
		(0.030)		(0.230)	(0.060)
Same-nation second-hand			−0.618**	−0.410^{+}	−0.292
			(0.189)	(0.039)	(0.287)
Model log likelihood	−556.25	−549.10	−547.98	−547.02	−540.39
Likelihood ratio test	85.47**	99.77**	102.00**	103.92**	117.17**
vs baseline model (d.f.)	8	9	9	10	10
Likelihood ratio test		14.30**	16.54**	18.46**	24.81**
vs Model 1 (d.f.)		1	1	2	2

$^{+}$ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$, two-sided z tests.
Standard errors are in parentheses below each coefficient estimate. Model 5 uses a decay factor of 0.9 on the orders, deliveries, and second-hand variables. The likelihood ratio test for this model is against a re-estimated Model 1 that has same-nation orders discounted by 0.9.

that they have a negative and significant effect on adoptions, in support of Hypothesis 2. This coefficient estimate is greater in magnitude than that of orders, and the difference is significant, in support of Hypothesis 3 ($\chi^2 = 7.67$, $p < 0.01$).[4] Abandonment is entered in Model 7, and had a negative and significant coefficient in support of Hypothesis 2. Again the magnitude is significantly different from that of orders, in support of Hypothesis 3 ($\chi^2 = 4.03$, $p < 0.05$).

Model 8 enters both variables to see if the effects can be parsed out, and it suggests that abandonments are no more important than other sales. Sales remain significant in this specification, but abandonment is not significant. Recall that abandonments are also sales, so the abandonment coefficient shows whether an abandonment has a different effect than a regular sale. Thus, it seems that every sale has the same chance of influencing others, so variables that seek to distinguish between the final abandonment of the fast ferry type and a sale of a fast ferry that keeps some in stock are making finer distinctions than the decision makers do.

Finally, Model 9 replicates Model 8 with all diffusion variables recalculated to have a decay factor of 0.9 per year, as in Table 2. As in Table 2, this improves the model fit and is the best-fitting decay rate. The findings are exactly the same as in Model 8, as same-nation sales are negative and significant, and significantly different in magnitude from orders ($\chi^2 = 5.33$, $p < 0.05$). Hence, Hypotheses 2 and 3 are both supported in Model 9 as well.

[4] This is a Wald test of the restriction that the orders coefficient equals the negative of the sales coefficient (because they have opposite signs). Thus it is a two-sided test of difference in coefficient magnitude. The significance levels would be somewhat higher if the test were one sided, as the hypothesis is stated.

Deliveries and abandonments

The findings so far suggest that two types of information slow the spread of a disappointing

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Table 3. Diffusion of fast ferries, models with sales and abandonments

	Model 6	Model 7	Model 8	Model 9
Ln GDP per capita	0.288**	0.296**	0.288**	0.231*
	(0.109)	(0.110)	(0.109)	(0.111)
Growth in GDP per capita	−0.005	−0.004	−0.006	−0.002
	(0.040)	(0.040)	(0.040)	(0.040)
Firm age	−0.004	−0.003	−0.004	−0.004
	(0.004)	(0.004)	(0.004)	(0.004)
Firm size	0.616**	0.619**	0.616**	0.605**
	(0.144)	(0.145)	(0.144)	(0.144)
Ln average ship size	−0.806**	−0.815**	−0.806**	−0.791**
	(0.171)	(0.172)	(0.171)	(0.171)
Proportion passenger ships	−0.600*	−0.577+	−0.600*	−0.580+
	(0.295)	(0.296)	(0.295)	(0.297)
Ship type Herfindahl	1.877*	1.785+	1.876*	1.822+
	(0.931)	(0.935)	(0.931)	(0.936)
Same-nation orders	0.101**	0.062**	0.100**	0.171**
	(0.019)	(0.013)	(0.019)	(0.030)
Same-nation sales	−0.317**		−0.300**	−0.386**
	(0.093)		(0.109)	(0.143)
Same-nation abandonment		−0.561*	−0.084	−0.195
		(0.260)	(0.289)	(0.283)
Model log likelihood	−549.03	−553.39	−548.99	−546.17
Likelihood ratio test	99.90**	91.19**	99.99**	105.61**
vs baseline model (d.f.)	9	9	10	10
Likelihood ratio test	14.43*	5.72*	14.52*	13.25**
vs Model 1 (d.f.)	1	1	2	2

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$, two-sided z tests.
Standard errors are in parentheses below each coefficient estimate. Model 9 uses a decay factor of 0.9 on the orders, sales, and abandonment variables. The likelihood ratio test for this model is against a re-estimated Model 1 that has same-nation orders discounted by 0.9.

innovation. One is information leaking from its adopters, as measured by deliveries of newly built ships and arrivals of secondhand purchases. The other is inferences from the actions of adopters, as measured by sales of ships and full abandonment of the ship type. The next step is to combine these effects and to examine the possible effects of the oil price increase. These analyses are shown in Table 4.

Model 10 combines orders, deliveries, and sales, and shows significant effects of each, though again the effect of correlation among these covariates is seen. Deliveries and sales are only significant at the 10 percent level when both are included. However, this is due to larger standard errors, not to smaller coefficient estimates, suggesting that the earlier models in which each is significant give an accurate portrayal of how the slowdown of the diffusion happens. Decision makers grow more skeptical, both as a result of deliveries and the information that may leak from the adopting organization, and from their interpretation of sales as evidence of disappointment by the selling organization. The greater standard errors also mean that the difference in magnitude of the coefficient of sales and orders are no longer significant, so Hypothesis 3 is no longer supported (it regains support in Model 13).

Next, Model 11 was estimated to examine the effect of the oil price increase, which would have reduced the profitability of ferries delivered after 1999. In this model, deliveries remain significant and sales gain in the level of significance, but the fit is practically unchanged. Hence, the model does not suggest that the oil price increase is especially important for explaining the effect of deliveries.

Model 12 is the same as Model 10, except that the diffusion variables have a decay specification, and it shows that the results are maintained except that the significance level of same-nation deliveries increases. The decay specification had better fit to the data, just as in the earlier tables. Likewise, Model 13 is Model 11 respecified with decay variables. It shows an improvement in fit over Model

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Table 4. Diffusion of fast ferries, models with deliveries and abandonments

	Model 10	Model 11	Model 12	Model 13
Ln GDP per capita	0.316**	0.306**	0.247*	0.235*
	(0.112)	(0.111)	(0.113)	(0.113)
Growth in GDP per capita	−0.008	−0.006	−0.003	0.003
	(0.040)	(0.040)	(0.042)	(0.041)
Firm age	−0.003	−0.003	−0.004	−0.004
	(0.004)	(0.004)	(0.004)	(0.004)
Firm size	0.618**	0.615**	0.597**	0.591**
	(0.144)	(0.144)	(0.144)	(0.144)
Ln average ship size	−0.811**	−0.809**	−0.787**	−0.782**
	(0.171)	(0.171)	(0.171)	(0.171)
Proportion passenger ships	−0.596*	−0.590*	−0.576+	−0.563+
	(0.294)	(0.295)	(0.297)	(0.300)
Ship type Herfindahl	1.836*	1.826+	1.760+	1.744+
	(0.930)	(0.933)	(0.934)	(0.940)
Same-nation orders	0.110**	0.105**	0.236**	0.211**
	(0.020)	(0.019)	(0.036)	(0.033)
Same-nation deliveries	−0.061+		−0.166**	
	(0.035)		(0.052)	
Same-nation deliveries, Post 1999		−0.054+		−0.126**
		(0.030)		(0.043)
Same-nation sales	−0.197+	−0.224*	−0.236+	−0.347**
	(0.111)	(0.104)	(0.134)	(0.134)
Model log likelihood	−547.37	−547.31	−539.48	−540.72
Likelihood ratio test vs baseline model (10 d.f.)	103.21**	103.34**	119.00**	116.52**
Likelihood ratio test vs Model 1 (2 d.f.)	17.75**	17.87**	26.63**	24.15**

+ $p < 0.10$; * $p < 0.05$; ** $p < 0.01$, two-sided z tests.
Standard errors are in parentheses below each coefficient estimate. Models 12 and 13 use a decay factor of 0.9 on the orders, deliveries, and sales variables. The likelihood ratio test for these models is against a reestimated Model 1 that has same-nation orders discounted by 0.9.

11, but not over Model 12. Hence, although the high fuel consumption is reported as a reason for the loss of popularity of fast ferries, the analysis does not single out the oil price increase as a shock that led to a decisive change in how the information from proximate deliveries was processed. It seems likely that other forms of negative information were also disseminated, such as the reliability problems that the fast ferries experienced.

Sensitivity tests[5]

Additional models were also estimated, but not shown in the tables. First, while the models in the tables are first-adoption models that remove each firm from the data once it has made its first adoption of a fast ferry, it is also possible to analyze adoption as a repeatable event. That analysis gave similar results as those shown in the table. Deliveries had a negative effect, and so did sales or abandonments, but high correlation of these variables led to marginal significance levels when they were entered jointly. This analysis also had an additional finding that underscored the heterogeneity of the value of fast ferries. An indicator variable for prior adoption was entered, and had a positive and significant coefficient estimate. Thus, while many firms abandoned the fast ferries they bought, some ordered additional ones.

Second, the models in the tables did not incorporate market saturation effects as one might get if each nation could only support a certain number of fast ferries. Nation differences make estimation of saturation difficult. However, models adding a quadratic effect of nation orders were also estimated, as saturation could be seen through a negative coefficient estimates for the quadratic term of

[5] This section has benefited from the valuable suggestions of two anonymous reviewers.

orders. This model showed a significant negative effect of the quadratic term of orders consistent with saturation, while the other effects remained significant. However, the estimates suggested that the rate decreases when the order count exceeds 25, which is true for only 4.2 percent of the observations. Hence, the substantive evidence for saturation is not strong.

Third, the negative effect of deliveries could also be interpreted as a competitive preemption effect. One test of this would be to increase the lag of the deliveries variable from one year to two and reestimate Model 2. The logic behind such a test is that preemption would be evident to other firms immediately after delivery (although it might occur when the order is placed as well), while negative value could take longer to understand. Thus, a worse fit of the two-year lag model would favor the preemption interpretation, while better fit would favor the disappointment interpretation. The two-year lag model had better fit than the model displayed in the table, suggesting disappointment, but the difference of Bayesian Information Criterion (BIC) statistics was in the inconclusive region.[6] The evidence is thus not strong enough to exclude competitive preemption as a contributing factor in the negative effect of deliveries on the adoption rate.

Fourth, the models were reestimated with the diffusion variables recalculated as proportions of the firms in each nation rather than counts of firms, giving results that closely matched those in the tables.

Fifth, to examine whether the negative estimate of deliveries might be a 'lever effect' resulting from its positive correlation with orders, models were estimated with deliveries entered but not orders. Deliveries were not significant in this model. This is expected because a model that does not specify orders is misspecified, as it fails to account for the influence of orders on adoptions, and the deliveries variable cannot capture both this (positive) effect and the later (negative) effect of outcome information being revealed post adoption.

Finally, if secondhand sales of fast ferries were a result of failed adoption, and hence were at a discounted price, they should be more likely to go to lower potential markets than the original adopting firm. A simple test of this is to examine whether the destination nation had lower GDP than the origin nation, as higher GDP nations tend to have a less price-sensitive customer base. Indeed, the transnation sales in the data were associated with an average drop in GDP per capita of 18.4 percent. While this is only suggestive evidence, it does indicate a likelihood that many sales were made at a discount.

DISCUSSION AND CONCLUSION

The canonical diffusion studies concern either an innovation of high value to all adopters (Rogers, 1995) or one of ambiguous value that obtains legitimacy through its spread (DiMaggio and Powell, 1983). Neither type covers the case of greatest interest to strategic management: an innovation of uncertain value *a priori* but potentially high positive or negative value after adoption—a value that may be heterogeneous across adopters. Innovations that are not only heterogeneous but also disappointing—so that most adopters experience a negative value—are of particular interest. A practical reason to be interested in disappointing innovations is that they present the greatest challenge for decision makers. A theoretical reason is that they reveal the differences between different information sources and types better than innovations that give out uniformly positive signals. Finally, they have seen little study, even though the existence of such diffusion processes has been noted by many (Apodaca, 1952; Burns and Wholey, 1993; Rao, *et al.*, 2001). By showing that the experience of others reduces the spread of disappointing innovations, this study has demonstrated that diffusion processes are sensitive to the outcomes experienced by the adopters.

The finding has particular interest because the empirical analysis concerns the diffusion of technological (and commercial) secrets, which is a distinct diffusion process because it is costly for the organizations that release information (Levitt and March, 1988). Innovations that may affect the competitive advantage of the adopting firm produce incentives to hide the true value. When the innovation is successful, there is a strong incentive to conceal this fact in order to delay its adoption by competitors. When the innovation is disappointing,

[6] The likelihood ratio test is the preferred statistic for model fit, but cannot be used here because these models are non-nested. Hence, the BIC test is used instead. See Raftery (1995) for details.

there is a weaker incentive to conceal the information, but a firm that wishes to offload investments associated with it to some third party may still wish to avoid broadcasting the negative value (Akerlof, 1970). Although the diffusion of secrets is distinct from the diffusion of innovations in which the organization that releases information is unaffected or positively affected (Levitt and March, 1988), it has not been given sustained research attention.

The adoption of highly heterogeneous innovations is a product of a very difficult decision-making problem, and it grows even more difficult when past adopters seek to avoid information release. Thus, it addresses the issues of information spread and belief formation that are so important in research on strategic decision making (Cyert and Williams, 1993). A key question in this research is how an innovation that originally seems promising, and thus gains some level of adoption, comes to be seen as disappointing. This question is central because it reveals how decision makers weight different types and sources of information. I made the simplifying assumption that firms can assess the value of the innovation they adopt after starting to use it (Strang and Macy, 2001), and this seems to be a good first approximation. The next step is more subtle, however, because it involves asking which other firms are in a position to discover this evaluation, perhaps with some error, or can infer it from the action of abandoning the innovation. If the innovation had the same value for all firms, this would be a trivial issue, but in the more realistic case of heterogeneously valued innovations, there is no easy answer. Broadly speaking, a greater weight of evidence will make a slowdown of the diffusion process more likely, but this leaves the question of how evidence is weighted for empirical investigation.

The answer provided by this investigation is that 'evaluations leak out.' Surprisingly, this leak seems to be as efficient as the inferences that can be drawn from the action of selling the innovative technology. Perhaps this is a result of the heterogeneity of value, which limits the inferences that can be drawn from sales (Terlaak and Gong, 2008). Information about the actual cost of operating an innovative technology, on the other hand, is more readily applicable to a decision even for firms that differ in other aspects, such as the market demand for the product made by the technology. The suggested weighting of evidence by firm is, thus, that actual use is the most powerful, sale by a proximate firm is less powerful, use by a proximate firm is potentially powerful but can give a range of different value signals, while adoption by another firm is the least powerful signal. However, this is a theoretical argument with limited evidence so far. Significantly more research is needed to verify these propositions and to examine whether local release of information can slow the diffusion of disappointing innovations.

For research on strategic decision making and diffusion processes, these findings suggest that the model of highly risk-averse decision making is less accurate than one of decision making under uncertainty, but with no special bias against adoption. The social construction model is supported by the role of the adoption of others, but the evidence obtained here suggests that the social construction is grounded in evidence from the outcomes of adopters. When this evidence suggests that the innovation has negative value, fewer firms adopt. Thus the decision makers are neither cowards nor dullards, but opportunistic users of available information about an innovation of uncertain value. Inferences from the behaviors of others enter the decision because other forms of diagnostic information are scarce.

The scarcity of research on disappointing innovations suggests that replication of these findings would be valuable. The prediction that discrediting information will slow the diffusion is an important addition to diffusion theory, so the main difficulty to overcome is finding suitable data. The approach used here of separating the adoption decision from the post-adoption learning is highly effective for innovations that are purchased as investment goods, and should be a productive approach for future work as well. Abandonment decisions are also informative, as other studies have found (Burns and Wholey, 1993; Greve, 1995; Rao *et al.*, 2001), and it is particularly important to compare these two information sources as the present study has done.

The findings of this investigation clearly show the benefits of being well placed to receive information about innovations. When a disappointing innovation spreads, there are savings from learning from others' disappointments instead of one's own. Even better, a firm that learns not only that an innovation is disappointing on average but also about the heterogeneity in its value, might be able to use this knowledge to selectively adopt it in situations

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where it is most beneficial. Given the wave of secondhand sales seen in the aftermath of diffusion processes such as the one studied here, such a firm would gain greatly. The more common patterns seen in this data are firms that adopt and then abandon after a short period of use, and firms that adopt and learn from their own experience that additional adoptions are beneficial. Heterogeneity in value seems to place a premium on own experience, to the cost of many firms when the innovation is disappointing in general.

A promising extension of this work would be to examine the effect of firm attributes on the relevance judgments on managers who consider information from past adopters. Relevance judgments have been shown to influence how past adoption decisions are evaluated (Haveman, 1993; Greve, 1998; McKendrick, 2001), and have been predicted for abandonment decisions as well (Terlaak and Gong, 2008). Another extension would be to examine additional channels of information on the value of innovations. The local influence from same-nation deliveries shown here is most likely founded in concrete connections between the firms, such as personal friendships among managers or job mobility across the firms. Examination of these mechanisms would shed light on how firms can identify which innovations to adopt and which to avoid under the difficult conditions of uncertainty and heterogeneous value of adoption. New knowledge on how decision makers select which uncertain innovations to adopt and which to avoid would be a major contribution to the study of strategic decision making.

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