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A Theory of Digital Firm-Designed Markets: Defying Knowledge Constraints with Crowds and Marketplaces

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Abstract. In this paper, we investigate the ways in which new forms of organization enabled by digital technologies, such as crowdsourcing and digital marketplaces, are allowing firms to circumvent and defy traditional knowledge constraints. This is part of the broader question of when and why these forms of organization are more efficient relative to alternatives, given that some firms simultaneously utilize crowdsourcing, marketplaces, and traditional forms of organization. We observe that an important cluster of these new organizational forms are able to circumvent knowledge constraints, because they combine elements of market and hierarchical organization in firm-designed hybrid arrangements. We further categorize these firm-designed markets into one-sided market arrangements (crowds) and two-sided market arrangements (marketplaces). To explain their efficiency relative to hierarchies and relative to each other, we take a knowledge-based perspective and review ways in which firm-designed markets reduce or remove both first-order (known unknown) and second-order (unknown unknown) knowledge constraints compared with hierarchies. Our argument hinges on the notion that firm-designed markets provide semidirected and undirected search and generativity mechanisms that allow firms to go beyond what is possible with centrally directed search.

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Keywords: two-sided markets • economic organization • open innovation • digital economy • knowledge-based view • ecosystems • market-hierarchy hybrids • uncertainty • crowdsourcing • platforms

1. Introduction

Digital technologies have enabled novel forms of economic organization that are able to solve problems and accomplish tasks in new ways, especially when it comes to circumventing knowledge constraints. For example, when a firm is not sure who in the world can solve a specific problem in the best and most cost-efficient manner, it may use a crowdsourcing contest to find the right person. That person may turn out to be living somewhere the firm would never have thought to look, having skills the firm would typically not have thought to search for, and being able to solve the problem in a way the firm would never have thought possible. Such crowdsourcing contests are employed by large firms, such as Apple and Google, using digital crowdsourcing systems built by themselves or sometimes specialty platforms like TopCoder (for custom software) or HackerOne (for security "bug bounty" programs).

An even greater story of how firms have been able to expand their profits beyond their own knowledge areas involves platforms, such as the Apple App Store and the Google Play Store, through which the platform owners profit handsomely from a variety of apps that not only fall outside their own expertise, but are often solutions to problems they did not even know that people had, or could not have imagined that enough demand would be there to render these apps profitable. For example, the Flappy Bird game built by a lone Vietnamese developer with relatively low production quality in the course of just two to three days, became a sudden sensation in early 2014 and was earning tens of thousands of dollars per day at its peak through in-app advertisements and sales (Terdiman 2014). Neither Google nor Apple, if they were even in the game development business, could possibly imagine that a game like this would be such a sensation, and yet they both enjoyed hefty cuts from Flappy Bird's revenue.

In this paper, our main task is to investigate how new digital forms of organization have allowed firms to circumvent their knowledge constraints and expand their sources of profit far beyond their own areas of expertise. Scholars have tackled this digital transformation and what it means for organizations from various perspectives. A line of work has focused on the notion of "platforms" or "multisided markets," emphasizing the unique issues that arise when a business is involved in facilitating and profiting from transactions and interactions of other parties with other parties (Eisenmann et al. 2006, Tiwana 2013). Another line of work has focused on "crowds" and how they allow firms to benefit from access to a large pool of labor and knowledge that was previously inaccessible on this scale (Kittur et al. 2007, Brabham 2010, Afuah and Tucci 2012, Kohler 2015). Large digital businesses like Apple and Google often employ crowds in various crowdsourcing arrangements (such as for bug reports, feature requests, localization) and also orchestrate platforms where other parties transact with each other (as in app stores, digital books, music stores, etc.). Many of these novel ways of organizing are made possible by the advent and increasing ubiquity of digital technologies and the relative limitless and near costless information that they enable (Altman et al. 2015, Majchrzak et al. 2018).

Our premise is that many of the new affordances provided by digital technology involve the ability to mix market mechanisms with hierarchical mechanisms of economic organization in new ways, producing what has been referred to as "market-hierarchy hybrids" (Felin and Zenger 2011). In this paper, we refer to these hybrid arrangements as digital "firm-designed markets" to emphasize the agency of the organizational designer, as opposed to the more commonplace use of the term "market" as an entity that is external to all firms and designed by no one in particular. Firm-designed markets can be considered as a type of meta-organization because the boundaries of the firm are expanded into a cluster of legally autonomous firms or individuals not necessarily linked through employment relationships (Gulati et al. 2012).

A key question about firm-designed markets for strategy scholars is when and why are these forms of economic organization efficient relative to alternatives (Nickerson et al. 2017). For example, taking a problem-solving perspective, Afuah and Tucci (2012) addressed the question of "[w]hen might crowdsourcing be a better mechanism for solving problems than the alternatives of either solving them internally or designating an exclusive contractor to solve them?" (2012, p. 356). Taking a knowledge based perspective, in this paper, we attempt to locate the organizational efficiency of firm-designed markets in their ability to solve first-order and second-order uncertainty problems (Kerwin 1993, Bammer and Smithson 2012).

The agency of the organizational designer in the notion of "firm-designed markets" manifests itself in the choice of design architecture. We specifically distinguish between crowd-based systems as one-sided architectures (such as Google's "Crowdsource" app) and marketplace systems as two-sided architectures (such as Google's Play Store). Firms like Google that utilize these mechanisms also simultaneously engage in regular hierarchical employment as well as pure market contracting. This suggests that there are certain tasks and circumstances for which each of these types of organization provide efficiencies.

We argue that crowds and marketplaces provide different knowledge efficiency gains relative to each other, and relative to hierarchical organization. Specifically, if we think of uncertainty as comprised of a first-order knowledge constraint (known unknowns) and a second-order knowledge constraint (unknown unknowns), the first problem is addressable through directed search or "problemistic search" methods (Cyert and March 1963), because the firm has a starting point (it knows what to search for), but the second problem is difficult to tackle with directed search, because the firm does not know where to search (Nickerson et al. 2017). Both crowds and marketplaces are able to mitigate second-order uncertainty by more or less relaxing the knowledge requirements of fully directed search. Crowdsourcing arrangements resemble a form of semidirected search (because the firm sidesteps supply side knowledge constraints but still has to specify a demand-side problem), whereas marketplace arrangements resemble undirected search that often generates surprises or discoveries of simultaneous problem-solution pairs (von Hippel and von Krogh 2016) sidestepping knowledge constraints on both the supply and demand side. Although crowds and marketplaces also tackle first-order knowledge constraints, their ability to defy unknown unknowns is their main organizational marvel. We draw on many examples to support our arguments, but give special focus to firms like Google and Apple who engage in both crowdsourcing and platform design, in order to better understand exactly when and where each of these systems is most useful, and what aspects of knowledge constraints they tackle. A list of examples from these two firms is provided in Table 1. We also draw on some first-hand anecdotes we collected in a separate study through interviews with managers at TopCoder, a leading platform for the crowdsourcing of custom software development that has been used by Google for its Google Code Jam competitions.

2. Varieties of Knowledge Constraints and the Problem of Double Ignorance

Here, we are concerned with how new digital organizational forms defy knowledge constraints, so clarifying what we mean by knowledge constraints and which aspects or types of constraints are more relevant to our

Table 1. Examples of Crowd and Marketplace Systems Used by Google and Apple

Firm	Case	Description	Crowd or marketplace?	Incentives
Google	Maps Local Guides	Google Maps users around the world help verify information, add information and media (including geotagged images) about places which then contributes to the product for everyone	Crowd	Points, badges, early access, hotel and travel perks, small prizes such as cloud storage, better product experience, community
Google	Spam content detection	Chrome Personal Blocklist extension	Crowd	A browser extension that allowed people to flag spam websites and domains to be removed from personalized search results, and this information was aggregated by Google and incorporated in search algorithm
Google	Design suggestions feedback request	Used community forums to request feedback on next phone design. Krishna Kumar, a Google Product Lead, used a posting in a Google support forum to ask for feedback on how the next Pixel phone should be designed	Crowd	Potential improvement to Google phone product available
Google	User submitted geotagged images for Google Earth, Google Maps, and Street View	User images from an app acquired by Google (Panoramio) were augmented with images for Street View and also used in Google Earth and Google Maps	Crowd	Improved Google products (this has been replaced by Google Maps and Google Local Guides)
Google	Map Maker	Adding unknown roads and directions by users	Crowd	Improved Google products (this has been shut down and integrated into Google Maps)
Google	Code Jam	Programming contest to solve programming problems and identify talent (administered by TopCoder from 2003 to 2007)	Crowd (contest)	Prize money (currently $15K), recognition, job offers, competitive thrill and self-satisfaction
Google	Feedback, bug reports, and feature requests	Feature request forms and forums. Issue tracker has social ranking option (you can vote on issues you want resolved or features you want implemented)	Crowd	Improved Google products
Google	Bug Bounty Program	Google Security Reward programs provide various prizes for people who can find security vulnerabilities in its products (some managed through HackerOne)	Crowd (contest)	Monetary awards ranging from $100 to tens of thousands of dollars depending on type of vulnerability discovered
Google	Crowdsource app	Users around the world do micro tasks like image transcription, translation, handwriting recognition, etc.	Crowd	Improved Google products for local community/languages
Apple	iOS analytics data	Data collected from all users of iOS who opt in to "help Apple improve its products and services by automatically sending daily diagnostic and usage data"	Crowd	Improved Apple products
Apple	Location Services	Apple automatically collects Wifi hotspot and cell tower locations, as well as traffic data from iPhones that enable Location Services	Crowd	Improved Apple products and enabled useful features
Google	Play Store	Market for Apps, movies and TV, music, and books for Android devices (plus online retail for hardware and products sold directly by Google)	Marketplace	App and media producers find buyers, buyers find Apps and media. Google gets fees and data, and Android devices become more valuable

Table 1. (Continued)

Firm	Case	Description	Crowd or marketplace?	Incentives
Google	Ads and Search	Search engine and platform that uses web content and search data to enable targeting of ads	Marketplace	Users find websites, websites attract users, ad providers target users that search for certain keywords
Google	YouTube	Platform for production and consumption of video content	Marketplace	Users find content, content producers attract users, ad providers target users that search for or watch certain content
Google	Google Opinion Rewards app and Google Surveys	Users around the world answer short surveys in exchange for play store credits. Survey designers can purchase responses for as little as 10 cents per response	Marketplace	Survey providers get respondents, Respondents get Google Play credit (can be used on media and apps in play store). Google gets fees and data
Apple	App Store	Marketplace for iOS apps. In one project, Apple partnered with TopCoder to strengthen its Swift and iOS developers community	Marketplace	App producers find buyers, buyers find Apps. Apple gets fees and data, and iOS devices become more valuable
Apple	iTunes	Market for music, TV and movies	Marketplace	Media producers find buyers, buyers find media. Apple gets fees and data, and iOS devices become more valuable

discussion is a helpful first step. Scholars have tackled the varieties of knowledge constraints under various labels, such as uncertainty, unknowingness (Townsend et al. 2018), or ignorance (Smithson 1989). Although Smithson unpacks ignorance into sixteen types and subtypes, others have preferred more parsimonious typologies. Townsend et al. (2018) suggest a four-pronged categorization and argue that existing literature has suffered many confusions by conflating them into an umbrella notion of uncertainty. They suggest that the term "uncertainty" should be used to refer to a more specific condition describing a lack of information that can be resolved when the missing information is found, while the other three concepts of complexity, ambiguity, and equivocality can describe other forms of unknowingness involving too much information, problems processing and interpreting information, and the problem of conflicting interpretations of information. These latter three, they argue, are knowledge problems not necessarily resolvable through the accumulation of additional information.

To avoid the pitfall of conflating various notions of unknowingness, one could adopt the definition suggested by Townsend et al. (2018). However, the organizational devices we theorize about here also help tackle some issues of complexity, ambiguity and equivocality. In other words, using a distinction provided by Smithson (1989), although our arguments are focused on *informational* ignorance, some aspects of *epistemological* ignorance are also relevant. In either case, the distinctions between different forms of uncertainty is not always clear-cut. For example, March's (1978) definition of ambiguity as uncertainty about preferences involves aspects of both epistemological ignorance and informational ignorance. The idea that we may change our preferences after receiving new information is an aspect of informational ignorance, while the idea that we may have conflicting and inconsistent preferences, "that we simultaneously want and do not want an outcome, experience it as both pleasure and pain, love and hate it" (March 1978, p. 597) reflects a deeper kind of epistemological and interpretational problem.

March's notion of ambiguity as uncertainty about preferences highlights the limitations with commonly accepted notions of Knightian uncertainty: the inability to delineate possible future states, let alone to assign probabilities to them, is only part of the problem if we are ignorant about the desirability of states. A key consequence of ambiguity is that the same actor might see the same thing differently at different times and different actors can differ in their perceptions of the same thing and in their decisions about what actions should be taken (Daft and Macintosh 1981, Weber and Mayer 2014). At the firm level, we can attempt to abstract away from some of these problems by, for instance, assuming that for-profit firms will always prefer more profit over less. However, problems of uncertainty and preference ambiguity will remain regarding the intermediate outcomes that can be expected to lead to greater profits. The organizational tools of firm-designed markets (crowds and marketplaces) often defy these problems by allowing firms to avoid costs before profitability and desirability are proven.

Our main argument hinges on the notion that firm-designed markets provide semidirected and undirected search mechanisms that allow firms to defy knowledge constraints, especially those that cannot be resolved through directed search mechanisms. This is the fundamental problem of "not knowing what to look for" and relates to the distinction between known unknowns (first-order uncertainty) and unknown unknowns (second-order or meta-uncertainty). Although this distinction is popularly attributed to Donald Rumsfeld, it has been discussed by many thinkers before (Kerwin 1993, Bammer and Smithson 2012), and can be traced as far back as thirteenth century Persian poetry, where unknown unknows are referred to as the problem of "double ignorance."[1] The distinction is useful because it identifies a category of knowledge constraints that are particularly severe. Defying ignorance is an exceptionally hopeless endeavor if one does not even know what to search for or that there even needs to be a search. Kirzner (1979, p. 142) refers to the meta-uncertainty problem as the Shackle-Boulding knowledge paradox: "that we have to know what we want to know before we start looking for it" (Boulding 1968, p. 146). While search and collection of information seems to provide a viable path to tackling first-order uncertainty, resolving second-order uncertainty is much more elusive.

An important clue as to how meta-uncertainty may be tackled is provided by Bammer et al. (2012, p. 294) in describing their experience of facilitating a conversation among a variety of experts on uncertainty that approached the topic from different disciplines: "while we only become aware of our own meta-ignorance in hindsight, it is relatively easy to spot other people's meta-ignorance." In other words, an effective path to resolving meta-uncertainty involves interacting with other knowers with substantially different knowledge sets. At the organizational level, this means that an internal search process is not the best way to tackle meta-uncertainty; the organization must employ mechanisms that allow it to access a multiplicity of external agents with a variety of knowledge sets that are substantially cognitively distant (Gavetti 2012) or nonoverlapping with the organization's own knowledge set. This type of interaction is the key factor that has been enabled by digital organizational devices, which was not available on a mass scale before the digital revolution.

We emphasize that the problem of not having a starting point for directed search is not just a problem of informational ignorance. For example, it often involves types of ignorance that Smithson (1989) refers to as "irrelevance" or Medina (2013) refers to as "blindness." These are more "active" types of ignorance rather than passive ones and involve more than just not having access to information. Under the label of irrelevance, Smithson defines "untopicality" as people's intuitions about what is or is not relevant to search for which is limited by their cognitive domains, "taboo" as socially enforced disregard for knowledge, and "undecidability" as matters that may seem insoluble, nonsensical, or meaningless to someone given their distance from the knower's cognitive domain. Importantly, firm-designed markets as an organizational device allow the sidestepping of active ignorance by precluding the need for directed search.

3. Knowledge Constraints of Hierarchies

Traditionally, economic organization requires the firm to go through three stages of selecting actors, contracting with them, and monitoring their performance (Williamson 1975). In the context of online marketplaces, Wellman (2004) provides a similar categorization of the transaction into three stages of connection (search and discovery), deal (negotiation), and exchange (execution). In Table 2, we summarize how first-order and second order knowledge constraints manifest themselves in each stage, causing the firm to incur inefficiencies.

3.1. Selecting

Consider a firm that commences an economic activity by identifying a desired outcome. In the initial phase, the firm needs to select a set of actors with whom it can enter into a contractual agreement in the form of employment or exchange. From the onset, the firm faces a knowledge constraint in regards to knowing who would be the best set of actors to realize the outcome. Thus, the firm searches the market, incurring the cost of acquiring information about actors

Table 2. Examples of the Firm's Knowledge Constraints in Traditional Organizing

Stage	Selection		Contracting		Monitoring	
Type of ignorance	Known	Unknown	Known	Unknown	Known	Unknown
Example	How to evaluate available actors' suitability for tasks?	What is the best set of actors and skills for the task?	How to contract in order to pay for productivity?	What future contingencies may arise?	How to evaluate shown behavior?	What is the best behavior?

to be hired (Spence 1973) or be exchange partners (Williamson 1975).

The first-order knowledge constraint manifests in this selection process in two ways. First, the firm is faced with the information deficiency problem, because of its limited ability to collect information, resulting in its focusing on just a subset of the full set of actors in the economy it knows to be potentially suitable. This problem increases in severity with the number of actors and number of tasks required. Second, because contractual agreements are typically used for more than a single task (Cheung 1983), the firm is not able to perfectly assess actors against one another or their suitability for future work. This is known as the adverse selection problem (Eisenhardt 1989, Hölmstrom and Tirole 1989). Taken together, even though the firm would want to find the best among all those who are available in the economy, it "satisfices" and searches within a set of actors who are just "good enough" (Simon 1947).

Second-order knowledge constraints further exacerbate the inefficiencies of the deliberate search process. First, the *best* set of actors may not exist in the currently searched or considered population of players in the economy; it could be that other potential actors comprise the best set, yet the firm may not have any information on their existence. Second, the firm may not even know the best constituent skills for the task. Thus, the firm's effort in finding the best is inhibited by second-order uncertainty that makes more investments in the search process futile.

3.2. Contracting

Once past the selection stage, the firm faces knowledge constraints in the process of entering into a contractual relationship. For one, the firm is unable to obtain complete information regarding the input desired of individuals (Alchian and Demsetz 1972). It therefore resorts to an agreement in which the conditions of service provided are expressed in general terms, articulating the exact details at a later date (Coase 1988). That is, the firm is unable to utilize a contract that is closely tied to productivity (as opposed to wage) and risks paying a premium to the employee over the spot price for any piece of work. Similarly, in the case of contracting with an exchange partner, time and cost limits involved to identify future contingencies cause the firm to resort to incomplete contracts (Klein 1980). Therefore, as a remedy to the situation faced, the firm resorts to contract terms in order to elicit the desired behavior or safeguard against undesired behavior (Williamson 1985, Hart 1995, Kim and Mahoney 2005).

Similar to the selection stage, no matter the amount of resources used to collect information with which to improve the contract, second-order knowledge constraints inhibit drafting the most cost effective or best contract. It is impossible to identify all future contingencies ex ante (Williamson 1985, Hölmstrom and Tirole 1989), meaning that any contract optimized today may seem obsolete in the face of future state of events. This can result in a payment above the spot market price for the services rendered in future.

3.3. Monitoring

Finally, once the contract is in place, the firm incurs monitoring costs to ensure that actors behave in accordance with the terms of the contract, and that their effort is directed toward achieving the desired outcome. First is the issue of preventing shirking (Alchian and Demsetz 1972) or opportunism (Williamson 1985). Second, monitoring is required as a remedy for whatever could not be contracted upon ex ante (Hölmstrom 1979) and for misalignment of performance due to misinterpretation issues (Hodgson 2004). Third, the selected actors may be suboptimal with respect to their competence, requiring the firm to potentially incur more costs, such as costs for task-specific training (Spence 1973).

The firm faces various first-order knowledge constraints in obtaining information about the performance of actors. For instance, the firm might not be able to acquire the relevant information to shape the basis of evaluation due to hidden information (Arrow 1973), nonavailability (Milgrom and Roberts 1988) or nonobservability (Hölmstrom 1979, Kim and Mahoney 2005). Moreover, even in the face of identifying misalignment between actual and desired behavior, the firm may not be able to steer actors' performance in a favorable direction, even though it has legal leverage, due to the costs of third-party enforcement (Klein 1980) or employee dismissal (Kugler 2003).

Furthermore, the assumption that monitoring can improve the performance of actors presupposes the availability of information that correctly identifies desired behavior. However, as a result of second-order uncertainty, the information that a firm possesses regarding a desired behavior is itself imperfect, and it may therefore never know the best behavior for actors in terms of realizing an outcome. As an extreme example, one might think that actors should think behind their desks at the laboratory in order to find the solution to a complex R&D problem; however, it is also likely that an insight toward the solution might be gained by taking a nap (see, e.g., Wagner et al. 2004)! In other words, the firm cannot realize the optimum production possibility of actors through a traditional monitoring process, because it cannot fully comprehend the possibilities, and it is likely not even aware of this ignorance.

4. Market-Based Circumvention of Knowledge Constraints

The above arguments showed how economic organization within the firm is beset with knowledge problems. Our aim in this paper is to theorize the ways in which market-based solutions enabled by digital technologies in the form of market-hierarchy hybrids can tackle these knowledge constraints in new ways, beyond the capabilities of traditional hierarchies. To this aim, two key questions need to be addressed: What are the knowledge benefits of market mechanisms? And how can these benefits be put to the service of the firm?

4.1. Knowledge Properties of Market Mechanisms

The default view of markets in economic thought envisions them as mostly resource allocation mechanisms (as in Adam Smith's famous "invisible hand"), and this view remains persistent today, as can be seen in, for example, the literature on market design (Roth and Sotomayor 1990; Roth 2008, 2015). To appreciate the capacity of markets to tackle knowledge problems, we build on an alternative view of markets that emphasizes their knowledge properties.

Hayek (1945, pp. 519–520) contends that the problem of economic organization at the social level is not that of resource allocation, ". . . [i]t is rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know." Hayek's view is that the market solves knowledge problems in ways that go beyond the capacity of any possible central organizer. This view stresses the fragmentation of knowledge and its dispersion among the multitude of individual consumers and producers and, in line with this, the market is seen as an instrument to mobilize dispersed knowledge through the price mechanism. Through this specific lens, the prices arising out of freely competitive markets play a critical role in aggregating and passing information to actors in the economy, such as what goods to produce or what input mixes to employ in production (von Mises 1949). Hence, the market, in its state of "constant flux," continually brings in new competitors and achieves "systematic co-ordination of dispersed pieces of information available . . . throughout the economy" (Kirzner 1992, p. 53).

A crucial knowledge property of market mechanisms is that they are capable of addressing second-order uncertainty (Kirzner 1997). The competitive force of the market functions as a discovery procedure which goes beyond anything that could be deliberately aimed for through a centrally guided search process (Hayek 1968). Furthermore, markets are essentially knowledge generating systems that advance knowledge in society systematically and autonomously, because they create the conditions that incentivizes entrepreneurial participants to innovate (Romer 1990, Baumol 2002, Phelps 2013). No central planner is needed to direct this search for knowledge, and often the new knowledge produced comes as a surprise to many market participants as well as the market designer (Foster and Kaplan 2001). Market mechanisms are able to spur the discovery of unknown unknowns.

4.2. Crowds and Marketplaces as Different Solutions to Knowledge Constraints

Institutions, such as the market, may be viewed as a kind of "social technology" (Nelson and Nelson 2002), that can be put to the service of the firm like any other technology. The term "market-hierarchy hybrid" (Felin and Zenger 2011) can refer to a variety of organizational arrangements where market mechanisms are used as a technology in the service of the firm. Examples and terms used to describe some varieties of these hybrids include innovation contests (Boudreau et al. 2011), crowdsourcing (Poetz and Schreier 2012), or various forms of platforms (Eisenmann et al. 2006, Tiwana 2013), such as mobile app marketplaces (Jansen and Bloemendal 2013).

We propose that it helps to clarify the nature of market-hierarchy hybrids by making a distinction between two subtypes of firm-designed markets: those that implement the market mechanism half-way through a one-sided market arrangement, or crowd-based hybrids, and those that implement a full two or multisided market arrangement, or marketplace hybrids.[2] Crowds and marketplaces each have their own relative advantages and disadvantages, but both provide knowledge benefits that are able to tackle the hierarchy's knowledge constraints, and in particular the "hidden knowledge" (Felin and Zenger 2014) or second-order uncertainty problem.

Crowd systems aim to introduce properties of markets in places where they did not exist before, in order to benefit from the properties of markets, such as self-selection, competition, and price coordination. Although "price" in many crowdsourcing arrangements is nonmonetary and often very low per contribution, it is still present in the form of some incentive for crowd members to make their contributions. At the same time, crowd systems refrain from implementing a full two-sided market in order to maintain a monopoly position for the focal firm on the demand side of the market. However, monopoly rents on the demand side are not without costs. The trade-off here is that the firm only relies on its own knowledge and capabilities to be able to define a problem presented to the crowd (Afuah and Tucci 2012), and also relies only on its own absorptive capacity (Cohen and Levinthal 1990) to receive solutions from the crowd. Problem definition in crowdsourcing arrangements require being able to decompose a task into smaller well-defined components, which may not be an option for nondecomposable problems (Nickerson and Zenger 2004).

Marketplace systems implement a full (at least) two-sided market (Rochet and Tirole 2006), in which the focal firm typically has an important complementarity with all activity that occurs in the marketplace (Jacobides et al. 2018), but is no longer the only specifier of problems or the only recipient of knowledge on the demand side. This arrangement liberates the firm from having to rely on its own knowledge in defining problems and absorbing new information, and also allows the market to enjoy greater dynamism and sustainability because each side of the market can have the "requisite variety" (Ashby 1958) to keep up with the other side. By letting the market match problems and solutions, the firm as marketplace orchestrator is able to discover simultaneous problem-solution pairs (von Hippel and von Krogh 2016) rather than just solutions to problems that it has defined. On the other hand, in marketplace arrangements the firm typically loses control over the direction of search. While marketplaces are excellent mechanisms for generating surprises (discoveries of previously unknown unknowns), they are not very effective tools for the resolution of known unknowns. Unlike in crowd systems where the crowd focuses on solving the problem specified by the firm, in marketplace systems the supply side crowd focuses on a variety of problems specified by the demand side crowd. These differing characteristics lead some firms to utilize both crowd systems and marketplace systems in different areas of their business, alongside (rather than as substitutes for) traditional forms of organization.

If we think of instances of economic value creation as having a supply side and a demand side where value is created by matching a problem on the demand side with a solution on the supply side, then crowdsourcing can be viewed as better suited to tackling knowledge constraints on the supply side if a problem on the demand side can be specified. Marketplaces on the other hand can be viewed as mechanisms for tackling knowledge constraints on both the supply and demand side. This relates to March's (1978) definition of ambiguity as uncertainty about preferences (rather than just outcomes). A firm defines its knowledge problems according to some preference regarding what it would like to know that it does not. If that underlying preference is itself unknown, the firm has no starting point for search. Marketplace mechanisms allow the firm to bypass the limitations of its own preferences or what it thinks it prefers at any given time and let the dynamic demand side of the market decide what is preferable (and thus economically valuable) and what is not.

In the next two sections we delve deeper into the knowledge properties of crowds and marketplaces. In the discussion section we review the arguments in the framework of a comparison between crowds and marketplaces.

5. Crowdsourcing as a One-Sided Market Solution to Knowledge Constraints

> This trend [crowdsourcing] is going to be the industry ... I have no doubt ... these will be the predominant development models. These models will absolutely replace the old traditional developing models. —Jack Hughes, founder and chairman of TopCoder.com, interviewed in October 2012

Crowdsourcing enables firms to leverage digital technologies to go beyond their hierarchical boundaries and create firm-specific markets that encourage and direct outside participants to engage with firm-specific problems (Felin and Zenger 2011). In its essence, crowdsourcing harnesses the entrepreneurship of the crowd through a combination of market-like features, in particular its information aggregation and matching features (e.g., problems with solutions), which is complemented by the resources and initiatives of the firm (Felin and Zenger 2011). In contrast to pure hierarchy, in this arrangement, the firm no longer coordinates through orders that are legitimized by authoritative positions, but instead through defining the rules and providing signals to which each individual can freely adapt and respond. This, in turn, enables the firm to confront *both* first-order and second-order knowledge constraints in new ways, although the capacity of crowd systems to deal with second-order constraints is not as extensive as marketplace systems as noted earlier. The search for knowledge is not fully directed as in the hierarchy and not as undirected as in the marketplace. Rather, crowdsourcing represents a semidirected way to search for new knowledge. In the following, we illustrate this argument by revisiting the knowledge constraints involved in the three stages of transactions reviewed above for hierarchies. A summary of the arguments in this section is provided in Table 3.

5.1. Attracting Rather than Finding Actors: From Selection to Self-Selection

Recall that an important knowledge constraint of the firm lies in selecting and evaluating actors' suitability for tasks—in essence, determining how to find the best actors. With crowdsourcing, the firm leverages a decentralized process through which the same goal of identifying the optimum set of actors for tasks is sought via a different approach, that is, *attracting*

Table 3. Informational Efficiency Gains of Crowdsourcing Compared with Traditional Organizing

Change in the process	Attraction instead of selection		Spot market transaction instead of complex contracting		Outcome selection instead of monitoring	
Type of ignorance	Known	Unknown	Known	Unknown	Known	Unknown
How knowledge constraint is circumvented	Actors self-select tasks	Expand the set of market participants	Pay for outcome	Expands the compensation structure to follow market prices	Supervise progression toward outcome	Expands the bounds of possibilities for attaining outcomes
Logic of efficiency gain	Opportunity identification by actors rather than efficient selection by authority		Entrepreneurial profit anticipation by actors rather than anticipation of future contingencies by principal		Competition as a discovery procedure rather than centralized direction	

actors rather than finding them (Hayek 1948) and allowing them to self-select to participate (Afuah and Tucci 2012). In the selection process of traditional organizing, finding necessitates directed search for information about actors' knowledge, skills, behavior, talents, etc., in order to identify the best actors. In contrast, by attracting, such identification takes place through the market mechanism incorporated in the arrangement, where "the unknown persons who have knowledge *specially* suited to a particular task are most likely to be attracted to that task" (Hayek 1948, p. 95, emphasis added).

Whereas directed search begins at centralized points of decision-making in the hierarchy, the attraction process shifts the onus on to individuals and links it to their decision-making under the competitive forces of the market. When participating in crowdsourcing, individuals are signaled by prices (or other incentives playing the role of prices) in the form of entrepreneurial opportunities. Hence, the burden of knowing who should be doing what falls on the actors, who are now required to identify possible opportunities in the market that match the unique knowledge they possess about themselves and what they can do. Felin and Zenger describe the importance of this shift in the burden of knowledge for defying second-order uncertainty:

> . . . [T]he problem is not merely the dispersion of relevant knowledge, as prior work suggests. If the manager knows the location of the requisite dispersed knowledge (and can access or acquire it), dispersion need not be an impediment. The real difficulty arises when the manager is unaware of the location of the relevant knowledge for solving particular innovation problems. Under these circumstances, the manager cannot acquire knowledge, or contract for it, but must instead invite and motivate those possessing it to reveal themselves. (Felin and Zenger 2014, p. 917)

The process of self-selection by individuals achieves a coordinated outcome due to the existence of competitive market forces and the information signals they produce. As actors go through the process and self-select tasks, some face frustration and disappointment as they fail to deal with the uncertainties inherent to such an undertaking. For example, most individuals who compete in a crowdsourcing contest do not win any prizes. This negative feedback, while disappointing, nonetheless plays a crucial role on two levels. At the individual level, actors form opinions (Hayek 1968) about the value of their offerings in relation to what customers are looking for. They adjust their plans based on the market process, as entrepreneurs responding to profit opportunities (von Mises 1949). These individual learnings add up to a systematic equilibrating force, which results in an overall coordination at the market level (Kirzner 1997). Therefore, the problem of the firm concerning who should do what is addressed not based on the direction of a hierarchical authority that optimizes decisions through information accumulation but through the self-organizing process of the market where the actors themselves make such decisions and gravitate toward what they do best relative to perceived reward.

A quote by a senior manager of TopCoder (the platform used by Google for years to manage its Google Code Jam crowdsourcing contests) interviewed in 2012 demonstrates this further: "If you want really high quality output from an individual, you need them to bring their A-game as we say. Bringing their very best . . . So you don't force them to do tasks, you let them naturally gravitate to the tasks they enjoy doing. They aren't *penalized* for not participating. So therefore when they participate it follows that they are doing it because they want to do it very much and that is a very key thing" [emphasis added].

Crowdsourcing gives rise to a market that facilitates redistribution of actors to tasks in the economy, where formerly nonplayers become potential participants in the market. In doing so, a larger set of actors who has the potential to outperform others for specific tasks is given the chance to participate and create value, and this translates into *expanding the set of actors* the firm has access to in the market, bringing in new players from the pool of potential ones in the economy beyond what the firm was able to reach through centrally guided search. Digitalization has made it possible to broadcast calls for contributions and receive contributions from mass numbers of people around the world. To the extent that the market created by crowdsourcing can reach new potential players, it also expands the production possibilities of the economy as a whole (Moran and Ghoshal 1999) and spurs a new distribution of actors in a way that would have been inefficiently accomplished, or may be even impossible, in a traditional organizing form. As a result, the firm is able to obtain information on the existence of market players outside of its known set, thereby enabling a richer landscape search that taps into the vast landscape of problem solvers external to the firm (von Hippel and von Krogh 2016).

The expansion of the actor set is important for not only the aggregation of distributed knowledge it enables but also the competition of distributed knowledge of external actors among themselves and with the firm's own presumptions. As articulated by Nickerson et al. (2017, p. 282): "crowds are more than sets of actors with disparate knowledge; they are aggregations of actors with the potential for competing theories that reveal competing problems." In a study of crowdsourcing projects on the NineSigma intermediary platform, Pollok et al. (2019) find that attraction of crowd participants works best when the problem specification has a moderate knowledge distance with the knowledge set of the firm. If the problem is over-specified by the firm, it restricts the range of competing theories and innovative ideas that crowd participants can bring to the table. On the other hand, if the problem is too under-specified, crowd participants will have a difficult time understanding exactly what the firm wants and how they can add value.

A crowdsourcing initiative at NASA provides a great example. In an intriguing instance, they wanted to crowdsource the problem of modeling the positioning of solar collectors on the International Space Station (ISS) to generate as much power as possible. However, because of heavy investment in capital and the man hours required to set up the infrastructure, NASA utilized crowdsourcing not to find the solution to the original problem regarding the modeling, but rather to find a solution to the question of "how do we crowdsource this problem efficiently?" By doing so, a programmer who was not familiar with solar panels was able to provide an efficient and elegant solution to the latter problem (Nag et al. 2012). This example illustrates how crowdsourcing addresses second-order knowledge constraints; whereas the firm had no a priori information on the existence of programmers that could outperform potential experts in solar panel modeling, the created market brought a person to the set of potential actors who did not exist in the original set of professional modelers.

An even more aggressive strategy of expanding the actor set is seen when companies like Google and Apple collect data from every possible user to solve a problem or complete a task, because almost everyone has something to contribute. For example, anyone who opts-in to Apple's location services allows the company to automatically collect Wifi hotspot and cell tower location data as well as traffic data from their device, which Apple then uses to improve its products and services.

5.2. Spot Market Transacting Instead of Complex Contracting

By creating a competitive market, crowdsourcing also enables the firm to overcome the contracting hurdles that are found in traditional organizing. This entails switching from drafting complex and incomplete contracts—limited to what the individuals are expected to do (Coase 1937) with gaps left for adaptation to future contingencies (Williamson 1991)—to utilizing spot market contracting for labor. Spot market transactions follow a classical contract law, that is, "sharp in by clear agreement; sharp out by clear performance" (Macneil 1973, p. 738), thus rendering an ideal transaction in the market, where "individuals would be paid if and only if they completed the agreed-upon task in the agreed-upon manner in the agreed-upon time" (Stiglitz 2000, p. 1444).

Entering into a contractual agreement requires *anticipation* (Williamson et al. 1975) in both traditional organizing and crowdsourcing. In the latter however, rather than bearing the burden of incomplete information in anticipating future state of events, the firm sources single tasks—larger tasks are typically deconstructed into smaller subtasks (Afuah and Tucci 2012)—and only agrees, in the form of prices, to compensate for outcomes that meet certain expectations. To the extent that the firm must rely on its own knowledge to define problems, deconstruct them into smaller tasks, and set prices for them, crowdsourcing represents a semidirected type of search for knowledge. It leverages some of the benefits of market mechanisms while still allowing some level of targeting in the search for knowledge. Digitalization has made it possible to decompose tasks into smaller subtasks like never before, making possible new forms of crowdsourcing. For example, Google knows that it needs an enormous amount of data from human input to improve the localization and translation features of its products and services, making them available in a multitude of languages. Using it's "Crowdsource" app, Google breaks down the problem into thousands of microtasks involving image transcription, translation, and handwriting recognition, and allows users around the world to complete as few or as many of these microtasks that they like, at any time that is convenient for them.

On the individuals' end, these prices not only are the "signals to be deliberately consulted in order to find out the right thing to do" but also act as "flashing red lights alerting hitherto unwitting market participants" to the possibility of profit (Kirzner 1992, p. 150). Hence, the onus shifts to these individuals to anticipate entrepreneurial profit upon entering into an agreement regarding a particular task relevant to their given circumstances. In traditional models the outcome-based compensation scheme encourages effort on the part of the agent by shifting some of the risk from the firm to the agent (Milgrom and Roberts 1988, Eisenhardt 1989). In crowdsourcing, the application of the price mechanism goes beyond the imposition of risk to render opportunities for entrepreneurial profit. The profit opportunities embedded in existing prices of such a market attracts individuals whose labor service is priced relatively lower in other markets. It is this entrepreneurial profit anticipation that accounts for individuals' compliance with spot market transactions when it comes to their labor for idiosyncratic tasks, such as R&D problems. Participation in the market may then lead to profit realization or might just lead to other nonmonetary rewards, such as learning (Krueger 2007). Nonmonetary rewards are especially important when the tasks to be crowdsourced are broken down to such a micro level that cash rewards would no longer make sense as compensation. In Google's Crowdsource app, users are incentivized by improved Google products and increased availability in their localized language and community. Google Map's Local Guides program provides something in between cash compensation and improved products by working with a gamification system involving level-ups and badges, early access and special offers on Google products. Relatedly, Chandler and Kapelner (2013) have shown that perceived "meaningfulness" of small tasks affects the performance of crowd participants in Amazon's Mechanical Turk platform.

As a result of the above, first- and second-order knowledge constraints are curtailed, because the firm only pays for outcomes and avoids the burden of having to anticipate unrealized futures. Crowdsourcing can attract a set of actors for each task whose payment scheme is closely tied to productivity. Moreover, second-order uncertainty is curtailed by expanding the compensation structure to follow market prices. Crowdsourcing enables such a transaction—which formerly required a complex contract—to take place in a spot market format. Competitive market forces precisely locate the "man on the spot" (Hayek 1948) whose service specifically can be tailored to the firm's need. Therefore, the costs incurred by the firm more readily follow the market prices for each task at any given time frame, which is not an option for traditional organizing (Klein 1984). In addition, it is through creating a missing market, that is, a market that did not heretofore exist, that the firm is able to utilize such spot market transactions and expand the set of potential actors where it was not feasible beforehand.

5.3. Outcome Selection Instead of Monitoring

The essence of monitoring is verifying that the relationship between means and ends envisioned at the outset are in fact realized as events unfold, where detected misalignments call for corrective actions. Contrary to traditional organizing, in crowdsourcing there is no one employed actor or exchange partner whose behavior needs to be monitored. Instead, an open collective entity with a dynamic nature is responsible for realizing the outcome, which occurs through competition and numerous iterations among individuals comprising that entity. As a result, the need to have preconceived means-end relationships regarding specific actors, such as certain behavior compelled by contractual terms, is substituted by the process of selecting outcomes that arise through market forces.

First-order knowledge constraints are addressed here by replacing the singular need to measure and evaluate specific behavior of actors with outcome selection from a set that the market delivers. As a result, the firm reallocates resources targeted for monitoring to the process of supervising the realization of the outcome through the market process. This includes detecting misalignments regarding the conditions conducive to effective operation of the market process, such as the reward structure or task scope, and taking corrective actions accordingly. In other words, the burden of designing the opportunity for participation remains on the focal firm. For example, if a crowdsourcing contest fails to attract enough submissions, the firm may extend the deadline, limit the project scope, offer higher prices as prize, and so on. Google's Code Jam contests, specifically designed to attract talent, have evolved in terms of their rules, prizes, scope and other aspects over time. For a period of time they were managed through the TopCoder platform but are now administered directly by Google. Digitalization has made it possible to automate many aspects of crowdsourcing administration.

Additionally, with the shift to outcome selection, the decision-making and actions crowd participants is no longer limited to the possibilities imaginable by the firm's management, which excludes anything beyond a certain cognitive distance from their existing knowledge set. Crowdsourcing removes such limiting factors and expands the possible landscape to include more attainable outcomes through actions that might not be conceivable by managers or employees of the market-designing firm. This addresses second-order uncertainty by discovering information on novel and potentially superior ways to realize outcomes compared with what would be achievable in the traditional mode. Such information is the "yield" to the competitive process of the market which "*digs out* what is in fact discovered" (Kirzner 1992, p. 147, emphasis in original).

In crowdsourcing contests, multiple actors work on the same task with the knowledge that only a limited number of outcomes can be compensated. A byproduct of this is leaving the firm with various realized outcomes to choose from. A senior manager of TopCoder explained to us how the submissions of the crowd members for analytic problems could be of surprisingly high quality:

> crowds are amazing because when you get that kind of . . . sample size . . . what happens is, predictably, a few of the people, maybe three, maybe seven, maybe twelve, but out of the 300, a few of them had the right approach to that problem. And they moved the needle towards theoretical maximums, like towards how optimized this could be and they do it in ways often that even domain experts . . . don't approach

[Interviewed in November 2014].

This method of utilizing the contributions of many individuals, whose behavior are adjusted through the self-equilibrating market process, renders many threats of opportunitstic behavior ineffectual. The firm is no longer so concerned with monitoring individuals but rather the progress of the crowd. Alexy et al. (2013) point out some of the limitations of more traditional forms of collaborating, such as a lack of awareness of the complete set of potential partners, high costs of coordinating among multiple actors and inadequate incentives to collaborate when the firm is too selective in revealing knowledge. Crowdsourcing mechanisms are able to overcome such constraints.

An important mechanism utilized in crowd systems to help select and verify the best outcomes is to outsource the verification task itself to the crowd. This is typically achieved by triangulating the work of each crowd participant with the input of other crowd participants. For example, in the Google Maps Local Guides program, if one crowd member tags a location as being "wheelchair accessible," Google does not immediately update the publicly available information on Google Maps to include this tag until many more crowd participants have verified that the location is indeed wheelchair accessible. Such triangulation processes are automated with digital technologies and advanced algorithms. Statistical and machine learning models are developed that learn from previous data to assess the amount of verification required in each new case to be confident about the reliability of crowd-tagged information.

While crowd systems are a useful form of firm-designed markets, these initiatives are best described as half-way implementations of markets. They still require the firm to specify a problem on the demand side, and are often one-off initiatives that do not achieve the dynamism and continuous, systematic generation of new knowledge that can be achieved through full two-sided markets. To the extent that crowd systems require the firm to specify a problem, they are still restricted by the firm's knowledge constraints in some ways. What if the problem specified was not the best thing for the firm to be focusing on at all? The next section discusses two-sided market solutions that are able to circumvent additional knowledge constraints, by sacrificing more search control.

6. Marketplaces as Two-Sided Market Solutions to Knowledge Constraints

Having outlined some of the informational efficiencies of crowdsourcing as an example of one-sided market mechanisms used in the service of the firm, we now move on to explore the informational efficiencies of two-sided market mechanisms or firm-designed marketplaces. In marketplace systems the above used framework of selecting, contracting, and monitoring is no longer suitable because we move from the transaction level to the system-of-transactions level. The firm takes on a more meta-level role as the orchestrator (Tee and Gawer 2009, Tiwana 2013) of the marketplace where a variety of agents on both the supply and demand sides are matched together. It is no longer just about matching transaction partners with the firm itself. It is about matching other transaction partners to each other and benefiting in some way from the match.

This meta-level role of the firm also tackles knowledge constraints at a higher level. Namely, it deals with a fundamental problem that cannot be dealt with adequately when relying on one-sided crowd systems: the problem that the firm must still know what to ask for from the crowd. It must be able to specify the demand side problem, that is, it must know what problem if solved would be valuable. More fundamentally, it must know that the problem is there in the first place. Also, the firm must be able to absorb and work with the solution if and when it is found. The premise of firm-designed marketplaces is that if the firm is able to release itself from these knowledge requirements, it may be able to benefit from many problem-solution matches beyond just those that the firm itself is able to specify, search for, and absorb on its own.

Every potential problem-solution match that creates economic value, no matter whose problem or whose solution it may be, is an economic opportunity. Sometimes these matches are made in "the market" independent of any market designer, but in many instances such potential matches are not made until a marketplace is created that aides the matchmaking. The marketplace designing firm aims to find a way to systematically solve knowledge problems of the type "what problems exist for whom and what solutions can be provided for them by whom" usually in a particular category (such as transportation, housing), where previously existing mechanisms of market match-making are inefficient. The firm profits because the marketplace itself becomes a digital product that becomes complementary to every problem-solution pair matched. In other words, every match that is made is a newly discovered solution to the question of "what use does our marketplace product have?" Some market-designing firms are pure platform companies whose extent of complementarity with the transactions in their market ends here. They just profit by aiding the match (e.g., by taking a cut on each transaction). For these firms the marketplace is their entire business model and they typically do not exist independently of it. Well-known examples of these types of firms include Uber, AirBnB, and JustEat.

However, some market-designing firms have tools or technologies beyond the marketplace product itself that complement the problem-solution matches enabled by their marketplace. These firms then create marketplaces that enable problem-solution matches that involve their complementary tool or technology in some way. Rather than finding generic "Problem A to Solution B" matches, they find "Problem A to Solution B that involves tool X" matches. Depending on the number of complementary technologies, with each match made in their marketplace these firms discover a new solution to the question of "what use does our marketplace, and our tool X and our tool Y and … have?" Such firms are typically tool providers before they are marketplace providers. But they often learn that without marketplaces, a tool provider is limited by its own knowledge, imagination, and capacity to find uses for the tool that create value. With a two-sided marketplace, the firm can tap into a plethora of possibilities beyond its own knowledge, imagination and capacity. Among the bundle of complementary tools that they have, they may choose to provide some for free (subsidize their use) in order to maximize value at some other point in the chain of complementarities. An example is Google's Play Store mobile application marketplace (similar also to Apple's App store). Each match made in the Play Store is an answer to "what use does the Play Store marketplace have, plus the Android operating system, plus any smartphone running the Android operating system?" Google's strategy has been to provide the marketplace app and operating system for free, but take a fee on marketplace transactions, and has more recently profited from producing and selling high-margin smartphones that run on Android. In either case, Google is able to benefit from the knowledge properties of the marketplace in the sense that the Play Store frees Google from the burden of having to know what people need or want to do what things with what apps at what times, and what people can build those apps in what ways, and at what costs. The marketplace automatically finds solutions to this knowledge problem, and with every solution found, Google profits because of its complementarities without having to absorb or use the knowledge itself.

For example, after King Digital Entertainment released the Candy Crush Saga mobile game that worked on iOS and Android, Google and Apple discovered that millions of people around the world were willing to pay millions of dollars for features on the app. They both not only took cuts from those payments, but saw the value of their devices and operating systems increase because thanks to Candy Crush, people around the world were getting entertained in new ways by them. Google and Apple not only did not need to come up with the idea to ask for something like Candy Crush to be made, they also did not need to figure out how to make a game like this or hire any game developers. Apple and Google also did not need to figure out on their own that game developers in the Southern European island country of Malta (where King is based) were suited for the task of developing such a game in terms of both capabilities and incentives. Even after the problem-solution match is discovered in the market, Apple and Google do not need to absorb much knowledge about game development (supply side) or people's gaming preferences (demand side) to continue benefiting from this and future matches made in their marketplaces, although they do have the flexibility to exercise this "real option" should they so desire (Tiwana 2013). The market mechanism allows these firms to benefit from knowledge discoveries without having to engage in directed search for that knowledge. This sidesteps an important second-order knowledge problem, because if the firms were to rely on directed search, they would not have known what to search for to begin with. This sidestepping of directed search is a key property of firm-designed markets that differentiates them from other forms of organization, including one-sided crowd systems where the demand side problem must still be specified. Once the knowledge is discovered however, the marketplace owner-designer is in a uniquely advantageous position to exercise the real option of utilizing that knowledge if they desire. For example, if Apple or Google realize from their application store data that a certain type of app is particularly profitable or complementary with their ecosystem, they may themselves decide to develop and supply such an app. This is a real option in the sense that they have the option, but not the obligation, to do so. As another example, Netflix which is a marketplace that connects TV and movie providers to viewers, uses data on viewer's preferences to create its own original programming, which it prioritizes in its marketplace.

The two main functions of marketplaces that allow for the sidestepping of directed search are the ability of markets to autonomously allocate resources based on existing knowledge, and their ability to autonomously adapt to change by generating new knowledge (Stiglitz and Greenwald 2015). These functions are typically linked to the notion of an economy's "production possibility frontier" in the sense that the allocation function moves participants closer to the currently known production possibility frontier, whereas the adaptation function expands this frontier. Keyhani et al. (2015) and Keyhani and Lévesque (2016) model these processes as opportunity discovery and opportunity creation functions, respectively. The allocation and adaptation processes in a marketplace can operate largely autonomously without the need for central direction, and this autonomy is the key source of the information efficiency of designed marketplaces that eases the knowledge burden of the firm. However, this does not completely deprive the market-designer firm of agency. Firms that design and operate marketplaces may adopt policies and rules that optimizes market processes and have access to valuable information that they may utilize to augment the market's own knowledge processes. This knowledge augmentation of markets is a powerful mechanism largely made possible by digital technologies, and the capability to do it well is a strategic differentiator among marketplace providers. The three sections below elaborate on the autonomous allocation and adaptation functions, as well as the role of the firm in managing the marketplace for knowledge processes. Table 4 summarizes the arguments in this section.

6.1. Autonomous Allocation: Price as a Coordination Mechanism

The firm-designed marketplace combines elements of the coordination mechanism of markets (the "invisible hand") and the visible hand of hierarchies. It leverages the distributed decision-making of individual participants, but is also able to influence and shape the context and direction of these decisions. The marketplace designer defines the rules of the game as concrete parameters by which individual decision-makers plan their actions and gravitate toward what suits them best. Leveraging digital technologies, the marketplace designer also has some ability to influence and control prices (e.g., surge pricing controls), through signals or constraints placed on individual behavior, without completely directing that behavior. By giving such an entrepreneurial role to individuals, the firm no longer maintains an authoritative position to tell them "what to do" but provides signals on "what to search for" in pursuit of opportunities (Hayek 1948). This is akin to leveraging the "derived judgment" of others (Foss et al. 2007) on a mass scale. While in crowd systems the firm relies on its own judgement to specify the problem, it opens up the agency of judgement on the supply side. In marketplace systems, the agency of judgment is opened up on both the supply and demand sides.

Whereas theoretically in a frictionless market prices do all the job (Arrow 1974), in firm-designed marketplaces the market designer can augment price signals with additional information signals, with which individuals can make decisions to maximize their earnings. Hence, rather than leaving participants to base their decisions on just price, the firm provides them with contextualized signals which bear information above and beyond what prices can

Table 4. Hybrid Characteristics of Firm-Designed Marketplaces

	Hierarchies	Market economies	Firm-designed marketplaces
Basis of coordination	Fiat	Price	Price, rules and signals that ensure thickness, noncongestion, and safety
Basis of adaptation	Directed search	Distributed autonomous competition	Distributed autonomous competition influenced by firm direction and enabled with communication and knowledge exchange tools
Approach to knowledge constraints	Reduce dependence on individual knowledge through routines and authority	Aggregate distributed individual knowledge	Leverage distributed individual knowledge by augmenting with market-designer knowledge
Role of authority	Direction	Regulation	Orchestration

provide. Generating and distributing these signals is a task thus left on the shoulder of management and is beyond what the price mechanism can achieve on its own (Keyhani and Lévesque 2016). For example, the data that Google and Apple make available on their app stores, posting ratings and reviews publicly, listing top apps, and selecting editor's choices, augment price information to the benefit of the whole market.

From the market design literature we know that in order for the autonomous allocation function of the market to work well, the orchestrator needs to ensure the three characteristics of thickness, noncongestion, and safety (Roth 2008, Gans and Stern 2010, Agrawal et al. 2015). Market thickness refers to the numbers of participants on each side, such that enough matching opportunities exist. When aiming to access diverse knowledge beyond the marketplace designer's own knowledge set, the kind of market thickness that is also heterogenous becomes a critical feature (Gans and Stern 2010). In order to best enable the firm to overcome knowledge constraints, attraction mechanisms must solicit the participation of agents unconventionally related or cognitively distant knowledge sets (Nooteboom 2000). This is where attraction is most difficult because cognitive distance also means that the marketplace is more likely to fall in the blind zone of such agents, and the agents more likely to fall in the blind zone of the firm. Noncongestion optimizes the speed and efficiency of market clearing such that "transaction speed is sufficiently rapid to ensure market clearing but slow enough to allow participants to seek alternatives" (Agrawal et al. 2015, p. 977). Lastly, safety refers to the ability of market participants to trust that the whole system is reliable, cheating and misbehavior are averted, and transaction partners can be trusted. For example, the TopCoder platform as a marketplace provider ensures that individuals have certain qualifications upon joining the platform and polices the system such that individuals can be banned temporarily or permanently if they violate platform rules.

6.2. Autonomous Adaptation: Leveraging the Dynamism of Markets

In the market, individuals remain autonomous in making decisions and adapting to change. Because no one person's plan or vision determines the direction of the overall market's activities, the distributed competition procedure has a capacity to adapt and make adjustments in response to new contingencies that may arise. Both the discovery of these contingencies and the response to them is a distributed process that takes advantage of the distributed localized knowledge and imaginations of individual participants. The resultant mass of individual experiments in the market communicate with each other, particularly through price signals, that result in weeding out of failed experiments, prominence of successful experiments, and the dissemination of knowledge regarding what works and what does not.

Importantly, for market-level adaptation to work well, the market must be at least two or multisided, with enough "thickness" on each side (Roth 2008) because each side of the market must have the requisite variety and dynamism necessary to keep up with the other side. There is a positive feedback loop where dynamism on each side of the market drives dynamism on the other side. Many experiments are required on the supply side in order to attract a diversity of preferences on the demand side, and a diversity of preferences on the demand side in turn spurs a diversity of experiments on the supply side, each experiment learning from previous experiments. This feedback loop creates an autonomous system of knowledge generation that continually produces new knowledge without the need for central direction from the marketplace designer. Observers who have noted this knowledge generation property of markets has described it with phrases such as "a system for the generation of endogenous innovation" (Phelps 2013, p. 14) or "a system for standing on the shoulders of giants" (Metcalfe and Ramlogan 2005, p. 661).

The marketplace designer can also actively support the knowledge generation processes of the market by augmenting the price mechanism with additional mechanisms of communication, learning, memory, diversity and inclusion. Similar to the ways in which diversity of knowledge enables learning and creativity in both individuals and organizations (Cohen and Levinthal 1990), it also increases the knowledge generativity[3] of markets (Phelps 2013). Furthermore, a variety of mechanisms enabled by digital technologies can provide rich communication and knowledge exchange between participants that increase the interactivity of ideas and knowledge in the system, thus increasing the chance of new idea generation. For example, TopCoder has been able to produce software applications via crowdsourcing by utilizing a supporting IT-infrastructure for collaboration and interaction of crowd members. This involves mechanisms that lower the costs of interactions among actors so that crowd members collaborate to produce new knowledge (Tajedin and Nevo 2014).

As a marketplace designer, the firm takes a backseat to the transactions occurring in the market. This means that adaptation and knowledge generation happen autonomously through the interaction of the supply and demand sides, creating new knowledge and innovations that often "surprise" the marketplace designer, because due to second order knowledge constraints, the firm would not have even known to search for this kind of knowledge or innovation. This resembles the discovery of simultaneous problem-solution pairs discussed by von Hippel and von Krogh (2016). In return for this autonomous adaptation and surprise generation, the firm largely moves away from the position of being able to define specific problems that it wants the market to solve. For this reason, marketplaces are not particularly well suited to directed search efforts to resolve first-order knowledge constraints or "known unknowns."

6.3. Role of Authority: Market Orchestration

In firm-designed marketplaces, the firm takes on a role analogous to a government, but with certain differences in its capability and flexibility to control and influence the marketplace. Previous scholars have used the term "orchestration" to refer to the marketplace designer's unique role (Tee and Gawer 2009, Tiwana 2013). It is useful to recall that, as is the case with any other free market, a firm-designed market does not necessarily evolve into an optimal design on its own without human intervention and needs institutions that facilitate its formation and sustainability in the long run. As Roth (2012, p. 361) nicely puts it in his Nobel Prize lecture:

> . . . a free market is a market with rules and institutions that let it operate freely. When we talk about a wheel that can rotate freely, we don't mean a wheel that is unconnected to anything else. We mean a wheel that has an axle, and well-oiled bearings. I think that is a good metaphor for a free market. A free market needs institutions that let it work well.

Orchestration, in contrast to direction, refers to the means of coordination that replaces the organizing will of an authority in producing orders with a bundle of rules and signals to which individuals autonomously respond and make decisions. In contrast to the orchestration of internal firm resources (Teece 2007, Sirmon et al. 2011) or external partner resources, the scope of orchestration here expands to include as yet unknown market resources. Whereas the market design literature mostly focuses on the allocation function of markets, in our view if market mechanisms are to be effective organizational tools for countering uncertainty and knowledge constraints, orchestration must also take into account their adaptation and knowledge generation properties.

7. Discussion and Concluding Remarks

During the past few years, researchers have shown increasing interest in various aspects of the ways in which digitization is transforming economic organization trends under such labels as crowdsourcing, platforms, online markets, and so on. In parallel, there have been increasing calls for better theorizing to reflect today's changing organizational context, characterized by more open innovation, fluid boundaries and a wide array of organizational designs (Felin and Zenger 2011, 2014; Gulati et al. 2012; Tushman et al. 2012; Altman et al. 2015). In this regard, Gulati et al. (2012) criticize current theory on organization design for its intrafirm bias and call for overhauling our conceptual tool-kit to reflect the rise of novel organizational forms and changing ways of organizing that they term meta-organizations, comprised of relations among multiple actors not characterized by employment and authority relationships. In a similar vein, Tushman et al. (2012) contend that the trend toward open innovation challenges received theory of the firm and organizational boundaries and call for updated and expanded theory on organization design. Scholars of organizations observing the rise of new organizational forms enabled by digital technologies must ask: what is the nature of these new forms and when and why are they more efficient relative to alternatives?

Our premise has been that an important cluster of these new forms are useful at least in part because they circumvent knowledge constraints in unique ways by combining elements of market and hierarchical organization in firm-designed market-hierarchy hybrid arrangements (Felin and Zenger 2011). Zenger et al. (2011) argue that "crafting governance structures that enjoys the virtues of *both* markets and hierarchies" (p. 115, emphasis in original) can be value generating, yet they consider such combinations to be a challenge, because one component relies on centralized decision-making through hierarchy and the other on disaggregated decision-making through price. Such apparent incompatibilities make it far from trivial that firm-designed markets are always feasible and efficient relative to alternatives. (Felin and Zenger 2011, p. 163) recently noted that:

> while we are *descriptively* learning much about these market-like practices and forms, nonetheless the *theoretical* foundations behind them, their implications for *comparative* governance (market vs. hierarchy), their possible forms (market–hierarchy hybrids) and implications for strategy and competitive advantage have yet to be fully vetted in the organizational literature.

Market-hierarchy hybrids combine elements of two extremes: Hierarchical organization emphasizes the central authority and the directing role of the management as the key characteristics of firm coordination. Demsetz (1988) sees authoritative direction as a substitute for education where individuals lacking the knowledge required to realize an outcome are directed by those who possess such knowledge. At the other extreme, with its focus on price, Austrian economics-based arguments about the efficiency of markets like those of Hayek relegate the role of manager to a largely invisible one (Teece 2014). Firm-designed markets provide an alternative in between: where the market process is utilized, but not left to its own devices, and where the distributed knowledge of a mass of outside participants is leveraged to the benefit of the firm and is augmented with the knowledge and managerial capability of the market-designer. In an important argument, Puranam et al. (2014) contend that any form of organizing can only be novel if it solves at least one of the universal problems of organizing, that is, task division and allocation and reward and information provision, in a new manner relative to existing forms. By this criterion firm-designed markets are a novel form of economic organization. They have become popular as firms are becoming aware of their power in overcoming some of the limitations of other modes. As Williamson puts it "flawed modes of economic organization for which no superior feasible mode can be described are, until something better comes along, winners nonetheless" (1985, p. 408).

A wide variety of market-hierarchy hybrids are implemented in practice, and a major program of research in the literature has focused on trying to distinguish between different types of these hybrids through comparative analysis of various characteristics, such as purpose, structure, and dynamics. For instance, Boudreau and Lakhani (2013) distinguish between contests, collaborative communities, complementors, and labor markets. Contests differ from collaborative communities, where the glue of socially embedded norms is stronger (Boudreau and Lakhani 2009), whereas labor markets are characterized more by matching. Others (e.g., Gulati et al. 2012) have made similar types of distinctions.

We have attempted to contribute to this research agenda by making a distinction between two major subtypes of market-hierarchy hybrids that can be classified as firm-designed markets. These are one-sided market arrangements we refer to as crowds, and (at least) two-sided market arrangements we refer to as marketplaces. Following the suggestion from Puranam et al. (2014) that information provision is a key universal problem of organization, we have focused our arguments on the information angle by asking: what are the informational efficiencies of firm-designed markets, and how do they differ between crowd-based and marketplace systems? Our comparison of crowd-based and marketplace systems as solutions to knowledge constraints is summarized in Table 5.

Crowds enable semidirected search in the sense that they relax some of the knowledge requirements of fully directed search, but still rely on the firm's ability to define problems, decompose tasks, and understand, absorb, and put together solutions provided by the crowd. Marketplaces instead relax the requirement that the firm be the only problem specifier or the only solution absorber. The trade-off is that marketplaces provide less leeway for the firm to target the direction of search to its known unknowns, but instead produce more surprises sidestepping the firm's unknown unknowns. Furthermore, while crowds require a relatively low level of market governance effort, marketplaces that generate new knowledge are dynamic systems that require extensive effort to design, govern and orchestrate.

von Hippel and von Krogh (2016) have pointed out that frequent occurrences of serendipitous discovery of simultaneous problem-solution pairs is evidence that firms that rely only on their own knowledge and problem-definition capabilities are constrained by second-order knowledge constraints and suggest that tapping into the vast landscape of external problem solvers is required to circumvent this constraint. In response, Felin and Zenger (2016) have argued that the existence of problem-solution pairs available for discovery means that they were likely produced by a *market* of external problem finders and problem solvers. We follow their line of thinking and argue that the market that produces simultaneous problem-solution pairs can be a firm-designed market strategically employed to counter second-order knowledge constraints. In other words, firm-designed markets

Table 5. Comparison of Crowds and Marketplaces as Distinct Types of Firm-Designed Markets

Firm-designed market type	Crowds	Marketplaces
Market architecture	One-sided	Two or multisided
Search	Semidirected	Undirected
Adequacy for first-order uncertainty	Strong	Weak
Adequacy for second-order uncertainty	Medium	Strong
Extent of surprise generation	Medium	High
Extent of problem definition required by firm	High	Low
Extent of absorptive capacity required by firm	High	Low
Extent of market design, governance, and orchestration effort required by firm	Medium	High

can be thought of as organizational mechanisms for the pursuit of serendipity.

The strategic utilization of firm-designed markets is no trivial task, and heterogeneity in their design and orchestration means that some firms are better at profiting from designed markets than others, which in turn means that market design and orchestration capabilities are a determinant of competitive advantage ceteris paribus. Much work remains to be done on identifying the design parameters of firm-designed markets and why some work better than others. The economic literature on market design theory (Roth and Sotomayor 1990; Roth 2008, 2015) provides a useful starting point, but is limited in that sense that it views markets mainly as resource allocation mechanisms, not uncertainty resolution and knowledge discovery mechanisms (Metcalfe and Ramlogan 2005, Phelps 2013). Therefore, the existing literature on market design tends to ignore design parameters of markets that enable discovery and innovation. Much work remains to be done to flesh out these features and the implications of market generativity for strategy.

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Endnotes

[1] The poem, which is attributed to Naser od-Din Tusi (1201–1274), is translated in Axworthy (2016, p. xi) as follows:

Anyone who knows, and knows that he knows,
Makes the steed of intelligence leap over the vault of heaven.
Anyone who does not know, but knows that he does not know,
Can bring his lame little donkey to the destination nonetheless.
Anyone who does not know, and does not know that he does not know,
Is stuck forever in double ignorance.

[2] Further underscoring the basic unity of the structures of crowds and marketplaces, Majchrzak et al. (2018) refer to an example of marketplaces as a "two-sided crowd."

[3] We borrow the term "generative" from Jonathan Zittrain's (2008, 2006) theory of technology generativity, where it refers to the property of a system that is capable of generating unprompted change endogenously through distributed processes.

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