2

A Sociotechnical Ecosystem Perspective of Sharing Economy Platforms

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2.1 INTRODUCTION

In barely more than a decade, sharing economy platforms transitioned from venues for true sharing of underused assets by people with social and environmental motivations, to a number of for-profit – although not always profit making – corporations worth tens of billions of dollars each, to a pillar for coping with the COVID-19 pandemic that enabled easier access to essential resources. The short, yet intense, history of the sharing economy is filled with overoptimism about its business potential and social consequences. This history reveals sharp contrasts between the high valuation of sharing companies and concerns about their potential for sustainable profit-making. It also features public debates regarding the consequences of sharing economy business models for the participating labor forces, reports of discrimination and user abuse, and concerns regarding the broader negative social and economic externalities of these platforms.

The debates over the costs and benefits of sharing economy platforms have been vast and have engaged a multitude of disciplines such as business and management science, economics, computer science, and different engineering disciplines, sociology, law, and public policy. Each of these disciplines has naturally focused on a limited set of problems and tried to understand these platforms through levels of abstractions established in those disciplines. For example, for economists, the multisided market has been the dominant level of abstraction by which many platforms' strategic decisions and market dynamics have been studied, whereas the notion of matching, and efficiency, and equity of various matching algorithms has been the center of attention for operations researchers and management scientists. Much of the social science literature on the subject has focused on the macroeconomic context, the evolution of capitalism, and the potential of sharing platforms to abuse their workers. And the list of disciplines/concerns/levels of abstraction goes on.

These disciplinary approaches are crucial because they not only are rigorous and subject to peers' scrutiny, but they also provide valuable methodologies to be used in interdisciplinary and system-level studies. However, many important questions that

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must be addressed in order to understand the underlying trade-offs of sharing economy platforms, and in order to provide useful insights to some of the debates mentioned earlier, fall at the *boundaries and intersections of different levels of abstraction* and require a system-level approach. Key questions arise at the boundary between multisided markets and the employee/contractor debate, at the intersection of economic externalities and the evolution of social norms, and at the intersection of matching algorithms and regulatory design. A systemic perspective on sharing platforms adds other benefits as well. Such benefits follow from two premises: First, that a holistic approach, which focuses on the relationship between different parts of the system, will provide additional useful insights; and second, that using a systemic perspective enables us to transfer findings, experiences, and insights between contexts that seem different in detail, but have enough system-level commonalities to justify such transfers.

My overarching thesis in this chapter is that many of the fundamental challenges of sharing economy platforms can best be understood and dealt with by considering these platforms embedded in a *sociotechnical ecosystem*. This perspective, which is the first contribution of this chapter, builds upon the diverse literature on business and industry ecosystems, but it is a departure from a narrow view of ecosystems that is focused mostly on business decisions from the perspective of the platform owner. In justifying this new perspective, I will first make a case for a sociotechnical approach to sharing economy platforms and will describe different lenses that constitute this approach. Then I will argue that many crucial questions about the design, governance, and regulation of sharing economy platforms are best formulated by embedding the platform in a sociotechnical ecosystem, which is a departure from the more common notion of business and industry ecosystems. To further justify this transition, I will provide a few examples of such ecosystem-motivated issues and questions that include a broader consideration of socioeconomic externalities, decisions about modes of platform governance and the relative weight of internal versus external regulations, and public–private partnerships.

My second contribution in this chapter is to provide a set of differentiating dimensions that can help with classifying various sharing economy platforms, guide decisions regarding ecosystem boundaries, and shape more relevant sociotechnical questions and hypotheses for a given sharing economy. These differentiating dimensions intend to serve a middle ground for two schools of thought, one that stipulates that each sharing platform needs to be treated as a separate case and there is little insight that can be transferred from one platform type to another, and the other that seeks to create levels of abstractions for studying the sharing economy platforms that are applicable to all such platforms. Establishing such differentiating dimensions, instead, acknowledges that the answer to many fundamental design, governance, and regulation questions can vary from one platform to another; however, it strives to further pin down those dependencies by identifying various classes of sharing platforms to enable more reliable transfer of insight from one case to another and

determine when such transfers make sense. In so doing, it helps to create models and methods that can work for all members of each class.

2.2 THE SOCIOTECHNICAL APPROACH: WHY AND WHAT?

Sociotechnical systems and the sociotechnical perspective have been used in different contexts and different applications in the past few decades. The notion is based on the pioneering works by Eric Trist in the 1950s and 1960s at the Tavistock Institute for Social Research in London (Trist 1981), and later found its way to other fields and applications such as sustainability (Geels 2019), innovation management (Geels 2005), energy systems (Li, Trutnevyte, and Strachan 2015), and digital ecosystems (Morgan-Thomas, Dessart, and Veloutsou 2020). Such applications often involve important changes in the definition, scope, and goals of the approach, which makes it hard, and largely unhelpful, to provide a unifying definition that includes all uses of the term in the academic literature. Suffices to say that while the focus of the first generation of studies using a sociotechnical approach was primarily on guiding the innovation and change process in an industry ecosystem, the notion of sociotechnical has resurfaced in recent years to make a case for an integrated approach towards design, governance, and regulation of modern engineered systems. This recent attention is motivated by recognizing that such systems are increasingly connected, with complex interactions among social and technical aspects, both during the design process and after introduction in the market. Moreover, the technical side of these systems coevolves with the social and institutional sides (Heydari and Pennock 2018), a feature with broad implications for design, governance, and regulation.

With this contemporary perspective of sociotechnical systems, I argue that sharing platforms are paradigmatic examples of complex sociotechnical systems (Heydari and Herder 2021). They involve multiple classes of social agents (mostly individual humans, but also groups and organizations in some cases) with heterogeneous types on different sides of the platform, whose relationships are dynamically regulated by the structure and behavior of the platform. In a way, sharing platforms also make a great case study for the so-called *technological systems approach* (Carlsson and Stankiewicz 1991) that looks at "networks of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology." The interaction between the social and technical sides, however, goes beyond the usual dynamics seen in most engineering systems where the dynamics are often unidirectional and include adaptation of the social layer to changes in the technical layer (e.g., changes in human travel patterns following the prevalence of commercial airplanes). Instead, in many sharing economy platforms, the social and technical sides often *coevolve*, where new local or population-level norms are formed on the social side, as a function of the structure of the platform (e.g., basic modules of transactions or spatiotemporal constraints) and the function of platform algorithms (matching criteria, level of transparency, review aggregation

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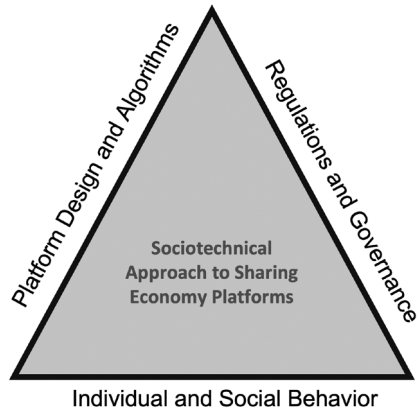

FIGURE 2.1 Three components of a sociotechnical approach to sharing economy platforms.

methods, and pricing strategies). This combination of platform structure and function can give rise to new social norms or steer the existing ones. Examples of such norms include trust, cooperation, equity and fairness, communication norms among different sides of the market, and how platform users balance some trade-offs such as those between data privacy and match efficiency. These evolutions in norms and collective behavior then result in evolutionary changes in the platforms, either through shifts in the way people prioritize different considerations to balance various trade-offs, or, increasingly, as a result of artificial intelligence algorithms that learn to adjust platform behavior in response to such changes.

This sociotechnical perspective, which is based on recognizing a coevolutionary dynamic between the social and technical side, can be captured by the sociotechnical triangle (Figure 2.1). These three lenses are crucial in many aspects of the sharing economy, informing core questions such as the following: How can we design modular architecture and algorithmic incentives to promote trust between different sides of transactions? How can we balance external regulation and self-regulation, based on platform internal governance mechanisms? How can we think about and measure neighborhood externalities of platforms such as Airbnb in the short term and long term?

2.3 THE ECOSYSTEM PERSPECTIVE: MOVING FROM BUSINESS TO SOCIOTECHNICAL ECOSYSTEMS

The mutual dynamic perspective described earlier goes beyond the interaction of platform design and participants' behavior and often extends to other areas such as technology and regulation. This extended perspective would then require us to think of sharing economy platforms in a broader ecosystem, the second lens of a systemic perspective. In this section, I will argue that we need to make a transition from the

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more common notion of business and industrial ecosystems to the more contemporary and expansive notion of sociotechnical ecosystems. The need for such a transition is not restricted to sharing economy platforms, but as I will argue in more detail, it is more crucial for these types of systems due to some of their characteristics that are either unique or are bolder compared to other products' or services' ecosystems.

The notion of business ecosystems entered the management-science and product-design literature as an alternative to the more linear supply-chain framework, largely through the influential writings of James F. Moore during the 1990s. The framework was inspired by the notion of biological ecosystems, which capture complexity-related concepts such as self-organization, coevolution, emergence of new forms and behaviors, and complex dynamics of simultaneous competition and cooperation. In one of his first publications to introduce the concept, Moore suggests that, "a company be viewed not as a member of a single industry but as part of a business ecosystem that crosses a variety of industries. In a business ecosystem, companies coevolve capabilities around a new innovation: They work cooperatively and competitively to support new products, satisfy customer needs, and eventually incorporate the next round of innovations" (Moore, 1993, p. 76). The concept was then further developed by a number of other scholars in the past two decades and applied to a wide range of cases in different industries (Adner and Kapoor 2010; Autio and Thomas 2014; Iansiti and Levien 2004; Pierce 2009). Given the metaphoric nature of the concept, however, not all the studies that use the notion of ecosystem as a framework agree on a common definition (see Tsujimoto et al. [2018] for a review of the literature).

The ecosystem perspective of industry platforms has also been introduced in the past, often in a narrower sense, which includes the combination of a multisided platform, a set of related firms that develop their complementary products and services, and in some cases, the end users (Cusumano, Gawer, and Yoffie 2019). This perspective of platform ecosystems has been used primarily to model and provide recommendations for two different faces of innovation that occur *within* and *outside* the platform-owning firm (Gawer and Cusumano 2014), or to inform organization designers to opt for a more suitable organization structure, level of openness, and degrees of product and organizational modularity (Baldwin 2012, Heydari, Mosleh, and Dalili. 2016). Although various definitions for platform ecosystems are offered in the literature, the majority of these definitions are focused either on the technology or on the markets. In the former, platform ecosystems are considered, as "a set of stable components that supports variety and evolvability in a system by constraining the linkages among the other components" (Baldwin and Woodard 2009), while in the latter, they focus on issues such as network externalities across different platform sides, market competition among different platforms, and the complementary roles of firms whose products are designed based on one or more platforms (e.g., smartphone platforms or cloud computing platforms). Although different in their components, both these approaches have focused on the perspectives of platform owners (Schreieck, Wiesche, and Krcmar 2016) to inform their business decisions.

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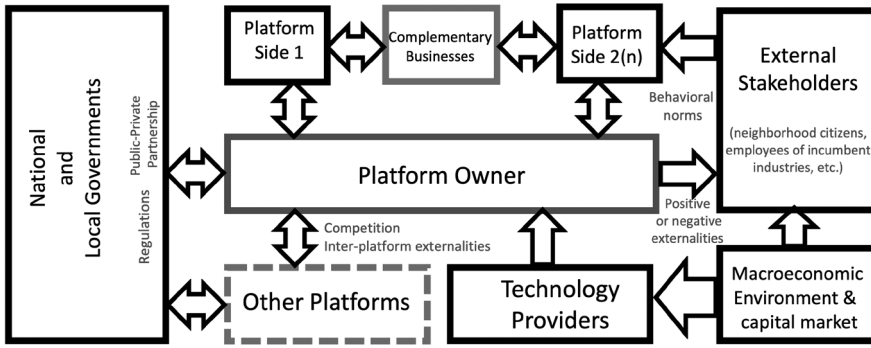

FIGURE 2.2 Sharing economy platforms ecosystem components

Here, I argue that we need a broader sense of ecosystems for sharing economy platforms that goes beyond innovation modeling and business complementors and extends the ecosystem boundary to include a broader range of stakeholders. This extended notion of platform ecosystem helps with formulating more relevant questions regarding analysis, design, governance, and regulation of sharing economy platforms. It also helps in creating shared value between the platform owner and the societal stakeholders (Porter and Kramer 2011, Rong et al. 2021), which then can be addressed using the sociotechnical perspective mentioned earlier.

The need for a more expansive view of ecosystems isn't limited to sharing economy platforms. In fact, it can be applied to a wide range of products and services. Having said that, this need is particularly bold for certain platform-based companies and sharing economy platforms in particular for a at least three interrelated reasons. For one thing, many of these platforms are taking up parts of the roles of public infrastructures, making them essential for the socioeconomic wellbeing of many regions. Moreover, there are many potential negative and positive externalities that touch various corners of the social fabric, especially in urban environments, because these platforms change the meaning of ownership and blur the line between what is business and what is personal use. Finally, these platforms are one of the key contributors to a rapidly evolving notion of work, both for those who directly use these platforms and those whose previous forms of work are being disrupted by sharing platforms. In what follows, I will elaborate more on the components (Figure 2.2) and benefits of this expansive view of the sharing-platforms ecosystem.

A. A Broader Perspective of Externalities: The literature on platform systems has always been cognizant of externalities, with most of the attention being focused on network externalities, also known as network effect. The discussion thus has focused on how additional agents who use the platform affect the utility of other agents who are on the platform. In addition to this – often positive – externality, critiques of sharing economy platforms sometimes point to potential negative externalities of such platforms based on their negative impact on others who do not use the platform. One

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example of such indirectly affected people are neighborhood residents who might be negatively affected by Airbnb (Gurran and Phibbs 2017), or who might be affected by increased congestion caused by ride sharing (Schaller 2021). Other examples are workers and owners of incumbent industries, such as hotels owners and employees who might be affected by Airbnb (Roma, Panniello, and Lo Nigro 2019; Zervas, Proserpio, and Byers 2017), or Medallion owners and cab drivers who might be affected by Uber (Angrist, Caldwell, and Hall 2017; Rogers 2015). The ecosystem view of sharing platforms leads us to think more broadly about externalities, especially when it comes to their regulation and the evaluation of their overall effect on social welfare.

First, the scope of platform externalities should be expanded in the range of stakeholders who are affected. Importantly, the scope should also include efforts to understand the mechanisms by which externalities affect certain stakeholders. For example, on the supplier side, in addition to the dyad of platform and incumbent workers, sharing platforms could trigger creation of a number of complementary businesses whose owners and employees are not technically platform users, but they provide facilitating services to platform users. Airbnb, for example, resulted in the emergence of a series of start-up companies and local businesses that help the hosts by providing them with cleaning services (Flycleaners), management (Beyond stay, Keycafe), guest communications (Guesty), marketing (Renting your place), and pricing analytics (Pricelabs, Beyond Pricing). Airbnb also helped stimulate local businesses such as professional photographers and property managers. Moreover, the penetration of sharing economy platforms into urban neighborhoods can stimulate local businesses by bringing visitors to otherwise residential neighborhoods, which in turn can result in potential positive externalities for neighborhood residents because of improvements in service quality, or negative externalities due to potential increase in prices. Measuring the relative magnitude of these two factors requires comprehensive empirical studies, something that the research community of sharing platforms could consider in the future.

We also need to consider the interplatform interactions as a particular instance of broadening the scope of externalities. Such interplatform interactions could happen across different platforms that provide similar services whose interactions go beyond the widely studied competition (Armstrong 2006; Rochet and Tirole 2003) and in some cases can involve cross-platform positive network effects that can become more complex than the usual single-platform network effect often discussed in the literature. For example, growing an initial group of drivers is often easier for a new ride-hailing company that enters a city with an existing base of drivers who work with a competing company. It might also be easier to attract the first group of customers who already have gone through the learning curve of a similar concept with a competing platform. More important, however, is the interaction of complementary platforms, as happens for example in the case of ride-sharing and short-term rental platforms (Zhang et al. 2020), where easier and more affordable access to transportation into residential neighborhoods enabled by ride-sharing platforms makes short-term rentals more attractive

for prospective visitors, which in turn results in more use of ride-sharing services, once those visitors decide to stay in the residential neighborhoods. Other examples include interaction of short-term rental companies with travel and hospitality platforms such as TripAdvisor, Yelp, and Urbanspoon. Although much of the discussions in these areas are anecdotal, we can expect that in the coming years, new network externality models with the goal of formulating and quantifying a more general notion of network effect will emerge in the academic literature of sharing economy platforms.

Beside the expansion in scope, one needs to differentiate between the *short- versus longer-term externalities*, with special attention to the latter, which are often more difficult to identify and measure. The longer-term view is crucial, primarily for two reasons. First, the prevalence of sharing platforms can change the structure of social interactions and impact local norms, sense of belonging, and social capital, a rather slow process in nature. Such changes, in turn, can result in changes in collective behavior, with possible negative consequences for local residents. For example, a recent study by (Ke, O'Brien, and Heydari 2021) demonstrates that spatial penetration of Airbnb (as opposed to merely the number of Airbnb visitors) in a neighborhood can result in an increase in criminal activities in subsequent years, presumably due to its negative effect on the overall sense of belonging by removing a set of long-term resident nodes from the neighborhood social interaction network.

B. Regulation and Governance in Platform Ecosystems: Regulating sharing economy platforms has been a controversial issue (See the Chapter 7 in this volume), with some scholars going so far as to conclude that successful regulatory avoidance is one of the main driving forces behind the rapid growth of sharing platforms (Stemler 2017). Various categories of regulations include platform-user protections, competition and antitrust concerns, taxes, privacy concerns, discrimination, and other forms of market failures. Here, I briefly emphasize two points, related to the ecosystem perspective.

B. 1. Public–Private Partnership: First, the relationship between governments and platform owners needs to include *public–private partnerships*. Public–private collaborations have largely been discussed in the context of urban mobility as a way to make urban transportation more accessible, affordable, and efficient. They can be implemented at various levels, such as dynamic trip-planning, on-demand minibuses, and first- and last-mile ride sharing (Bouton, Canales, and Trimble, n.d.); Also see (Chapters 8 and 9 in this volume.). More recently and with the goal of establishing trust between the platform and local governments, Airbnb has introduced City Portal in fifteen pilot cities in North America, which claims to streamline information about various travel-related trends to provide cities with more information about their Airbnb businesses, share with them detailed data that they can use for their urban resource-management activities, and provide easy-to-use tools for city officials to design and implement short-term rental policies (Airbnb n.d.). Although it is likely that sharing economy companies enter such partnerships as a public-relations activity to avoid strict regulations down the road, successful public–private partnership can

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have a wide range of public benefits by increasing access to financial resources for public infrastructures, contributing to efficient dynamic resource allocation using analytics collected by sharing platforms, and offering efficient solutions for the last-mile problem in many transportation and logistics services. However, not all public–private partnerships based on sharing economy platforms are successful, and it remains a crucial area of research to identify determinants of success and failure based on the differentiating characteristics of sharing economy platforms (see Part IV).

B.2. Public Mediated Governance: Even when we restrict our attention to the regulatory role of governments, we need to think beyond restrictions that are implemented to limit negative externalities and avoid different forms of market failures. Although such regulations are needed in some cases, they often tend to be static, responding to yesterday's problems. The interaction of such static, reactive rules with dynamic, adaptive algorithms used by platforms and some of their users could result in undesirable (game-theoretic) equilibria. Meanwhile, platform owners often argue that regulatory frameworks that were designed for incumbent industries (e.g., hotels or taxi cabs) do not apply to them, in part because they can self-regulate by leveraging a wide range of algorithmic platform governance mechanisms that are available to them. In a way, this argument tries to extrapolate from the success of marketplace platforms in efficient dynamic matching of market sides (thereby shaping supply and demand via dynamic pricing) to make a case for the efficacy of self-regulation. This claim holds that those adaptable, dynamic algorithms can be extended to other areas where the sociotechnical behaviors in the ecosystem need to be steered, based on the objectives that the regulator has in mind. Such a solution could draw elements from both the market and regulatory perspectives. Much of the concerns of regulators can still be addressed using internal algorithmic governance that can be embedded into the design of the platform; however, the design specifications, objectives, prioritization of conflicting goals, and the verification processes cannot be left solely in the hands of the platform owners and must be determined by what I refer to as *public-mediated platform governance*. Given the complexity of platform regulation and the increasing prevalence of platforms, I expect that questions on the relative role of external regulation versus public-mediated governance, the implementation mechanisms for the latter, and the role of citizens in providing inputs to some of the key decisions of platform governance will be key areas of research and public discussion in the coming decade.

2.4 BUILDING A TAXONOMY FOR SHARING ECONOMY ECOSYSTEMS

The ecosystem perspective of sharing economy platforms is useful in formulating a number of important questions, some of them related to the discussions offered in this section. For example, how many of the goals of the regulator can be achieved using external regulation as opposed to platform-mediated governance? How widely should regulators look in capturing the effects of positive and negative externalities

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in order to make regulatory decisions? Or when it comes to internal platform design and governance: How much control does the platform owner need to exert on transaction details, pricing, and active matching of different sides of the market? How much transparency, modularity, and openness are optimal for platforms in order to balance the trade-off between competition and growing their ecosystem? How actively does the platform owner need to intervene to establish trust between different sides of platform transactions and how can the platform owner balance this need with the privacy concerns of users? How much should platform owners and public agencies pursue public–private partnerships?

The short answer to all these questions is that *it depends*, and the answer varies for different types of platforms and different characteristics of the ecosystem in which they are embedded. But can we go further than this short answer? How can we know, more specifically, what drives the answer to these questions? In this section, I take the first steps in digging beyond that short answer by providing a number of key dimensions that amount to a taxonomy of sharing economy systems that can help us answer different ecosystem-related questions. In addition to setting forth some important differentiating dimensions, I explain why those dimensions are important and provide a few examples of how those dimensions affect some of the key questions related to platform control or governance. I intend in this section to use broad brush strokes in describing the driving forces active in each dimension. A comprehensive description for any given platform will require a more thorough mapping of the ecosystem, more precise formulation of the questions using the sociotechnical approach, and further modeling and empirical work.

The taxonomy I provide here differs from other taxonomies of sharing economy platforms. Although some comprehensive classification studies have been conducted in recent years (Acquier, Daudigeos, and Pinkse 2017; Benoit et al. 2017), the majority of these classification efforts have focused on making sense of the variety of business models used by sharing platforms, either as a whole (Muñoz and Cohen 2017; Sanasi et al. 2020), or in a particular sector or essential component such as mobility (Cohen and Kietzmann 2014), hospitality (Kuhzady et al. 2021), and logistics (Carbone, Rouquet, and Roussat 2018). However, my goal is to introduce a number of dimensions that could be used to better approach the ecosystem-driven questions, some of which I presented in the previous section. Furthermore, these dimensions can be used in conjunction with the sociotechnical approach that brings together the engineering design, business models, and regulatory and governance aspects of sharing economy platforms.

2.4.1 *Key Differentiating Dimensions of Sharing Economy Platforms*

A. What is shared: Sharing economy platforms are used to share resources among different platform participants; yet it is not often immediately obvious what is shared on these platforms. Here I divide the shareable object into three categories:

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Information, physical assets, and labor. Although many platforms share a combination of these objects, for most of them, one of these objects is more distinct, which in turn determines some important characteristics of the platform.

A.1. *Information*: Given the digital nature of modern sharing economy platforms, information sharing is often at the heart of how these platforms operate. In fact, the information intensity of a service or product is a strong predictor of its propensity to become a successful platform. We need, however, to distinguish between cases in which information is shared between the platform and its users, and those where platform-enabled information exchange among users is the main function of the platform. The first type of information sharing is ubiquitous among multisided platforms and serves two intertwined functions. Information shared with the platform by the users reduces various forms of transaction costs for other types of transactions; for example, data about users' locations, preferences, past transactions, and social networks can facilitate the search and matching process. This high-resolution data, provided voluntarily by the users to serve such functions, can then be used by platform owners to generate additional revenue, often in the form of direct or indirect advertisements.

Apart from this ubiquitous form of user–platform information sharing, information can be the main object of exchange in many multisided platforms such as LinkedIn (job-related information between employers and jobseekers), Yelp and Angie's List (information about business quality), and StackExchange (questions and answers [Q&A]). Whether all these companies can be classified as sharing economy platforms is not fully clear and depends on the breadth of the definition one uses for the sharing economy. I would argue that Q&A services such as StackExchange better satisfy the narrower definition of the sharing economy, compared to companies such as LinkedIn or Yelp. This is because, unlike Yelp or LinkedIn where information exchange is not targeted, transactions on StackExchange are targeted sharing that happens between two parties (questioner and responder) and are driven by differences in the ownership level of a resource (expertise in this case). In my classification, while I recognize the ubiquitous role of information sharing in all digital platforms, I only consider information as the main transaction object when platforms can be classified as sharing economy systems and are used primarily for exchange of information among users.[1]

A.2. *Physical Assets and Labor*: Although information can be the main article of exchange for some sharing platforms, the majority of these platforms are founded to facilitate the sharing of either physical assets or human labor, and some of the key characteristics of sharing platforms can be linked to the relative importance of these two different types of sharing articles.

The first generation of sharing platforms was mostly based on sharing unused *physical assets*, primarily in transportation (unused car seats in the early days of

[1] From this standpoint, we can consider the product Q&A feature of Amazon where previous buyers respond to questions by a prospective buyer as a form of sharing service.

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BlaBlaCar) and lodging (Couchsurfing and the early version of Airbnb). The choice of physical assets (as opposed to digital assets) to identify the first generation of sharing economy is a conscious choice – to satisfy the standard definition of sharing economy platforms mentioned earlier. However, I acknowledge that virtual mechanisms such as digital right management or non-fungible tokens that can artificially introduce *scarcity* in digital assets can in theory enable forms of platform-based sharing of digital assets that are closer to how we define sharing economy platforms here.

B. Transaction Heterogeneity (and Uncertainty): Heterogeneity, also known as diversity in some contexts, is an important common feature of complex systems that creates a fundamental system-level trade-off, enabling adaptability, evolution, and resilience on the one hand, and making it harder to predict, manage, and change the systems on the other. Moreover, higher heterogeneity may result in higher uncertainty, making it more challenging to manage resources and predict their supply and demand. Much of the complexity management in complex engineering systems revolves around implementing an appropriate level of heterogeneity at various layers (e.g., products, agents, modes, and rules of interactions) to balance this trade-off. The dominant system design mechanism uses the principle of modularity, which works in two steps. It first maps a large number of possible realizations of heterogeneous attributes to a smaller set of modules. It then creates standard interfaces that facilitate interaction between different modules.

Managing transaction heterogeneity is a key differentiating attribute among various sharing economy platforms. These platforms face at least two layers of heterogeneity when it comes to transactions they enable: Spatiotemporal heterogeneity, and agent's type diversity. As I will discuss, while managing the former type has been instrumental in the success of most sharing platforms, the latter plays a major role in the governance schemes of the platforms.

B.1. Spatiotemporal Heterogeneity is the very basic form of heterogeneity and refers to the diversity relating to when and where the demand or supply for articles of transactions occur. Traditionally this type of heterogeneity was managed by creating spatiotemporal modules, for example, by creating stations and timetables for public transportation systems. This form of spatiotemporal heterogeneity was in fact a major barrier for peer-to-peer (P2P) platforms until recently, and a key value for on-demand platforms such as Uber and Lyft is their successful management of this aspect of heterogeneity, thanks to the prevalence of smartphone devices, accurate supply and demand prediction, and demand and supply shaping through different incentive mechanisms. These mechanisms make it possible to modularize the unit of transaction to a more or less standard product, such as a ride to the airport, or a standard bedroom on a second floor in the Alfama neighborhood in Lisbon in the second week of June. As we will see, such modularization becomes challenging as other forms of heterogeneity are added.

B.2. Agents Heterogeneity: Besides differences in the time and location of supply and demand, participating agents on a platform can be different in other aspects

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such as preferences, skills, and reliability. I refer to all these other aspects as agent type. Although this dimension of heterogeneity is also present in most sharing platforms, the associated complexity of this dimension and the consequent governance mechanisms can vary substantially across different platforms. On one end of the spectrum lie platforms such as Uber and Lyft for which differences in agents' types are either not large (e.g., driving skills), not of primary importance (e.g., make and model of the car, within a given vehicle category, or the personality of the driver), or can be ranked on a single dimension (e.g., safety and reliability). Mechanisms such as review help with standardizing the last group, since it is often expected that the reviews are not affected by heterogeneous, multidimensional preferences of platform users, and thus that much of the information about these attributes can be encapsulated in standardized review scores. As we move to the other end of the spectrum, agents' differences become wider (e.g., skill level of professionals on Upwork), preferences become more heterogeneous on a wide range of dimensions (e.g., preferences of Airbnb users for the type of a $150/night apartment in Berlin), and the weights they assign to those preferences increase (e.g., Airbnb host personality).

What are the consequences of this dimension on platform governance? Using principles of modularity in complex systems, I argue that smaller heterogeneity range, significance, and dimension, enables creation of more standardized modules, which in turn opens the door for a higher level of control by the platform owner over different aspects of transactions. Standardized modules can enable control over pricing, where, for example, a "6:00am ride from downtown to the airport in a sedan" can be considered as a standard transaction module that can be priced. Lower dimensions of complexity also eliminate the need for direct exchange of information between different sides of the transaction, which in turn can enable algorithmic matching between them, further leaving transaction control in the hands of the platform owner. This contrasts with a platform like Airbnb that falls towards the middle of the spectrum, where heterogeneity, especially on the demand side inhibits automated matching, allows direct communication and negotiations between different sides, and leads the way to delegate much of the pricing decisions to the landlord. An example of a platform that resides close to the other end of the spectrum is ebay in which both sides of the platform (sellers and buyers) experience large multidimensional heterogeneities, which in turn push the platform owner to delegate a large portion of control to the users and to market mechanisms such as auctions.

C. Transaction Stakes: Sharing platforms can have different levels of transaction stakes as a function of various forms of risks associated with those transactions. Besides financial and safety risks, higher stakes can be the result of concerns about opportunity cost, poor experience, reputation, discrimination, and privacy. I also expect that, everything being equal, transactions with longer time commitments show higher stakes (a few minutes of an Uber ride, compared to a few days of Airbnb stay). The difference in the level of transaction stakes is crucial for platform governance, since it directly affects trust, which is central to the success of sharing

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platforms. In general, platforms with higher transaction stakes need stronger governance mechanisms to ensure a sufficient level of trust between different sides of the platform. These mechanisms include prescreening of users, mechanisms to ensure participation and quality of reviews, mechanisms to promote trust as an emergent collective norm among platform users, and transparent, punitive measures to deal with special cases. This is why Airbnb, which exercises less governance control compared to Uber in pricing and matching dimensions, demonstrates stronger control when it comes to trust mechanisms.

D. Time Urgency: I define time urgency as the average time between the availability of supply and demand and the execution of the actual transaction. Based on this definition, ride hailing applications often have a high level of time urgency, on the order of minutes, due to their on-demand nature, although the time urgency is generally lower for long distance carpooling platforms such as BlaBlacar. Lodging platforms such as Airbnb and Homeaway have a medium level of time urgency on the order of days to weeks. Labor matching platforms such as TaskRabbit and Upwork, on the other hand, are highly heterogeneous in their time-urgencies, which can range from hours to months depending on the nature of the service.

As for the impact of time urgency on platform values and their governance, it interacts with the two types of heterogeneity mentioned earlier – spatiotemporal and agent type – in two different ways. Higher time urgency increases the role of platforms in managing spatiotemporal heterogeneities for the reasons described earlier, thus adding to their value from their users' perspective, while making it more possible for platforms to exert their control over on-demand transactions. As time urgency decreases, the overall value of the platform might decrease. This is because lower time urgency makes room for higher competition and creates the possibility of *multihoming* where users simultaneously evaluate multiple platforms for the same type of transaction. Lower time urgency also increases the relative importance of agent type heterogeneities, which in turn forces the platform to relinquish some of its control.

E. Network Effect: Most sharing platforms owe most of their value to some form of network effect, at least in the earlier phases of their operation. In platform-mediated P2P markets, this network effect is often cross-sided, which means that users on one side are the source of value for users on the other sides, which in turn will increase the number of users on those sides, resulting in a positive feedback of constantly adding users – and value – to the platform. This increase in value as a result of positive cross-sided network effects manifests itself in the form of lower wait-time (e.g., for ride hailing passengers), lower idle time (e.g., for ride hailing drivers), wider geographical coverage (e.g., for Uber and Airbnb), and a more diverse set of choices. The network effect can be local or global, depending on the nature of what is shared on the platform and time urgency. In general, the network effect becomes more localized when transactions include physical assets and have higher time urgency. The scope of network effect is a key determinant of market competition forces and subsequent policy and regulations.

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Although cross-sided network effect is often considered as one of the main reasons for the near-monopolistic behavior of sharing economy platforms, one needs to be cautious about its role as a barrier to entry in the long-run. One reason is that ironically, cross-sided network effect is technically not a *network* effect, since it often has little to do with the social network of users. This is in stark contrast to how network effect works for social media platforms where much of the value of the platform for users depends on the presence of the members of their social network on the platform. Switching to a different platform then requires a coordinated decision of social networks clusters, which is difficult to achieve in most cases. On the other hand, it is theoretically possible for a new ride-hailing platform to enter the market and establish the initial network by subsidizing rides and paying more to the drivers, similar to how Uber grew in its early days. Cross-sided network effects, however, can create barriers to entry for new platforms in the long run by enabling the economy of scale that is required to build certain physical and logistical infrastructures, favorable terms with other corporate partners, and public–private partnerships.

Sharing platforms can also demonstrate various degrees of same-sided network effect, where the value of the platform for users of one side is modulated by the number of other users on the same side. Some forms of same-sided network effects are more or less universal among most sharing platforms. For example, many platforms demonstrate negative effects related to short-term issues like congestion and competition (e.g., more passengers drive up the price and wait time on a Friday night). Other forms of same-sided network effects, however, can vary substantially across different platforms, depending on some of the characteristics discussed earlier. Reviews are one of the main mechanisms that create this same-sided network effect, where both the quantity and quality of reviews by other users can improve the choice quality for a user on the same side of the platform. Whether this type of same-sided network effect benefits from the social networks of users depends largely on the level of agent type heterogeneity. When agents are heterogeneous in type and in multiple dimensions, as discussed earlier, we can expect users to benefit more from structured same-sided network effect. For example, most people care little about who reviewed the Uber driver who is being matched to them, while learning that their friend enjoyed staying with a family-owned Airbnb in Barcelona would carry great weight. Consequently, platforms with higher agent-type heterogeneity could be more successful in establishing mechanisms for structured same-sided network effects as an additional barrier to entry. Regulators need to take on this often-neglected lens in addition to the commonly discussed cross-sided network effect.

2.5 CONCLUSION

Platform systems are touching various corners of our socioeconomic lives and are creating gray areas in many traditional dichotomies: Employees versus independent contractors, ownership versus access, external regulation versus self-regulation,

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public versus private, and competitive versus monopolistic markets. We can only benefit from the promise of sharing economy platforms, while addressing valid concerns about some of their negative consequences, by increasing our understanding of these grey areas, making choices among them, and understanding and quantifying the trade-offs between these choices. This chapter argued that this can best be achieved by establishing a sociotechnical ecosystem framework that includes a set of lenses borrowed from the sociotechnical approach towards complex systems, an ecosystem perspective that builds upon previous work on business and industry ecosystems, and a set of differentiating dimensions that can help with building classes of sharing economy platforms to create useful levels of modeling abstractions and enable transfer of insights across different platforms. However, more research and case-based studies must be conducted to take this framework to the next level, that is to fully operationalize it and better show its power vis-à-vis other existing frameworks in the literature. I leave this challenge for future research by the interdisciplinary community active in this area.

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