

Within and Beyond Firm Boundaries: Can Strategic Digitalization and Cross-Firm Information Integration Lessen Complex Uncertainty?

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Abstract

Inefficiencies and coordination failures in firm decision-making may be caused by the lack of common or shared information. As complex uncertainty is a driver of such failures, research is needed to delineate the roles of technology, digitalization, and cross-firm information integration to address the problem within and beyond firm boundaries. Relational contracts within firm boundaries are pervasive, so maintaining shared information among decision-makers is hard. Thus, increased digitalization to reduce uncertainty is relevant for decision-making. Since interorganizational systems can promote interfirm governance and information commonality, connecting digitalization and firm transaction costs has become more important. Because the effects of uncertainty reduction depend on IS capabilities and effective cross-firm information integration, our study offers new insights into performance differences for linked firms. To illustrate, we analyze cases with complex uncertainty theory.

1. Introduction

Information economics and game theory provide tools to examine the implications of information, digitalization, and incentive problems in a variety of information and technology contexts involving the firm. The issues include *information asymmetry* (Bapna et al. 2016), *information cascades* (Duan et al. 2009), *signaling and information sharing* (Lin et al. 2005), and *information transparency* (Granados et al. 2010).¹ Yet economists have emphasized the importance of understanding the *coordination problems* that are driven by the lack of *common information* resulting from *complex uncertainty* (Holmström 2012). To better understand *contractual incentives*, economists (Tirole 2009, p. 291) suggest future work should “*emphasize the need for a commonality of information to achieve efficient contracting*” and cross-firm coordination for greater effectiveness in collaboration with one another.

We introduce this *complexity uncertainty theory* perspective with two questions. (1) With the lack of common or shared information that affects the

coordination of decisions within and between firms, can this perspective yield useful insights? For this, we will focus on the role of digitalization and cross-firm information integration for uncertainty reduction in decision-making. (2) Given pervasive complex uncertainty within and beyond firm boundaries, can this view act as a bridge that connects disciplines?

Decision-makers’ (DMs) beliefs about uncertainty in decision-making apply to important interfirm business decisions, such as joint investments in information systems (IS) or complementary information security protocols. The hierarchy of their beliefs in Bayesian game theory can be used to illustrate what we mean by complex uncertainty. With incomplete information, DMs’ *first-order beliefs* are about a decision setting’s fundamentals, like its payoffs from cross-firm efforts to target a new customer base. Their *second-order beliefs* are about other DMs’ first-order beliefs, how their decisions are a by-product of their uncertainty about the details of what their partners will do, and so on. Uncertainty arises when DMs don’t have knowledge about each other’s beliefs (Morris 2014). In settings that require coordination, complex uncertainty influences their behavior.²

Based on the DMs’ beliefs, a *common knowledge assumption* for solution tractability has been proposed. It removes complex uncertainty in most models (Aumann 1976). Prior work has shown why weakening this assumption can change equilibrium outcomes (Bergemann & Morris 2013). Such equilibria may not be robust with complex uncertainty (Rubinstein 1989).

The lack of shared information and the presence of information asymmetries represent problems that may affect the effectiveness of coordination. The first occurs if DMs have imprecise knowledge about each other’s beliefs, including their higher-order beliefs (Weinstein & Yildiz 2007). For example, they may have different assessments of the competitive forces at work in their joint marketplace. The second highlights coordination difficulties due to information asymmetries with the fundamentals, such as how their individual decisions

¹ To reduce the cognitive demands on readers who are unfamiliar with the disciplines of theory and research that support this investigation, we offer a glossary of terms and sources. (See Appendix Table A1.)

² The beauty contest metaphor of Keynes, when judges vote for who they believe is the most popular contestant among other judges – not their own preference, is an apt example.

affect their payoffs. Uncertainties facing the DMs are key in their calculus for coordination; they may not be handled in a predictable way if a lack of information commonality is present (Morris et al. 1995). For analyzing complex uncertainty, theorists have replaced the common knowledge assumption with less strict ones such as *common-p beliefs* (Monderer & Samet 1989). Agents believe with probability p that others similarly believe that still others believe something to be true with at least probability p – a knotty prospect.³

The importance of these information problems can be understood using *transaction costs*. When two firms interact in a strategic setting, *behavioral uncertainty* arises when one has little confidence in the predictability of another's actions. This often occurs, for example, when a supplier changes the prices of the resources it supplies to a buyer, disrupting the latter's price competitiveness on the final goods it sells. This is a form of uncertainty that is known to influence the boundaries of the firm too: the buyer may seek greater vertical integration instead of relying on procurement market transactions (Williamson 1985). Such problems are sources of uncertainty resulting from the buyer's lack of information about the extent to which they share joint motives to maintain market stability and not complicate one another's value appropriation with the suppliers. They can arise from complex uncertainty driven by a lack of shared information among DMs.

To address information asymmetry, previous studies focused on signaling and credible information transmission (Lin et al. 2005). This has occurred both in formal contracting as well as based on informal agreements and acknowledgments about how the parties limit their own self-interests. To address complex uncertainty, the key is to promote shared information among the DMs. Thus, emphasizing this new uncertainty perspective encourages cross-firm planners to use technology-enabled mechanisms (e.g., digitalization, information-sharing standards, and interfirm platforms) to reduce complex uncertainty within and beyond firm boundaries. Compared to those made in arm's-length transactions, decisions in firms are made differently (Cyert & March 1963). So, to understand how they make decisions, we need to investigate their black-box conceptualizations of how the underlying mechanisms work (Levinthal 2017).

Firms' internal decisions are mostly influenced by informal, unwritten *relational contracts* (Gibbons 2005), with no need to use contract lawyers. Third-party contract enforcement is eliminated because internal relational contracts are self-enforcing (Baker et al. 1987). However, complex uncertainty often arises when

different parties fail – in a single firm and across boundaries of two firms – to achieve an understanding of individual incentives that are at work in different operating divisions or entirely different firms.

Complex uncertainty is known to reduce *relational governance* effectiveness. Due to the opaque nature of *relational contracts*, uncertainty is driven by related agents' knowledge of the contrasting perspectives they bring that bear on their decision effectiveness. This is the *clarity problem* (Gibbons & Henderson 2012). The complex uncertainty perspective highlights the need for cross-department and cross-firm digitalization to support information sharing, improving their understanding of one another's views. While partners can use formal contracts to govern business relationships more explicitly than relational contracts, relational contracts are prevalent because they are more flexible and less expensive (Gibbons 2005). We will suggest how firms can address complex uncertainty.

2. Complex Uncertainty & Firm Decisions

Firms can create, maintain, and cultivate communities by sharing information within and across their boundaries, by supporting people to form links and associations with one another on matters of common interest. Technology service providers do this by encouraging the formation of user groups and participative social media forums or creating supplier groups, so buyer policy changes are more readily tracked and expected, for example. This gives DMs clearer incentives driven by relational contracts that develop between the parties over time. In a somewhat more negative way though, they also may play a role to punish opportunism and facilitate better alignment and coordination. Yet such relationships still may suffer from a lack of clarity due to unwritten and ambiguous expectations. These issues arise when DMs struggle to build a shared understanding of the incentives present in relational contracts. Such challenges illuminate the advantage of written legal contracts and related precedents. The law's advantage, as an alternative, is to precisely express unclear aspects of relational agreements (MacNeil 1980), so the cooperating parties more transparently understand them.

With shared implicit incentives inside firm boundaries, reducing uncertainty among DMs can improve the efficacy of a firm's decision-making capabilities. Three mechanisms allow a firm to address unacceptable internal uncertainties. First, the lack of clarity about incentives from relational contracts must be recognized. By enhancing transparency and firm-

with rational behavior and value-maximizing economic thinking.

³ The Scottish psychiatrist, R.D. Laing, proposed similar complexities – *knots* in human perception – when uncertainty is present in parallel

level knowledge sharing, intrafirm digitalization can help the DMs obtain awareness of their incentives.

Multiple equilibria often emerge in repeated strategic interaction models, increasing the uncertainty that DMs face. Even when two of them believe they'll be better off by cooperating, they still may struggle with overly complex incentives and inefficient coordination, despite their best efforts. Across firm boundaries, incentives tied to future expectations may work more effectively if digitalized cross-firm links are leveraged to improve DMs' joint understanding. This applies to coordination when cross-firm norms constrain individual opportunism.

Second, the firm-level mechanism is important, too. It involves constructs that impact the lack of clarity due to relational contracts. Written contracts provide precision and greater understanding, but relational contracts within a firm will be supported by its culture, rules, routines, and standard practices (Li 2014). They play different roles in reducing uncertainty and promoting shared understanding (Martinez et al. 2015). With decision transparency and stability, firm routines can reduce anxiety in situations of conflict and uncertainty (Nelson & Winter 2002). Further, social norms can act to coordinate social interactions. This is supported by the idea of a *correlated equilibrium* (Aumann 1987).

The DMs' coordination effectiveness depends on their perceived clarity for the relational contracts between them. To enhance the positive impacts for relational incentives, firms can leverage interfirm digitalization initiatives to promote their understanding of how to effectively support coordination. Such choreography is connected to firm learning and knowledge management. The key role of technology for these is known, but a mechanism to facilitate more beneficial firm decision-making still is needed.

Third, another mechanism focuses on DMs with *bounded rationality*. This is a source of uncertainty because there are different ways they perceive and react to relational contracts. This is challenging when unfamiliar DMs must coordinate with each other by relying on implicit incentives. Familiarity breeds trust, but it takes time for the *shadow of the past* related to their experience with one another to let mutual familiarity grow (Poppo et al. 2008). Thus, new firms or those with personnel changes must address the potential coordination issues that arise in the presence of complex uncertainty.

The lack of interfirm information commonality highlights a benefit of Enterprise 2.0 apps that implement interfirm social networks (Wang et al. 2014). Their goal is to promote employees' mutual learning and shared understanding. They also facilitate firm decision-making by reducing uncertainty and promoting

clarity, based on the extent of social network participants' linkages with one another – referred to as *social embeddedness* (Li et al. 2018). Members' understanding of social norms will be better, so higher social network intensity can support concomitant beneficial impacts on firm economic activities (Granovetter 2005).

This perspective aids understanding how integrated cross-firm systems support firm decisions, and how they can facilitate firm adaptation. This may involve changing incentive structures, routines, and decision-making authority, so DMs may still face short run uncertainties after such changes occur. Also, due to complementarities, unintended outcomes may emerge (Milgrom & Roberts 1990). Thus, change is difficult, and inertia isn't uncommon (Brynjolfsson & Milgrom 2013). But cross-firm strategic digitalization can help firms lessen the impacts of lacking shared information by helping to build adaptive capabilities.

3. Clarity & Interfirm Governance

Transaction cost theory has been extensively used in IS contexts such as IT-based outsourcing supply procurement. Our complex uncertainty perspective demonstrates that interfirm digitalization initiatives are connected to such relationships in ways that haven't been fully studied. Behavioral uncertainty plays a role in affecting interfirm governance, because the clarity problem lowers the firm's confidence in the predictability of its business partners' actions. However, with the common knowledge assumption, the importance of behavioral uncertainty and incentive clarity is greatly reduced (Morris 2014). With the complex uncertainty perspective though, we can obtain fresh insights about cross-firm digitalization influences transaction costs and interfirm governance.

3.1. Boundaries, Integration, & Decentralization

Coase pointed out that firm boundaries are determined by the relative economic efficiencies of markets and hierarchies in terms of transaction costs. With environmental and behavioral uncertainty, more vertical integration makes sense due to increased risk associated with market-based transactions. With the advance of digitalization, one key benefit of IOS is facilitating decentralization and interfirm coordination. While they lower interfirm coordination costs, the positive impact on decentralized decision-making is often limited by incentive problems (Han et al. 2011). For example, due to incompatible incentives though, information sharing is more challenging beyond firm boundaries (Li 2005).

Our perspective highlights a new channel for digitalization and information sharing to reduce

interfirm coordination costs. With complex uncertainty, coordination effectiveness depends on the clarity that DMs have about others' perspectives and how decisions will be shaped. They may fail to cooperate even if they know they can't gain from not cooperating though. This suggests that, beyond reducing information asymmetry and improving monitoring, controlling behavioral uncertainty should be an objective when firms collaborate digitally. Compared to improving information sharing, enhancing information commonality is unlikely to involve incentive issues though. Uncertainty due to the lack of shared information increases collaborating parties' coordination costs and highlights the integration-decentralization tradeoff and the boundaries of the firm.

3.2. Contract Complexity & Governance Costs

For long-term relations, contract incompleteness is unavoidable (Hart & Moore 1999). Contract complexity increases contracting and enforcement costs as well. With the high costs of writing, enforcing, and renegotiating formal contracts, relational governance using implicit incentives is more cost-effective for guiding interfirm relations. But clarity about the incentives is still an issue: it is harder for DMs to reach a joint understanding of implicit incentives (Gibbons & Henderson 2012). Such uncertainty prompts information sharing and digital technology-based information integration to reduce relational governance costs and facilitate support for relational incentives.

The role of cross-firm systems integration in improving information quality and transparency, in the presence of complex uncertainty, highlights the need to empirically investigate the role of shared systems and strategic digitalization. Empirical evidence has begun to show the negative impacts of behavioral uncertainty on relational governance (Wehner et al. 2017). One direction is to study the link between the effectiveness of relational governance and how digitalization-enabled information sharing can align cross-firm incentives. Another way is to study if IT aids governance via channels for reducing uncertainty.

For long-term business partners, they can gradually promote mutual trust and reduce the need for formal incentive contracts (Gulati & Nickerson 2008). Familiarity breeds trust and confidence. From our perspective, cross-firm strategic digitalization can reduce uncertainty by allowing partners to replace contractual incentives with relational ones. Thus, for firms that leverage technology to get more familiar with each other, they will be able to lower their governance costs by relying on informal agreements.

3.3. Opportunism & Interfirm Expectations

Pervasive relationship opportunism justifies finding effective interfirm governance mechanisms (Menard 2013). For many long-term relationships though, opportunistic behavior is rare due to the quasi-structural role played by future firm expectations of its collaborators' continuing engagement for joint profitability. Researchers have often demonstrated that long-term gains from collaboration usually outweigh short-term gains from opportunism. One thing is evident: effectiveness of future expectations between partners may be hindered by less-than-best interfirm understanding. Due to *trigger strategies* in repeated firm-to-firm interactions, the punishment of opportunistic behavior may vary greatly (Hill 1990).⁴ And, when partners have difficulty understanding their future together, the effectiveness of relational incentives will weaken considerably.

Business partners can use *coordination schemes* and *relational choreography* to facilitate collaboration. While reducing uncertainty and enhancing information commonality, they also have problems because the relational contracts only exist in the DMs' mental models. Thus, digital integration for interfirm coordination isn't limited to information sharing and monitoring. A goal of digitalization is to enhance their shared understanding, for example, of their firms' cultures and routines.

Strategic digitalization complements other non-digital ways for enhancing information sharing and commonality. Promoting more shared understanding and reducing uncertainty can be accomplished through approaches involving steering committees, which are useful to aid interfirm coordination (Reuer & Devarakonda 2016). Another way to address clarity in coordination is to formalize relational contracts so they become *guiding principles* (Frydlienger & Hart 2020). Both require formalized interaction and documentation, suggesting a complementary role for IT.

4. Fintech Firms & Complex Uncertainty

To ensure the results of our exposition are meaningful for the readers, we analyzed three illustrative cases to assess the validity of the proposed theoretical perspective: *complex uncertainty theory*. We assessed firms that emerged during the Fintech Revolution in financial services (Gomber et al. 2018), a setting fraught with complex uncertainties for business leaders, tech strategists who commit time and effort to compete successfully, and their partners and customers. This motivated our selections of firms from Europe,

automatically punishes its adversary if the latter deviates in some way.

⁴ *Trigger strategies* arise when an agent cooperates at first but then

North, and Central America. They act as a basis for supporting our claim that complex uncertainty in high-tech financial services is being addressed on behalf of traditional financial services partners through digitalization and cross-firm information integration partnerships on a global basis now. We examined how innovation has been reducing undesirable uncertainty by addressing information asymmetry, relational contracts, and interfirm collaboration, as a basis for understanding relational clarity issues. (See Appendix Table A2 for a summary.)

Case 1. Reducing Interfirm Uncertainty: Adyen's Platform to Rational PSP Services Complexity

In the past decade, *technology innovation* has had salient impacts on financial services. They involved core *business process disruptions* and have led to *sector transformation* (Gomber et al. 2018). We see the emergence of service capabilities that consumers and observers view as cheaper, better, and faster (Bansal et al. 2015), while business partners in the fintech sector have achieved a greater extent of information integration. Nowhere is this truer than for *payment service providers* (PSPs), as challengers for more open banking, especially in Europe (Heins 2019, p. 1), diminishing *information asymmetries* between firms as PSP intermediation has been rationalized:

"Whether they be credit cards, debit deposits, real-time bank transfers, or other types of payments, payment PSPs make the experience of a money transfer straightforward for the customer and stress-free for the merchant. All ... relationships to the various payment schemes (credit cards, debit cards, mobile apps, Apple, or Google Pay, or even AliPay) are managed by the PSP, opening ... the merchant to focus on the relationship with the customer. ... [Traditional bank] institutions have ... begun to feel the pinch due to increased competition in the payments industry. As they struggle to update their ... legacy systems and properly respond to changing regulations, large parts of their revenue streams are being sapped away by fintechs and other competitors."

Amsterdam, Netherlands-based Adyen (adyen.com) is a market leader among Euro fintechs, with a market capitalization of EUR 54 bn. Adyen lags the U.S.-based PSP, Stripe, with its much larger market capitalization of USD 95 bn though.⁵ Adyen's valuation has been earned through its effort to reduce complex uncertainties that have existed for payment services customers and Adyen's industry partners since the 2000s. A driver of innovation was the mid-2010s European Central Bank directive, PSD2, to create cross-border instant payment capabilities based on *real-time gross settlement* (RTGS). This was a basis for diminishing the time for consumers to receive irrevocable funds. In this setting, Adyen succeeded in building a cross-firm transaction and information sharing platform that allowed it to

disintermediate and reduce the number of PSPs, while creating more direct links.

Payments services have been a contract business involving banks and too many PSPs. Although technology innovation led to the creation of many start-ups, there also has considerable strategic rivalry in the payment services niche for the mobile channel, the card networks, merchant and consumer groups, and somewhat different operational emphases (e.g., Klarna's buy-now-pay-later card services, and Paypal's digital payments).

At the same time, digitalization has resulted in changes to the PSPs' business models and processes and provides new revenue and value-producing opportunities by using emerging technologies. Adyen's payment services offer a global and agile payment solution without operational complexity and resource constraints, diminishing the relational clarity and incentive problems from existing *relational contracts*.

The service provider offers a payments software backbone to support a unified commercial experience across different geographies and payment methods (Gartner 2022). The highly integrated payment platform also delivers end-to-end solutions that manage payment flow, eliminating the many parties involved in traditional processing, and the resulting complexities and cross-firm uncertainties. This creates *lower transaction costs* for merchants and incentives for greater cross-firm collaboration.

Adyen provides greater transparency to payment service users compared to other PSPs, too. It configures the payment process so merchants must set up their own accounts. An integrated system with cutting-edge data analytics capabilities provides customer insights for different regions and across different channels, enabling merchants to customize their customers' experience, increase profitability, and prevent fraud. This contrasts with other PSPs that use one large merchant account in which funds are deposited. These tend to be expensive and limiting in terms of payment capabilities and delivering regional and cross-channel insights though. Adyen also uses a pricing model that limits interchange fees and commissions, while other PSPs use *fixed-pricing models*, by charging a flat fee plus a percentage of the transaction amount, also reducing uncertainty. *Interchange-plus pricing* is complex but transparent, unlike easier but costlier fixed models (Mokaya 2022).

For *cross-firm information integration*, Visa and Adyen have grown their joint e-business revenues with *network tokenization*, by replacing *primary account numbers* (PANs) with anonymized tokens.⁶ They have

⁵ Private valuations are as of April 2021 from sources such as *CNBC*, *Forbes*, *Bloomberg*, and *companies.marketcap.com*.

⁶ Visa payments uses tokenization technology. Its solutions are

unique, with flexibility to choose how to integrate, build, and manage token services to support richer, more secure, and more personalized services that its institutional partners can leverage with customers.

collaborated since the 2000s and committed to driving tokenization adoption since 2017, by sharing the vision of network tokens e-business with more manageable cross-firm digitalization and information sharing. Deploying network tokens is an innovation-led approach that Adyen has worked closely with Visa to prepare its payment platform to be a streamlined transaction-making utility, with fewer uncertainties for its active partners. This enabled Adyen to rapidly scale its network tokenization strategy across its merchants.⁷

Case 2. Controlling Uncertainty: FX Remittances without Cross-Currency Settlement at SingX

A financial technology start-up, SingX Pte. Ltd., launched a cheaper, faster, and more convenient online remittance platform in Singapore in 2016. It charges consumers a fraction of what they earlier paid for overseas transfers. Its FX platform helps consumers and SMEs save up to 90% of typical remittance charges, which average ~8%, according to World Bank data, and are not transparent to customers – while reducing *information asymmetries* for the payer and payee in transactions, by reengineering the process for cross-border funds transfers. SingX's platform is simple and user-friendly. Customers register for an account on its website. Upon document submission and in-person ID verification, an account is approved for use.⁸ SingX partners with licensed remittance operators in each country where it has been licensed to do remittance transactions by their central banks (Fintechnews Singapore 2017).⁹

Transaction costs are not usually important for large financial flows in international trade, foreign direct investment, or development assistance. The costs are only a small share of the total transactions. But they are salient in the remittances business sub-sector for individuals. Higher costs result in greater use of informal channels for money transfers, which require undesirable *relational contracts*, higher *transaction costs*, and daunting *complex uncertainties* for institutions, so individual remitters may refrain from sending money to their family's homes. Lower transaction costs, in contrast, can increase remittance volume and enhance inclusion by redirecting funds from the informal to the formal channels. Lower costs cause shifts in remittances, but a larger market size and scale economies with fintech remittances have effects, too (Beck & Martínez 2011).

⁷ Visa network tokens replace sensitive data and incorporate the additional information needed to deliver the latest digital commerce innovations. The increased security means card issuers are more likely to trust transactions. In combination with technology that ensures network tokens are always up to date, this process enables increased authorizations and improved checkouts via *cross-firm digitalization*.

⁸ Customers initiate transfers for the remittance amount into SingX's

Since the launch of the World Bank's *Remittance Prices Worldwide* (RPW, remittanceprices.worldbank.org), the market for such services has evolved to stress greater price competition. Innovative players have emerged to compete with traditional ones, such as the banks, *money transfer operators* (MTOs), and postal system. New products have also been developed, including some enabled by new technologies and others by existing technologies. In this evolving environment, it is more challenging to accurately describe remittance products by a single label. Third-party providers offer services to transfer funds internationally, for which they fund transactions, among other options. For example, it can be done via a bank account, but describing these services as *account-based remittance innovations* is inaccurate. For this, RPW now brings together instruments used to fund such transactions those used to disburse funds to the receiver. Till now, the cheapest method for funding a remittance transaction was mobile money while the most expensive option was via bank accounts (The Economist 2017, The World Bank 2017).

SingX's business model, compared to bank transfers, enables users to save up to 90% in remittance charges when transferring funds to India, Malaysia, and Hong Kong. It does this by cutting telecom charges, FX-related bank commissions, and offering transparent live FX rates – while offering new opportunities for *interfirm collaboration* and service innovation in a newly-competitive market. It charges handling fees made known to customer up front though. The platform's transparency enables customers to keep track of live FX rates, empowering them to remit funds when the FX rate is right for them. They also enjoy the ease of remitting money anytime by using mobile phones, and SingX's approach to enhancing *customer informedness*.

Case 3. Chivo in El Salvador: Replacing the Nation's Fiat Money to Reduce Consumer Uncertainty

On June 9, 2021, El Salvador's government announced legislation making *central bank digital currency* (CBDC) legal tender in the country, replacing the U.S. dollar as the nation's fiat money. El Salvador was first in the world to formally announce Bitcoin (BTC) as its fiat money solution (Kharpal 2021). If Salvadorans use it to receive remittances, senders overseas will require enablement services to exchange their local domestic currencies with BTC and send them to El Salvador via the Lightning Network.¹⁰ Traditional

account. The overseas recipient receives money overseas hours after funds are received from the customer without an FX transaction.

⁹ SingX, like bigger banks, implemented information security measures to safeguard its customers' personal details. It also uses two-factor authentication and encrypted data transmission methods.

¹⁰ *Lightning* is a solution for BTC trade scaling. The Lightning

banks in the remittance market will offer new crypto-services and other fintech firms will step into the gap.

BTC is built on a digital encryption solution to avoid *double-spending* based on blockchain's hash function scheme. Entrepreneurs, observers, and "money libertarians" have called for governments to permit trading and exchange of BTC in different countries.¹¹

For citizens to access the system, the government designed processes to limit complexity, transaction costs, and purchase fees, and support the crypto market with competitive spot prices (Nambampurath 2021). The relative *transparency* of BTC blockchains make it so that counterparty *information asymmetries* in transaction are minimized. Users will have access to BTC trading via a *government exchange*. It also doesn't have a fee, aligning it with services in El Salvador.

Salvadorans use an e-wallet, Chivo, the first entry point to access and trade BTC. It offers trading functionality and e-wallet storage through Lightning Network connectivity. Chivo wallet use makes it so there are no commissions to send or receive remittances and to make or receive payments or convert BTC to USD. The Chivo e-wallet is compatible with other blockchain e-coin wallets in many countries. There are no compulsory use requirements either and citizens may adopt other wallets. No commissions are charged to merchants either and the implementation of Chivo supports the development of interfirm digital currency innovations that weren't possible with U.S. dollars in El Salvador. This eliminates the *relational contracts* that were present with U.S. dollars as El Salvador's fiat money and money laundering.

The Development Bank of El Salvador also facilitates automatic convertibility for setting up a BTC reserve for its new digital national currency. Businesses that get paid in BTC can opt to receive USD instead, for example. Funds held or received in BTC or USD in Chivo's e-wallet can be withdrawn in USD as cash at any time. Conversion also can be performed via 200+ ATMs spread around the country (MacDonald 2021). Government policies based on the digitally enabled technology innovations may alleviate the uncertainty of BTC's use as a fiat currency in other ways too.

BTC was created to replace currency and its shortcomings in economic exchange. Early on in 2021, some shops accepted BTC in addition to cash. But, as its value fluctuated, BTC's monetary function almost

disappeared. So then, why has El Salvador tried to promote BTC as its fiat currency? First, in line with the United Nation's 3030 Sustainable Development Goals, a key purpose was to expand financial services to the public with BTC as an incentive. In 2011, about 86% of adult Salvadoran citizens were unbanked, though the Internet penetration rate improved in recent years, and the proportion fell to 71% (Statista 2022). When BTC is used as a legal currency, it can finance a house in El Salvador or be used as the base currency for a loan.

Second, it was intended to stem the country's outflow of fees for international remittances. The fee burden for U.S. to El Salvador payments has been high – something that BTC use can reduce. Third, there was also conscious intent to reduce U.S. influence via the USD. El Salvador, surprisingly, did not have its own currency.¹² Prices were controlled for a time, but its economy was shaken by changing U.S. monetary policy and economic instability, setting up BTC adoption.¹³

5. Conclusion

Why does complex uncertainty resulting from the lack of information commonality create an information problem different from information asymmetry? Can cross-firm information digitalization play key roles in addressing clarity in interfirm coordination? Why does the complex uncertainty perspective shed light on the interconnections among digitalization, interfirm information integration, and organizational decision-making? Can this perspective be used to demonstrate the potential impacts of technology on firm boundaries and relational governance?

By asking these questions, we have been able to offer support for the theoretical value of better understanding complex uncertainty driven by the lack of clarity in cross-firm relationships, though more questions were raised than we answered. We summarize the implications for digitalization to support effective and integrated information sharing. (See Table 1.)

While Cyert & March (1963) focused on firm decision-making structures, more recent studies have highlighted constructs such as firm culture and routines (Winter 2013). One can understand emerging firm intelligence by focusing on interactions between the constructs and decision-making by a firm and its partners. Emphasizing enhancing information

Network enables *hashed time lock contracts* with bidirectional payment channels, which allow transactions to be routed securely across multiple P2P channels (Lorini et al. 2018). Such contracts are conditional though: the recipient still must notify the sender about a payment's receipt by some pre-specified point in time.

¹¹ The Bank of China warned in 2013 that BTC trading among banks and BTC exchanges was to be banned. In 3Q 2021, China made all crypto transactions illegal to ensure governmental control.

¹² In 2000, the fixed rate Colón was scrapped by El Salvador with its *dollarization* policy. USD was adopted as legal currency when macroeconomic indicators were strong. Replacement was to improve economic stability, but recent decades brought unexpected and difficult challenges that have been challenging to address.

¹³ El Salvador sought economic growth through the development of BTC crypto-mining capabilities. Countries with low electricity demand and resources have a price advantage.

commonality through strategic digitalization is a new perspective that we propose. It links with the emergence of firm intelligence in two ways. First, the firm can leverage information systems to reduce complex uncertainty faced by its DMs, thereby facilitating more efficient coordination. Second, by enhancing how the firm's culture, routines, and standardized procedures are understood by DMs, emerging technologies for digitalization deepen our understanding of these constructs to support firm-level decision-making.

Complex uncertainty also helps us to understand how digitalization enables and sustains the sources of performance gains for firms. Understanding such sources has been a long-standing goal among strategy researchers. Levering IT to enhance firm capabilities also has attracted the attention of many in IS research, though its role to improve information commonality among DMs hasn't been linked to capabilities or performance differences.

Table 1. Five Dimensions for the Effects of Complex Uncertainty

KEY ISSUES	IMPLICATIONS OF COMPLEX UNCERTAINTY	FOLLOW-UP QUESTIONS
Transaction costs	Digitalization and information sharing can control how complex uncertainty affects integration-decentralization and the efficiency of a firm's boundaries.	Can empirical studies of technology reducing complex uncertainty be designed?
Relational contracts	By reducing complexity, shared digital platforms can address relational contract clarity, which may undermine successful relational governance.	With tradeoffs for contract and relational incentives, what evidence suggests digitalization efforts can facilitate relational incentives between divisions and firms?
Decisions inside & across boundaries	Firm culture, norms, and routines reduce complex uncertainty, so cross-firm information sharing and commonality among DMs should be implemented.	How can IOSs be designed to strengthen uncertainty reduction via cross-firm digitalization and shared information?
Interfirm collaboration	With innovation, cross-firm systems become a resource to control complex uncertainty and enhance a firm's ability to collaborate with its partners.	What evidence suggests digitalization aids firm collaboration and limits uncertainty?
Future firm collaboration	By enhancing partners' understanding of future expectations, IOSs strengthen relationship continuity.	How can research assess positive impacts of cross-firm integration to enhance deeper future collaboration?

From the complex uncertainty perspective, leveraging digitalization to address the clarity problem in cross-firm linked decision-making goes beyond investing in new IT. It requires significant resources, committed leaders, and consistent strategies to develop systems that can reduce unacceptable complexity that hampers decisions. Further, firm performance advantages over its competitors often come from their capabilities to adapt to changing environments. Lacking information commonality among DMs can lead to maladaptation, for example. So, integrated digitalization may play a unique role in sustaining performance differences of apparently similar, but unique firms.

For researchers interested in competitive advantage driven by superior strategic digitalization capabilities, it will be worthwhile to consider our proposed theory perspective for future work. Also, for those seeking to understand the business value of technology, our theory should motivate rethinking IT's role in enhancing decision-making within and beyond firm boundaries.

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Appendix Table A1. Glossary of Terms & Their Definitions

TERM	DEFINITION	REFERENCES
<i>Common knowledge</i>	If people have identical prior beliefs, and their posterior beliefs are common knowledge, and must be the same. This is true if they base their posteriors on different info. They can't agree to disagree.	Aumann (1976)
<i>Common-p beliefs</i>	An event is a <i>common p-belief</i> if everyone believes it with probability of at least <i>p</i> , everyone believes with probability at least <i>p</i> that everyone believes it with probability <i>p</i> or more, and so on ad infinitum.	Morris (2014)
<i>Complex uncertainty</i>	Economic theory is based on equilibrium outcomes where agent beliefs are common knowledge and assume complex forms of uncertainty (e.g., on beliefs of other players, etc.). With <i>complex or higher-order uncertainty</i> , they are not common knowledge nor easily accommodated in predictive models.	Weinstein & Yildiz (2007)
<i>Contractual</i>	Rational choice is required for parties to recognize in incomplete contracts that they aren't aware of what they aren't aware of, and not expend high costs to design complete contracts for contingencies.	Williamson (1985)
<i>Correlated equilibrium</i>	Individual players decide on actions by private assessment of a signal's value. If no player deviates from their strategies, the distribution of actions that the signals are tied to will be a correlated.	Aumann et al. (1987)
<i>Digitalization</i>	Digital technology is used to transform a firm's business model, for new customers, revenues, and value-creating business opportunities, from what was traditionally done via digital transformation.	Bughin et al. (2019)
<i>Ex post maladaptation</i>	In transaction cost economics with incomplete contracts, the parties haggle in response to changing conditions of exchange so less-than-best outcomes may arise due to ex post contract negotiations.	Williamson (2010)
<i>Implicit incentives</i>	<i>Explicit incentives</i> involve monetary or interfirm gain-sharing rules; <i>implicit incentives</i> arise from soft relational opportunities (e.g., collaboration, income splits, joint cost reduction, and info sharing).	Gibbons & Henderson (2012)
<i>Information asymmetry</i>	Describes different levels of information that players possess, influencing their ability to make effective decisions (e.g., consumer purchases when suppliers' price info is incomplete).	Bapna et al. (2016)
<i>Information transparency</i>	Level of availability and accessibility of information to participants, implying that the quantity of information and quality of the support for accessing it are effective in its interpretation.	Zhu (2004)
<i>Informational cascade</i>	A situation in which a DM's external information obtained from others overrides their private assessment, so they make a sequentially matching decision even if the public signal is incorrect.	Duan et al. (2009)
<i>Informational commonality</i>	A requirement in incomplete contracting that the parties to agreements that are not fully specified will benefit from reaching agreement in the presence of shared or common information.	Morris et al. (1995)
<i>Relational contracts</i>	Informal agreements between parties founded on mutual trust and incentives that are created for their predicted behavior based on implicit threats that may arise as they collaborate in the future.	Baker et al. (1987)
<i>Relational governance</i>	A governance mechanism in interorganizational relationships based on trust and positive expectations related to parties' collaboration, with social exchange, open communication, and information sharing.	Poppo et al. (2008)
<i>Relational incentives</i>	Interfirm incentives founded on a scheme to create behavioral incentives between parties in incomplete contracts that use incentives with specific content (e.g., reputational, monetary, rewards, etc.).	March (1994)
<i>Shadow of the past (future)</i>	Alternate paths for how trust forms between firms, with experience in interactions governed by incomplete contracts vs. mutual expectations of the shared benefits of reliable future collaboration.	Gibbons & Henderson (2012)
<i>Signaling</i>	One party to an incomplete contract party shares credible information about itself for another to receive and process, with the result that its demeanor in interfirm collaboration will be more predictable.	Williamson (1985)
<i>Social embeddedness</i>	Economic rationality is embedded in interfirm relationships, so corruption and malfeasance are prevented based on their mutual trust, historical relations, and expectations of future collaborative gains.	Gulati & Nickerson (2008)

Appendix Table A2. Complex Uncertainty Theory Application: Findings for Three Illustrative Fintech Firms

CASE	ISSUE	FINDING
Adyen	Information asymmetry	Aggregating PSP services has diminished information symmetry between Adyen and its wholesale clients. They no longer require multiple payment relationships, and consumers benefit from faster payments settlement, too.
	Relational contracts	Limited payment interchange and commission fees and commissions, reducing formal contracting through shared information and tech standards. Relevant information integration is supported by network tokenization.
	Interfirm collaboration	Collaboration opportunities have been enhanced by its business partners having a focal PSP to work with, while Adyen and Visa pursue wholesale payment sector-facing interfirm digital integration through a joint platform play.
SingX	Information asymmetry	Innovating to disintermediate traditional FX trading and settlement intermediaries make it so fees, commissions, and changing FX cross-rate trade costs are no longer information asymmetries for remittance services customers.
	Relational contracts	Publicly available information on remittance service prices via the World Bank are creating further pressure to simplify relationships between SingX and domestic banks, thus reducing complex uncertainty between them.
	Interfirm collaboration	A key area for value cocreation comes with establishing new standards for account-based remittance services from banks, traditionally most expensive, but much more attractive now with the banks handing cross-national FX trades.
Chivo	Information asymmetry	Money for retail transactions by El Salvador's citizens suffers from unknowns related to U.S.-led monetary policy affecting the dollar's value in Latin America and large banks' remittance fees for FX trading services.
	Relational contracts	BTC e-wallet users can rely on simple payment processes with the Chivo app when they purchase goods or services, and relational contracts with merchants will be simpler when volatility is no longer driven by BTC speculators.
	Interfirm collaboration	Although it hasn't been observed in El Salvador yet, we expect an upwelling of money-services innovations, as observed with the roll-out of Australia's <i>New Payments Platform</i> (NPP) for fast settlement of digital retail payments.

Note. For additional information on the Reserve Bank of Australia's 2018 faster payment settlement initiative and the related financial and business services it has spawned, visit RBA's NPP webpages at www.rba.gov.au/payments-and-infrastructure/new-payments-platform.