EXTERNALITIES, INCENTIVES AND STRATEGIC COMPLEMENTARITIES: UNDERSTANDING HERD BEHAVIOR IN INFORMATION TECHNOLOGY ADOPTION

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“Externalities, incentives and strategic complementarities: understanding herd behavior in IT adoption,”

ABSTRACT

Herd behavior arises in many instances of information technology (IT) adoption. This study examines the economic and behavioral bases for herd behavior and decision conformity. We investigate the roles of payoff externalities, observational learning and managerial incentives in influencing IT adoption decision-making. Our study underscores the benefits of viewing various drivers of IT adoption herding in a unified framework focusing on equilibrium coordination under strategic complementarities. Motivated by the recent advance in behavioral economics and behavioral game theory, our study relates IT adoption herding to a range of individual-level problems, including managerial incentives, managerial behavioral biases and limited rationality. We develop a coordination game of IT adoption within the unified framework. Our analysis of the game demonstrates that, under strategic complementarities, behavioral biases or incentive problems of a small minority of decision-makers may dramatically impact aggregate outcomes.

Keywords: Behavioral game theory, bounded rationality, economic theory, equilibrium coordination, herd behavior, informational cascades, IT adoption, managerial behavioral biases, network effects.
1. INTRODUCTION

In recent years, there have been many instances of information technology (IT) adoption in which we have observed herd behavior, as many decision-makers lost touch with their own cautious value-maximizing approaches to investment decision-making, and decided to follow the decision of a few “smart cookies.” Bikchandani and Sharma (2001) define herd behavior in terms of three related aspects: (1) the actions and assessments of investors who decide early will be critical to the way the majority decides; (2) investors may herd, or organize their adoption behavior on the basis of the wrong information, which may lead to the wrong decision; and (3) if they do make the wrong decision, then experience or new information may cause them to reverse their decisions, and a herd may be created in the opposite direction. We adopt a more general view of herd behavior and consider it to be a manifestation of behavior conformity that may or may not require learning and information transmission among decision-makers (Bernheim 1994).

Herd behavior has long been studied in other academic fields, including finance and economics, where the literature is well developed. See Bikchandani et al. (1996) for a comprehensive review. In some cases, such as stock market upswings or the Internet bubble in the early 2000s, herding is driven— in the well-known words of past Federal Reserve Bank Chairman, Alan Greenspan—by people’s “irrational exuberance” (the “hype” part of the well-known hype cycle). Recent theoretical and empirical stud-
ies suggest that, in many other cases, herd behavior is rather counterintuitively caused by the decisions of reasonably rational people. In some situations, such rational decisions at the individual level may result in significant information and welfare losses in the marketplace and the economy.

In IT adoption, herd behavior has the potential to generate several problems. First, valuable information about new technologies may be lost (or at least poorly aggregated) when IT managers blindly follow others’ adoption decisions. Second, payoff externalities-driven herding makes early adopters’ decisions disproportionately important, and it gives other adopters little chance to compare and experience different technologies. Third, managers may intentionally imitate others’ adoption decisions because of their career concerns, and their reputation-motivated decisions usually fail to maximize expected IT investment payoffs (Ottaviani and Sørensen 2006; Scharfstein and Stein 1990).

These potential problems motivate us to investigate the basis for herd behavior in IT adoption. A common and well-studied justification for IT adoption herding is positive payoff externalities often induced by positive network feedback.1 Recent studies have indicated that many technology markets are subject to positive network feedback that makes the leading technology grow more dominant (Brynjolfsson and Kemerer 1996; Gallaugher and Wang 2002; Kauffman et al. 2000; Li 2009a, 2009b). Because positive network feedback makes a firm’s IT adoption returns rise when others adopt the same technology, it usually gives managers strong incentives to adopt the technology with the larger installed base of users. In addition to the studies of positive payoff externalities, a few information economics studies demonstrate how rational herd behavior may arise because of informational cascades (Banerjee 1992; Bikhchandani et al. 1992, 1998) or managers’ career concerns (Scharfstein and Stein 1990; Zwiebel 1995). Both theoretical perspectives emphasize the role of information processing and transmission in influencing investment decision-making.

Informational cascades occur when individuals ignore their own private information and instead mim-

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1 Network externalities may not necessarily lead to positive payoff externalities. In some situation where firms adopt same technology to compete with each other, the competitive losses due to congestion effects may dominate the gains from positive network feedback. Positive payoff externalities, even in markets without strong competitive pressures, are usually concave in network size.
ic the actions of previous decision-makers. Those mimetic strategies are rational when private information, swamped by publicly-observable information accumulated over time, becomes statistically irrelevant (Li 2004; Duan, et al. 2009). This is why informational cascading is sometimes referred to as *statistical herding* (Ottaviani and Sorensen 2000). Like informational cascade models, career concerns models have information economics and Bayesian games as their theoretical foundations, but they are distinguished by examining investment herding through the lens of agency theory. The primary implication of those models is that managers concerned about their reputations may imitate others’ investment decisions to positively influence others’ inferences on their professional capabilities. Although reputational herding decisions are rational for individual managers maximizing their human capital returns, they are usually not in the best interests of those firms that hire their managers to maximize investment payoffs.

Empirical evidence of herd behavior has been recently documented in stock analysts’ equity recommendations, emerging technology adoption, and television programming selection (Hong et al. 2000; Kennedy 2002; Walden and Browne 2002; Welch 2000). There is also extensive experimental evidence of rational herding and informational cascades in the economics literature (Alevy et al. 2006; Anderson and Holt 1997; Celen and Kariv 2004a; Hung and Plott 2001). Another related experimental study of behavioral conformity used senior IT and business decision-makers instead of college students as subjects (Tingling and Parent 2002). (For a review of the literature on rational herding, interested readers should see Devenow and Welch 1996, and Bikhchandani et al. 1996, 1998.)

Despite the growing literature on herd behavior and some anecdotal evidence of decision conformity in IT adoption, systematic studies of IT adoption herding are still rare in the information systems (IS) literature (Weber and Kauffman 2011). Based on a synthesis of the previous rational herding models, we propose a unified theoretical framework within which the interplay among various drivers of IT adoption herding can be better understood. In particular, our study makes a contribution by illuminating the relationship between strategic complementarities and adoption decision conformity. Consequently, it demonstrates why IT adoption with strategic complementarities is a unique and important context for studying herd behavior. By linking herding behavior to coordination under strategic complementarities, our work
also sheds fresh light on the role played by incentive problems and limited rationality in influencing IT adoption dynamics.

2. PAYOFF EXTERNALITIES: DOES ADOPTION HERDING PAY OR HURT?

One type of positive payoff externalities commonly observed in the IT market is network externalities (Economides 1996; Katz and Shapiro 1994). Network externalities are sometimes referred to as demand-side economies of scale. They stem from the presence of significant technology switching costs and the benefits associated with a large installed base of compatible technologies. In the context of IT adoption, network externalities tend to reward herding decisions by increasing the payoffs to IT adopters who associate themselves with the majority. Herding in the presence of network externalities also decreases IT adopters’ risks of being stranded in technologies with too small installed user bases. See Table 1 for some related constructs.

**Table 1. Key Constructs Related to Payoff Externalities in IT Adoption**

<table>
<thead>
<tr>
<th>CONSTRUCT</th>
<th>DEFINITION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rational IT adoption herding</td>
<td>IT adoption herd behavior that can be justified by an individual decision-maker’s rationality.</td>
<td>Three types of rational justifications exist for IT adoption herd behavior.</td>
</tr>
<tr>
<td>Network externalities</td>
<td>A type of externality involving positive payoffs. The value of a technology increases as the number of users increases. Often referred to in prior literature as network effects.</td>
<td>Common in IT markets, and create payoff incentives for decision-makers to herd in IT adoption.</td>
</tr>
<tr>
<td>Negative payoff externalities</td>
<td>Occur when a firm’s return from adopting a technology decreases as more firms adopt the same technology.</td>
<td>They usually punish IT adoption conformity and make informational cascades less likely to occur.</td>
</tr>
<tr>
<td>Technology switching costs</td>
<td>Costs incurred for a user to switch from one technology to another. Users may face technology lock-in if switching costs are significant.</td>
<td>Adopters facing significant switching costs may have more incentives to join an IT adoption herd.</td>
</tr>
<tr>
<td>Tippy markets</td>
<td>Markets subject to strong network externalities make technology competition highly unstable and one technology can quickly become dominant.</td>
<td>Tippy markets coexist with massive herd behavior in IT adoption, and can create “winner-take-all” situations.</td>
</tr>
</tbody>
</table>

In technology markets subject to network externalities, IT diffusion processes are often characterized by *path dependencies*. They represent the situational specifics of irreversible managerial decisions and their impacts on the decisions of others. Many managers believe that network externalities and technology switching costs work in tandem to justify imitative technology adoption. In some cases, strong network effects create a “tippy” technology market, in which one technology very quickly emerges as the domi-
nant product because of massive adoption imitation. In such a winner-take-all market, most managers have strong incentives to associate themselves with the winner by quickly jumping on the bandwagon. Thanks to the adoption irreversibility caused by significant technology switching costs, this herding strategy is usually not a risky one. In many cases, the extrinsic network effects (sometimes also called *indirect network externalities*) created by complementary products and services can further increase the benefits of herding (Basu et al. 2003; Gallaugher and Wang 2002).

Although herd behavior driven by network feedback can be easily justified by individual rationality, it may lead to information and welfare losses. When strong network externalities are present, the installed user bases of competing technologies often play important roles in influencing adoption decision-making. Consequently, many managers cannot concentrate on the intrinsic merits and suitableness of competing technologies. Under many circumstances they do not even have enough time to compare all available technology choices because the competition may end very quickly in favor of a specific technology (Kauffman and Li 2005).

So does network externality-driven IT adoption herding pay off? Or does it hurt firms that adopt this way? At the individual level, each decision-maker gains by joining the herd and taking advantage of the positive network feedback. However, many decision-makers lose a chance to deliberate on the associated opportunities. Very often, as some have claimed for the VHS video format winning out over the Sony Beta format, the market may end up adopting an inferior technology, which will hurt all adopters in the long run. (Note that network externality is only one of the factors that made VHS prevail in the competition).

Payoff externalities, as a stand-alone justification for rational IT adoption herding, has its limitations. Strong network externalities may not be so pervasive in the technology market as many IT and business strategists expected (Liebowitz 2002; Li 2005; Porter 2001). As a result, imitative technology adoption strategies driven by those illusive network effects are not even rational at individual levels. Moreover, technology managers sometimes choose to adopt emerging technologies with superior performance instead of imitating others by using the dominant technology. Clearly, there is a tradeoff between the future
potential of superior new technologies and the network benefits of current technologies. Adoption herding may not persist if some firms find that the benefits of exploring new ITs outweigh those of exploiting the dominant IT with network benefits (Lee et al. 2003).

It is also worth noting that payoff externalities can be either positive or negative. Unsurprisingly, negative payoff externalities play an important role in mitigating a technology market’s propensity to adoption conformity. They are commonly seen in many competitive business environments where downward-sloping demand curves make a firm’s IT adoption payoff decrease as more firms adopt the same technology. Therefore, firms that imitate others’ IT investment decisions may be punished by intense *ex post* competition in the downstream market (Li 2004). Both the fiber cable network glut and the e-commerce gold rush exemplify how severely IT adoption herding may have been penalized by negative payoff externalities. Interestingly, herd behavior still happens in situations where negative payoff externalities are evidently present (Kennedy 2002). Because of the limitations of payoff externalities as a justification for rational adoption herding, we need to investigate other theoretical explanations of firm-level IT adoption herding.

3. INFORMATION EXTERNALITIES: TOO MUCH OR TOO LITTLE INFORMATION?

The theory of payoff externalities-driven adoption herding does not sufficiently emphasize two important features that are present in IT diffusion. The first feature is that *information asymmetries* and *information incompleteness* are pervasive in emerging technology markets. Different decision-makers have their own judgments about the value of a new technology based upon their own private information, and generally no one possesses perfect information in adoption decision-making. These information structure problems lead to the second feature: to improve decision quality, decision-makers try to learn valuable information by observing others’ IT adoption decisions. For those who make adoption decisions earlier, their actions may reveal private information to others, which generates *information externalities* (Celen and Kariv 2004b; Zhang 1997). Table 2 presents several key constructs related to information externalities. It emphasizes that the presence of information asymmetry and incompleteness gives decision-makers
incentives to engage in observational learning. In many competitive environments where credibility is an issue about word-of-mouth communication, observational learning is normally considered more reliable than conversational learning.

Table 2. Key Constructs Related to Information Externalities in IT Adoption

<table>
<thead>
<tr>
<th>CONSTRUCT</th>
<th>DEFINITION</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information asymmetry</td>
<td>Occurs when some parties know more relevant information than others in business transactions.</td>
<td>Can reduce market efficiencies, such as IT adoption herding.</td>
</tr>
<tr>
<td>Information incompleteness</td>
<td>Refers to situations in which decision-makers do not have complete information to make business decisions.</td>
<td>Pervasive in IT adoption; tends to negatively impacts adoption decisions quality.</td>
</tr>
<tr>
<td>Informational cascade</td>
<td>Decision-makers ignore their own private information that is overwhelmed by publicly observable information, and instead mimic others’ actions.</td>
<td>A primary mechanism that causes IT adoption herding.</td>
</tr>
<tr>
<td>Observational learning</td>
<td>Social learning process in which decision-makers acquire new information by watching others’ actions.</td>
<td>Used by IT adopters to obtain new information; may cause informational cascade.</td>
</tr>
<tr>
<td>Word-of-mouth learning</td>
<td>Decision-makers acquire new information through interactions with others; also called conversational learning.</td>
<td>A social learning mechanism in IT diffusion. Credibility is an issue.</td>
</tr>
</tbody>
</table>

Although observational learning can facilitate information transmission, it sometimes results in an informational cascade in which most people adopt the same technology independent of their own private information. Similar to the decision-making process that appears to be operative in the judicial body depicted in the cartoon at the beginning of this article, the reason why informational cascades occur with IT adoption is because the information revealed through others’ adoption actions may have accumulated enough to overwhelm a decision-maker’s imprecise private information. The opinions of Supreme Court justices, just like the opinions those expressed in a marketplace in which managers make IT adoption decisions, carry substantial weight with others. In this kind of situation, the action of a decision-maker (like an otherwise highly experienced Supreme Court justice) may not depend on his private information. Instead decision-makers may rationally disregard their own information and imitate the prevailing decision, which makes their actions convey no new information to later decision-makers. The outcome is that valuable private information will be lost, and market efficiency will be negatively impacted because of poor information aggregation.

A related question is whether informational cascades result from too little or too much information. Corporate decision-makers frequently struggle with too little information to make sound IT adoption de-
cisions. That is why they want to gather and share valuable information from observing one another’s adoption actions (Au and Kauffman 2004). Paradoxically, once they engage in observational learning, they may obtain too much accumulated information, to the extent that it may be strong enough to swamp their private information. As a consequence, an informational cascade will occur and most people will imitate a few early adopters’ decisions that are unfortunately based upon very limited information.

As two mechanisms that cause IT adoption herding, informational cascades and network externalities are not mutually exclusive; in fact, they can be mutually reinforcing. Informational cascades are sometimes fragile though: they can be stopped or reversed by enough newly-arrived information. For example, many firms will be observed to adopt Technology A over Technology B in a herd when their private information is dominated in an informational cascade, even though everyone knows that the valuable information contained in such a cascade is limited. If some credible information is revealed to support Technology B, the adoption cascade can be quickly stopped or reversed. Informational cascades are more resilient in the presence of network externalities though. Once formed, later IT adopters who intentionally aggregate to reap the benefits of positive network feedback will reinforce the informational cascade (Li 2004).

The strength of informational cascade theory as an explanation for rational IT adoption herding is its emphasis on social learning under information asymmetries. Social learning can sometimes mitigate a market’s propensity to be influenced by informational cascades though. Most informational cascade models assume that decision-makers can only infer information from observing others’ actions. This exacerbates the information aggregation problem of rational herding. In a simple world where every decision-maker truthfully tells others his private information, no valuable private information will be lost and the information aggregation problem disappears. In fact, prior innovation diffusion studies have recognized the significant role played by word-of-mouth learning in affecting technology diffusion (Rogers 1995).

Nevertheless, the effectiveness of informal and conversational information sharing in preventing informational cascades should not be overestimated. The major obstacle for effective word-of-mouth learning under many IT adoption scenarios is that individual decision-maker may not have truth-telling incen-
tives. Potential adopters can benefit from talking with early adopters if what they are told is credible. But who can guarantee the truthfulness of the so-called cheap talk? In competitive environments where most IT adoptions occur, individuals may have strong incentives to misinform others through strategic lying or signal jamming (Crawford 2003). At the market level, informational cascades are more likely to occur when the incentive problems associated with information revelation block credible conversations. At the firm level, decision-makers’ incentives sometimes cause agency problems that provide another explanation for rational IT adoption herding.

4. MANAGERIAL INCENTIVES IN ADOPTION: PROFITS OR REPUTATION?

Since a herd involves a group of decision-makers, it is natural for researchers to concentrate on understanding the market-level interaction dynamics, such as payoff and information externalities. Significant developments in agency and incentive theory (Laffont and Martimort 2002) over the last three decades have nourished a new stream of rational herding research that explores the role of managerial incentives in fostering investment herding, however. (See Table 3 for definitions of reputational herding and incentive incompatibility).

Table 3. Key Constructs Related to Reputational Herding in IT Adoption

<table>
<thead>
<tr>
<th>CONSTRUCT</th>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputational herding</td>
<td>Managers concerned about their careers intentionally engage in IT adoption herding to enhance their professional reputations and to increase their own human capital returns.</td>
<td>Driven by implicit incentives of career-concerned managers and informational asymmetries in IT adoption.</td>
</tr>
<tr>
<td>Incentive incompatibility</td>
<td>Economic situations where interests of different parties are not perfectly aligned because of the differences in their objectives and motivations.</td>
<td>Without effective incentive contracts to ensure incentive compatibility, managers may engage in inefficient adoption herding.</td>
</tr>
<tr>
<td>Agency problems</td>
<td>Refers to those economic inefficiencies caused by conflicting incentives and information asymmetries between principles and their agents.</td>
<td>Agency problems in IT adoption sometimes cause managers’ sub-optimal decisions, including imitative adoptions.</td>
</tr>
</tbody>
</table>

Traditional capital budgeting theory suggests that firms maximize expected investment payoffs when they make their IT adoption decisions. Corporate managers hired by a firm’s owners or shareholders may have incentives to deviate from the firm’s goals and to pursue their own interests when they make IT
adoption decisions though. The conflicts of interest, coupled with information incompleteness, can lead to inefficient outcomes known as *market for lemons* problems, adverse selection or moral hazard.

In a seminal paper in agency theory, Holmström (1999) shows that reputation-concerned managers are very likely to make inefficient investment decisions in the absence of effective mechanisms to align their own interests with those of their firms. In some cases where managerial incentive problems are present, managers may herd solely for reputational purposes in investment decision-making. Scharfstein and Stein (1990), in their reputational herding model, make the case that many managers tend to intentionally imitate others’ investment decisions to improve their professional reputations. Intentional herding comes from the belief that managers do not wish to run the risk of being associated with those who are not identified as being in the highly-talented group. In a more specific context, reputation and career concerns are found to be important in promoting security analysts’ herd behavior commonly seen in their stock recommendations or earning forecasts (Graham 1999; Hong, Kubik and Solomon 2000).

We believe that reputational herding theory has some advantages in helping us to understand IT adoption herding. Like other important corporate investment decisions, senior managers usually make IT adoption decisions. Because their adoption decisions are not immune to agency and incentive problems, they will imitate others’ decisions to enhance their professional reputations if the situation warrants. Moreover, IT adoption decisions – especially strategic IT adoption decisions – are usually more susceptible to reputational herding. This is not because a good decision-making reputation is more valuable to IT managers like CIOs than to other managers. Instead, it is because the informational problems are usually more severe. Under many IT adoption scenarios, managers have to make their IT adoption decisions quickly with very limited information. Because IT adoption decisions are highly specialized tasks that involve a lot of technical details, there are also significant information asymmetries between the decision-makers (IT managers) and their supervisors (the firms’ owners or board of directors). Furthermore, the economic payoffs of many IT investments are notoriously difficult to observe or measure, at least in the short run, which gives managers more room to enhance their own reputations at the expense of their firms.
Most reputational herding studies use signaling or signal jamming games in which managers try to positively influence their supervisors’ and the labor market’s posterior beliefs about their capabilities through their investment decisions. Because the owners of firms or the labor market usually lack concrete evidence to indicate whether an individual IT project will be successful in the short run, IT managers’ professional reputations will heavily depend on the market consensus reached by peer managers or – if the project is very large and affects the entire firm’s prospects – short-term stock market reactions. As a result, IT managers who are concerned with their reputations are more likely to exhibit herd behavior in their IT adoption decisions than those who are not.

When IT managers are concerned about their career prospects, imitating the IT adoption decisions of others will be fully rational if doing so will result in a better professional reputation. The potential inefficiency and welfare losses stem from the conflicting interests among different parties. Therefore, the key to preventing inefficient reputational herding is to address the issue of incentive compatibility. By offering managers appropriate compensation contracts, firms in theory can provide them with explicit incentives to maximize investment returns.

Two difficulties arise in the context of IT adoption, however. First, it is usually hard to prospectively quantify IT investment payoffs. Incentives from ambiguously designed performance-based contracts are easily subjugated by the implicit incentives from managers’ career concerns. For example, compensation contracts based on short-term stock prices may exacerbate the efficiency losses caused by rational investment herding (Brandenburger and Polak 1996). Second, long-term performance-based compensation, like a bonus of stock options, is thought to be more effective in solving agency problems. However, an IT manager’s decision, unlike a chief executive officer’s, generally will have less impact on a firm’s overall performance. Therefore, long-term performance-based compensation must be significant enough to overpower managerial incentives for reputation building, which makes these compensation schemes very expensive to implement. We encourage IS researchers to study how to overcome this problem in designing optimal incentive contracts for managers who routinely make IT adoption decisions.
5. COORDINATION UNDER STRATEGIC COMPLEMENTARITIES

An in-depth understanding of the rational herding theories that we have discussed is the prerequisite for effective analyses of observed herd behavior in IT adoption. In this section, we first provide a synthesis of critical drivers of adoption herding. We then reexamine their roles in a unified framework that emphasizes coordination under strategic complementarities. We discuss why herd behavior may simply result from coordination among decision makers whose strategies complement each other. Using a simple coordination game of IT adoption, we further demonstrate that, in situations where strategic complementarities are present, aggregate IT adoption outcomes may be drastically changed by behavioral biases or incentive problems of a small minority of decision-makers.

5.1. A Synthesis of the Critical Drivers of Adoption Herding

We will address two issues before discussing the benefits of viewing herd behavior in a unified framework focusing on strategic complementarities. First, almost all rational herding models in the literature study investment herding in generic investment settings. Although studying herd behavior in generic investments increases the generality of the results, it sometimes fails to capture the distinctive features of certain types of investment like IT adoption. Table 4 shows how certain features of IT investments can make herd behavior and decision conformity more likely to occur.

Table 4. A Comparison between Generic Investments and IT Investments

<table>
<thead>
<tr>
<th>DRIVERS OF HERD BEHAVIOR</th>
<th>GENERIC INVESTMENTS</th>
<th>IT INVESTMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payoff externalities</td>
<td>Under many investment scenarios, it is unclear whether positive payoff externalities exist. Negative payoff externalities, existing in many competitive environments, may curb investment herding.</td>
<td>Many IT markets are subject to network externalities. Network effects and significant IT switching costs are the driving forces behind many instances of IT adoption herding.</td>
</tr>
<tr>
<td>Informational cascades</td>
<td>Decision-makers imitate others’ investment decisions when their private information is overwhelmed by the information acquired through observational learning. Cascades are generally fragile because they are often overturned by new public information.</td>
<td>Information incompleteness and information asymmetries in the IT market make observational learning important for decision-makers, and thus increase the possibility of an informational cascade. Because of positive network feedback, cascades are much more resilient to new information.</td>
</tr>
<tr>
<td>Reputational herding</td>
<td>Managers imitate others’ decisions to build their reputations and to increase their own human capital returns. For most investment projects whose returns are measurable, performance-based incentive contracts may alleviate the problem.</td>
<td>The financial returns of most IT investments are hard to measure, especially in the short run. Thus, contractual incentive provisions become much more difficult, which strengthens incentives for managers to engage in reputational herding.</td>
</tr>
</tbody>
</table>
Second, the three explanations for rational IT adoption herding that we have discussed so far have their own strengths and weaknesses. They rely on different theoretical foundations and emphasize different aspects of IT adoption. Table 5 compares the three types of adoption herding models.

**Table 5. A Comparison of IT Adoption Herding Models**

<table>
<thead>
<tr>
<th><strong>Comparison Dimensions</strong></th>
<th><strong>Payoff Externality-Driven Models</strong></th>
<th><strong>Informational Cascade Models</strong></th>
<th><strong>Reputational Herding Models</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical foundations</td>
<td>Payoff interdependency and strategic complementarities.</td>
<td>Information economics and Bayesian learning.</td>
<td>Information economics, contracting and agency theory.</td>
</tr>
<tr>
<td>Aspects of IT adoption emphasized</td>
<td>Switching costs and network externalities.</td>
<td>Information externality and social learning in IT adoption.</td>
<td>Managers’ incentives and career concerns in IT adoption.</td>
</tr>
<tr>
<td>Strengths of the theory</td>
<td>Many IT markets are subject to positive network feedback. Herding models are generally more intuitive and robust.</td>
<td>Models demonstrate how herding arises because of information asymmetries and the problems associated with observational learning.</td>
<td>Shows herding may be caused by managerial incentive problems and thus builds a bridge between agency theory and rational herding theory.</td>
</tr>
<tr>
<td>Weaknesses of the theory</td>
<td>Hard to explain herding in situations where network externalities are weak or negative payoff externalities are strong.</td>
<td>Simplified assumptions of market information structure and learning processes make these models unrealistic in some settings.</td>
<td>The conditions that lead to herding are complex and less obvious. Most models only deal with simple investment settings.</td>
</tr>
</tbody>
</table>

We believe that, to capture the important features of IT adoption herding, it is imperative to have a unified theoretical framework that reconciles the three explanations of herd behavior and, at the same time, yields new implications for future research. A key feature shared by most herding models is that various types of economic externalities (e.g., payoff or informational) may strengthen a decision-maker’s incentive to join a herd as more decision-makers join it. In game theory, this feature can be analyzed in a game with strategic complementarities (i.e., a supermodular game). In such a game, a player has stronger incentives to increase his strategy as other players increase their strategies and, as a result, players are generally better off when their strategies match each other (Milgrom and Roberts 1990; Vives 2005).

There are several benefits of examining herd behavior in a framework focusing on strategic complementarities. First, it is easy to justify the existence of strategic complementarities in most IT adoption situations where positive feedback and externalities abound. Second, there are some powerful tools for theorists to analyze supermodular games, including monotone comparative statics and the lattice theory,
which can be readily applied to model herd behavior in IT adoption. Third, such a framework demonstrates why herd behavior is more likely to occur when there are coordination difficulties under strategic complementarities. Fourth, this framework suggests that herd behavior is sometimes a manifestation of some structurally unstable decision-making environments where aggregate outcomes are very sensitive to behavioral biases or incentive problems of a small minority of decision-makers.

Table 6 shows the relationships between strategic complementarities and the three drivers of herd behavior proposed in the extant literature.

Table 6. A Unified Framework of IT Adoption Herding under Strategic Complementarities

<table>
<thead>
<tr>
<th>DRIVERS OF HERD BEHAVIOR</th>
<th>RELATIONSHIPS TO STRATEGIC COMPLEMENTARITIES</th>
<th>NEW IMPLICATIONS YIELDED BY THE UNIFIED FRAMEWORK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Payoff externalities</td>
<td>Positive payoff externalities often result in strategic complementarities. So powerful tools like monotone comparative statics can be readily used to analyze herd behavior in IT adoption.</td>
<td>Complementarities resulting from payoff externalities often lead to multiple equilibria in IT adoption. Herd behavior is more likely to occur because equilibrium selection is very sensitive to exogenous shocks or new public information.</td>
</tr>
<tr>
<td>Information externalities</td>
<td>Information externalities may also lead to strategic complementarities. When multiple equilibria exist, social learning can play an important role in influencing equilibrium coordination and belief formation (including higher order beliefs).</td>
<td>Observational learning may lead to Informational cascades in sequential IT adoption. It may play a more significant role in assisting decision-makers to coordinate their IT adoption decisions though.</td>
</tr>
<tr>
<td>Managerial behavioral biases and incentive problems</td>
<td>Reputation-based IT adoption herding is usually not dependent on strategic complementarities. Strategic complementarities often amplify the impacts of managerial incentive problems on aggregate IT adoption outcomes.</td>
<td>Under strategic complementarities, behavioral biases or incentive problems of a small minority of decision-makers sometimes dramatically impact aggregate outcomes. Depending on the efficiency of the resultant equilibrium, their impacts have different welfare implications for IT adoption.</td>
</tr>
</tbody>
</table>

Moreover, it shows that unifying the three theoretical perspectives in one framework can yield new insights into IT adoption decision-making. It is well known in the macroeconomics literature that strategic complementarities are often associated with multiple equilibria that may generate coordination difficulties (e.g., Cooper and John 1988). Herd behavior naturally emerges if there is a unique symmetric equilibrium on which all decision-makers coordinate. In these situations, herd behavior may be welfare-enhancing because, under strategic complementarities, all players are better off when their strategies match each other. However, because of equilibrium multiplicity in many coordination settings, equilibrium selection and coordination are very sensitive to exogenous shocks, new public information and information transmis-
sion mechanisms. Consequently, herd behavior that we observe in most IT adoption situations is characterized by impulsiveness, fragility and fad, which may lead to very complicated welfare implications.

While reputation-based IT adoption herding is not dependent on strategic complementarities, strategic complementarities often amplify the impacts of managerial incentive problems on aggregate IT adoption outcomes. Recent developments in behavioral game theory has provided strong evidence suggesting that, under strategic complementarities, a small minority of boundedly rational decisionmakers may disproportionately influence aggregate outcome. In many situations where strategies complement, rational decisionmakers are better off by mimicking the behavior of less rational ones (Camerer and Fehr 2006; Fehr and Tyran 2005). In our opinion, incentive and informational problems, like limited rationality, may lead to herd behavior as decisionmakers strive to coordinate under strategic complementarities. Depending on the efficiency of the equilibrium on which decisionmakers try to coordinate, herd behavior has remarkably different welfare implications for IT adoption. We elucidate these points using a stylized coordination game under strategic complementarities.

5.2. A Coordination Game of IT Adoption

There is a continuum of decision-makers of size one. Each decision-maker must decide whether to adopt an emerging IT. If a decision-maker adopts the technology, his payoff is given as \( r = \alpha \theta - \beta \), where \( \theta \) is the portion of decision-makers who adopt the technology. The cost of adoption \( \beta \) is evenly distributed on the unit interval \([0, 1]\), and each decision-maker knows his own adoption cost. As such, each decision-maker in this model can be indexed by his adoption cost. When a decision-maker decides whether to adopt the technology, he has the option to stay with the current technology. His payoff is normalized to zero if he chooses to stay with the old technology. So the investment payoff in our model is essentially the decision-maker’s incremental benefits from adopting the new technology. There are strategic complementarities, this is, \( \alpha > 1 \). So the adoption payoff increases as more decision-makers adopt the tech-
nology.² As demonstrated in the Two IT Adoption Scenarios Proposition (P1), when $\alpha > 1$, there is a payoff-dominant equilibrium in which everyone adopts the technology. (For the propositions and proofs, see the Appendix.) Furthermore, no one adopts the technology in equilibrium when $0.5 < \alpha < 1$. Therefore, when $\alpha$ is close to one, the equilibrium outcome is very sensitive to exogenous shocks or new public information. In this type of situation, herd behavior may be triggered when some minor change in some parameter like $\alpha$ occurs and forces decision-makers to coordinate on a different equilibrium.

Consider the situation where $0.5 < \alpha < 1$. If it is common knowledge that all decision-makers are rational, the unique equilibrium predicts that no adoption will occur. Suppose that a small portion, $0 < \eta < 1$, of decision-makers has limited rationality and believes that $\alpha > 1$. So their payoff-dominant strategy is to adopt the technology. This type of overestimation of strategic complementarities may occur when decision-makers formed inflated beliefs about network externalities (Li 2005). Liebowitz (2002) reminds us that “many business models applied to e-commerce were often based on unsupported and ultimately incorrect assumptions that all of e-commerce was subject to powerful network effects. How much of the [early 2000s] Internet meltdown can be laid at the doorstep of these mistaken business strategies cannot be ascertained with any precision, but a substantial portion of the damage can certainly be attributed to them.” Inflated beliefs about strategic complementarities may also be caused by the irrational exuberance surrounding some new technology (Porter 2001), managerial optimism (Graham et al. 2013) or decision-makers’ overconfidence (Malmendier and Tate 2005).

To avoid technical complications, we assume that boundedly-rational decision-makers’ adoption costs are also evenly distributed on the unit interval, so that whether a decision-maker has limited rationality will not depend on his adoption cost. Knowing all the boundedly-rational decision-makers will adopt the technology, rational decision-makers now have different expectations of the equilibrium outcome. Under this limited rationality scenario, only rational decision-makers will play the IT adoption game. It is com-

² The application of a linear payoff function, coupled with evenly-distributed idiosyncratic adoption costs, leads to a unique adoption equilibrium. When the cumulative distribution function takes a more general forms, multiple equilibria often emerge for this setting.
mon knowledge among the rational players that a small portion of the decision-makers will have inflated beliefs. In other words, the adoption decisions of those decision-makers with limited rationality will be exogenous to the adoption game played by all rational decision-makers.

As demonstrated in the Fully-Rational Decision-Makers’ IT Adoption Proposition (P2), because of strategic complementarities, a portion, $0 < \lambda < 1$, of the players will imitate less rational decision-makers’ strategy and adopt the technology in equilibrium, where $\lambda$ satisfies $\alpha [\eta + (1 - \eta)\lambda] = \lambda$. We conducted some numerical experiments, and they revealed that, when $\alpha$ is close to one, a small minority of boundedly-rational decision-makers may incentivize a significant portion of rational decision-makers to adopt the technology. (See Figure 1.)

**Figure 1. Percentage of Rational Decision-Makers Adopting the Technology in Equilibrium**

![Figure 1](image_url)

The results of our analysis reinforce Camerer and Fehr’s (2006) argument that the impact of boundedly-rational players on the equilibrium outcome may be amplified when strategic complementarities are present. In addition, the Fully-Rational Decision-Makers’ IT Adoption Proposition (P2) shows that this type of rational herd behavior improves overall welfare because both rational adopters and adopters with...
limited rationality are better off under this scenario. 

Next, we consider a very similar scenario under which a small minority’s incentive problem may reduce the welfare of all other decision-makers. Again, a continuum of decision-makers of size one must decide whether to adopt an emerging IT. A decision-maker’s payoff is normalized to zero if he chooses to stay with the old technology. When it is common knowledge that $\alpha > 1$, everyone adopts the new technology in equilibrium. Suppose that a small portion $\delta$ of decision-makers has a strong incentive to stay with the old technology. This incentive problem may arise because of reputation concerns, managerial rent-seeking or myopic learning (Edlin and Stiglitz 1995; Holmström 1999; Levinthal and March 1993). Assuming that the firms’ adoption costs are evenly distributed on the unit interval, our analysis demonstrates that, when $\alpha$ is sufficiently close to one, a small minority’s incentive to stay with the old technology will force all other firms to stay with the old technology. More precisely, as the Excess Inertia Conditions Proposition (P3) shows, whenever $\alpha (1 - \delta) < 1$, all decision-makers will coordinate on the equilibrium in which no firm adopts the emerging technology. This obviously will lead to a welfare loss. When this scenario occurs, a small minority of the firms will have an incentive problem due to strategic complementarities, which will induce all of the decision-makers to stay with the old technology. As a consequence, an inefficient inertia will occur for IT adoption. We consider this type of decision conformity to be rational herd behavior. In fact, herding may not necessarily imply limited rationality or suboptimal decisions; instead, rational herding is manifest in many cases where there is evidence of decision conformity.

It is worth noting that $\alpha$ in our model can be conveniently interpreted as the intensity of the positive network externalities. This effect is arguably the most common mechanism that leads to investment complementarities. Nevertheless, there are other mechanisms that may lead to investment complementarities too, including demand externalities, production externalities, demand spillovers, higher order beliefs and incomplete financial markets (Cooper and John 1988; Angeletos and Pavan, 2004; Morris and Shin 2002). It has long been proposed in the literature that the strength of network externalities can signifi-
cantly impact competitive dynamics (Katz and Shapiro 1994; Economides 1996). Many models have explicitly compared the strategic implications for strong externalities and weak externalities. For example, Angeletos and Pavan (2004) show that the unique equilibrium in their model is only obtainable when investment complementarities are below a certain threshold. Li (2005) shows that below-cost preemptive pricing is justifiable when the network effect is stronger than a given threshold. In our model, market dynamics behave quite differently under two scenarios: the weak complementarity scenario (0.5 < α < 1) and the strong complementarities scenario (α > 1). One important insight from our model is that suboptimal decisions of a minority of decision-makers could dramatically impact others’ strategies when investment complementarities are close to the threshold (α = 1). For example, as we have pointed out, while reputation-based IT adoption herding is usually not dependent on strategic complementarities, strategic complementarities often amplify the impacts of managerial incentive problems on aggregate IT adoption outcomes. In our model, reputation-based herding is considered as one of many types of managerial incentive problems that could lead to decision conformity. Our analysis here does not focus on how different types of incentive problems may lead to herding. Instead, it focuses on how complementarities can amplify adoption herding that is caused by some incentive problem or limited rationality.

6. DISCUSSION AND CONCLUSION

Our study provides a new unified framework for understanding IT adoption herding and the related fundamentals of managerial decision-making for IT investments. Network externalities, observational learning and managerial incentives have been proposed in the extant literature as critical drivers influencing managers’ IT investment decisions. By illuminating the relationships between strategic complementarities and the three drivers for IT adoption herding, this framework suggests that most existing herding models can be formally studied in some coordination game with strategic complementarities. Because our framework conceptually links IT adoption herding to equilibrium coordination with strategic complementarities, analytical tools of supermodular games can be readily applied to study IT adoption herding.

While a few explanations for IT adoption herding have been proposed in the literature, our study makes several contributions beyond justifying IT adoption herding using existing theoretical perspectives.
First, it emphasizes the fact that strategic complementarities often result from positive feedback and externalities that abound in many IT markets. Because strategic complementarities arise in many strategic settings, our framework covers a much broader range of IT adoption scenarios than what has been suggested by the existing theoretical perspectives. For example, empirical studies using some existing theoretical perspective must justify their choice of one theoretical driver of IT adoption herding over others. Our unified framework alleviates the task of theory selection and allows researchers to concentrate on studying the welfare implications of IT adoption herding.

Second, our unified framework reconciles IT adoption literature where decision conformity driven by network feedback is often deemed beneficial and rational herding literature where herd behavior is strictly welfare-damaging. It demonstrates that, in coordination settings where strong strategic complementarities lead to some unique equilibrium, herd behavior naturally arises and generally enhances welfare. Nevertheless, because complementarities often lead to multiple equilibria, herd behavior may reduce welfare (sometimes significantly) when it is associated with coordination failure or some inefficient equilibrium.

Third, our study offers fresh insights into the role of managerial incentives in influencing IT adoption dynamics. Managers’ motivation for herding is relatively simple in reputation-driven models proposed in the economics literature. Managers imitate others’ decisions to enhance their personal reputations that may be materialized in the labor market. Our study instead links managerial incentive problems to coordination when strategic complementarities are present. It demonstrates that managerial incentive problems, like managerial behavioral biases or limited rationality, may drastically impact aggregate IT adoption behavior. This result is significant because it shows that, when strategic complementarities are considered, the incentive problems or behavioral biases of a small minority of managers may dramatically affect most managers’ adoption decisions.

Fourth, our unified framework, partly motivated by the recent advance in behavioral game theory, has the potential of reconciling two conflicting viewpoints on IT adoption herding. Some researchers believe that herding, as a type of imitative behavior, tends to result rather naturally from people’s imperfect reasoning and cognition. In many cases, inefficient IT adoption decisions may be directly attributed to the
adopters’ bounded rationality (Au and Kauffman 2003). Thus, it will be helpful to explore some of the potential behavioral justifications of observed investment herding under certain circumstances (Schiller 1995). On the other hand, neoclassical economists often argue that strictly inefficient herd behavior may still arise in a fully rational world. Our study recognizes the fact that, in many situations, at least a small minority of decision-makers has cognitive biases or limited rationality. When strategic complementarities are present, the impact of such a small minority on aggregate outcomes is often amplified. Therefore, IT adoption herding may result from the strategic interactions between fully-rational managers and a small group of less rational managers. Empirical researchers usually adopt the neoclassical herding models in their investigations of IT adoption herding. They consequently face the challenge to justify using fully rational models to characterize real world managerial decision-making. Our unified framework, in contrast, not only accommodates limited rationality, but also highlights the importance of the strategic interactions between rational and boundedly rational decision-makers.

Our study has a few important implications on IT adoption and investment. It suggests that strategic complementarities in IT adoption make it important for managers to coordinate their decisions. When it is straightforward for managers to coordinate their strategies, herd behavior usually makes everyone better off. Unfortunately, coordination is complicated in many real world situations. Consequently, IT adoption herding, often characterized by impulsiveness, fragility and fad, may have complicated impacts on investment performance. Frequently, a manager’s decision depends on his belief about other managers’ characteristics. Because of strategic interdependence, behavioral biases or incentive problems of a few managers sometimes may benefit everyone (e.g., by avoiding a coordination failure). Under some other scenarios, limited rationality or incentive problems of a small minority may make everyone worse off (e.g., excessive inertia in new technology adoption).

Although our unified framework broadens the notion of IT adoption to encompass all IT investments with strategic complementarities, it excludes those IT adoption scenarios where a firm has fewer incentives to adopt a technology as more firms adopt it. As we point out earlier, IT Investments in a competitive industry sometimes yield negative externalities due to congestion effects. From the perspective of the
resource-based view, firms also have incentives to make their IT resource or IT resource configurations less imitable by others (Barua et. al. 2004; Wade and Hulland 2004). Consequently, our framework is not applicable to IT adoption situations where competitive pressure or resource imitability concerns completely eliminate strategic complementarities.

While our framework recognizes the role of observational learning in facilitating coordination, our stylized IT coordination game does not model observational learning. Because of equilibrium multiplicity in many coordination settings, equilibrium selection and coordination are very sensitive to exogenous shocks, new public information and information transmission mechanisms. New insights may emerge from future theoretical models that characterize the impacts of informational externality and observational learning on IT adoption herding.

Finally, we believe that the unified framework proposed in our study can also be applied in some contexts other than IT adoption. For example, we sometimes observe herd behavior in research topic selection, consumer online shopping patterns and so on. Our study suggests that researchers ought to pay close attention to a number of related issues when they study a decision-maker’s behavior in those contexts. The first issue is whether strategic complementarities exist or not. The second issue is whether strategic complementarities create some coordination problems among decision-makers. The third issue is whether a portion of decision-makers have incentive problems or behavioral biases. If this is the case, we want to know whether these decision-makers’ incentive problems or behavioral biases may drastically impact aggregate outcomes. Our future research will take up some of these issues.
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APPENDIX: PROPOSITIONS AND PROOFS

- **Proposition 1 (Two IT Adoption Scenarios).** When \( \alpha > 1 \), every decision-maker in the IT adoption game adopts the technology in the payoff-dominant equilibrium, and when \( \alpha < 1 \), no one adopts the technology in the unique equilibrium. This equilibrium is socially-inefficient when \( 0.5 < \alpha < 1 \).

  **Proof.** If a decision-maker with the adopt cost \( \hat{\beta} \) adopts the technology in any equilibrium of this coordination game, all other decision-makers with adoption cost below \( \hat{\beta} \) will adopt the technology in the equilibrium. Otherwise some decision-makers will play the game in an irrational manner. However, when \( \alpha < 1 \), we cannot construct any equilibrium with an adoption threshold of \( 0 < \hat{\beta} < 1 \). In this scenario, every decision-maker in the IT adoption game will adopt the technology in the payoff-dominant equilibrium. Similarly, we cannot construct any equilibrium with an adoption threshold of \( 0 < \hat{\beta} < 1 \) in situations where \( \alpha < 1 \). It is also easy to verify that adoption by all decision-makers is not a viable equilibrium. So the unique equilibrium entails no adoption by any decision-maker under this scenario. If all decision-makers adopt the technology, the average payoff of all decision-makers is \( \alpha - 1/2 \). So this unique non-adoption equilibrium is not socially-efficient when \( 0.5 < \alpha < 1 \). \( \square \)

- **Proposition 2 (Fully-Rational Decision-Makers’ IT Adoption).** When \( 0.5 < \alpha < 1 \) and a small portion of decision-makers, \( 0 < \eta < 1 \), adopt the technology because of their limited rationality, a portion, \( 0 < \lambda < 1 \), of the fully-rational decision-makers will also adopt the technology in equilibrium, when \( \lambda \) satisfies \( \alpha [\eta + (1 - \eta)\lambda] = \lambda \). Compared to the benchmark scenario where no rational decision-makers adopt the technology, rational adopters’ average payoff will be higher by \( \lambda/2 \), and the average payoff of adopters with limited rationality will increase by \( \alpha\lambda(1 - \eta) \).

  **Proof.** As illustrated in Proposition 1, any fully-rational decision-maker’s equilibrium strategy entails the characterization of an adoption threshold. Under this scenario, we can construct an equilibrium with an adoption threshold \( \lambda \) that satisfies \( \alpha [\eta + (1 - \eta)\lambda] = \lambda \). This equilibrium condition guarantees that any rational decision-maker with adoption cost less than \( \lambda \) will be better off by adopting the technology, and that those with adoption cost above this threshold will have no incentive to adopt the technology. Moreover, it is easy to verify that \( 0 < \lambda < 1 \) when \( 0.5 < \alpha < 1 \). Consequently a portion, \( 0 < \lambda < 1 \), of the rational decision-makers will adopt the technology in the equilibrium. On average, these rational adopters will be better off by \( \lambda - \lambda/2 = \lambda/2 \), and those adopters with limited rationality are better off by the strictly positive value, \( \alpha [\eta + (1 - \eta)\lambda] - 1/2 - (\alpha\eta - 1/2) = \alpha\lambda(1 - \eta) \). \( \square \)

- **Proposition 3 (Conditions for Excess Inertia).** While the payoff-dominant equilibrium entails adoption by every decision-maker whenever \( \alpha > 1 \), excess inertia – when everyone stays with the old technology – may occur when it is known that a small portion, \( 0 < \delta < 1 \), of decision-makers will stay with the old technology because of their incentive problems. This inefficient situation arises when either \( \alpha \) is sufficiently close to 1 or \( \delta \) is sufficiently large, that is, whenever \( \alpha (1 - \delta) < 1 \).

  **Proof.** As illustrated in Proposition 1, any equilibrium strategy entails the characterization of an adoption threshold. Suppose that we can construct an equilibrium with an adoption threshold \( \hat{\beta} \) in this scenario. To guarantee that any rational decision-maker with adoption cost less than \( \hat{\beta} \) is better off by adopting the technology, we must have \( \alpha (1 - \delta) > \hat{\beta} \). We can verify that this threshold is not obtainable whenever \( \alpha (1 - \delta) < 1 \). The payoff-dominant equilibrium entails adoption by every decision-maker when this condition is satisfied. This situation involving excessive inertia is caused by some decision-makers’ incentive problems. This leads to overall inefficiency because the average payoff for all decision-makers decreases by \( \alpha - 1/2 \). \( \square \)