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Ming Hu *Editor*

Sharing Economy

Making Supply Meet Demand

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Preface

Sharing economy refers to a market model that enables and facilitates the sharing of access to goods and services. For example, Uber allows riders to share a car. Airbnb allows homeowners to share their extra rooms with renters. Groupon crowdsources demands, enabling customers to share the benefit of discounted goods and services, whereas Kickstarter crowdsources funds, enabling backers to fund a project jointly. Unlike the classic supply chain settings in which a firm makes inventory and supply decisions, in a sharing economy, supply is crowdsourced and can be modulated by a platform. The matching-supply-with-demand process in a sharing economy requires novel perspectives and tools to address challenges and identify opportunities.

This edited book examines the challenges and opportunities arising from today's sharing economy from an operations management perspective. Individual chapter authors present state-of-the-art research that examines the general impact of sharing economy on production and consumption, the intermediary role of a sharing platform, crowdsourcing management, and various context-based operational problems.

Toronto, Canada — Ming Hu
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This book cannot exist without the strong commitment of our colleagues. I am grateful to each of the contributing authors for sharing their cutting-edge research with us. I would like to thank Professor Chris Tang, the editor of the Springer Series in Supply Chain Management, who has encouraged me to work on this book. I am grateful to Mirko Janc for typesetting each chapter exceptionally carefully and rigorously.

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Chapter 1
Introduction

Ming Hu

Abstract This introduction provides an overview of the book with highlights of all chapters.

This book aims to address what it takes to be successful in today's sharing economy from an operational perspective. Sharing economy may refer to an online platform that enables individuals or small entities as buyers and sellers to "transact" effectively and efficiently or a market model that allows sharing of access to goods and services. Operations management has the tradition of coming from and going back to real-life applications. It deals with the management of the processes of matching supply with demand. The emerging business processes in a sharing economy call for active management, as well as adequate attention from operations researchers. However, as the business side of a sharing economy is still emerging and rapidly evolving, there is a lack of a comprehensive overview of ongoing academic efforts in addressing its operational problems. To fill the void, this book is, to the best of our knowledge, the first to present cutting-edge research on sharing economy from globally recognized field experts organized in one place. For future research directions, a good resource is Chen et al. (2018).

1.1 Overall Structure

This book is comprised of 21 chapters that are divided into four parts.

- The first part (Chaps. 2, 3, 4, and 5) explores the *general impact* of sharing economy on the production, consumption, and society. For example, with sharing dynamics taken into account, how the sharing economy affects the

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consumption of goods and services and consumer welfare. Moreover, the section also highlights operational opportunities and challenges of a sharing economy.
- The second part (Chaps. 6, 7, 8, 9, 10, 11, 12, and 13) explores the *intermediary role* of a sharing platform that matches crowdsourced supply with demand. The decisions of the platform can be pricing decisions on the supply and demand sides, detailed matching decisions at the operational level, or decisions about capacity, information disclosure and payment schemes.
- The third part (Chaps. 14, 15, and 16) investigates the *crowdsourcing management* on a sharing platform with the goal to crowdsource both demand (group buying) and supply, such as funds (crowdfunding) and innovative ideas (tournament).
- The fourth part is (Chaps. 17, 18, 19, 20, and 21) dedicated to *context-based operational problems* of popular sharing economy applications, for example, how to dynamically rebalance bikes for a bike-sharing system, how to design service zones for one-way carsharing services such as Car2Go, and for homeowners how should they set prices on Airbnb.

Ultimately, the book introduces the reader to the fundamentals of operations in sharing economy and highlights the latest research on the topic.

1.2 Chapter Highlights

1.2.1 Part I: Impact of Sharing Economy

1.2.1.1 Economic Impact

In Chap. 2, Saif Benjaafar, Guangwen Kong, Xiang Li, and Costas Courcoubetis study an equilibrium model of peer-to-peer product sharing, or collaborative consumption, where individuals with different usage levels make decisions about whether to own or rent a homogenous product. Owners can generate income from renting their products to non-owners while non-owners can access these products through renting. The authors characterize equilibrium outcomes, including ownership and usage levels, consumer surplus, and social welfare. They compare these equilibrium outcomes in systems with and without collaborative consumption and examine the impact of various problem parameters. Their findings indicate that collaborative consumption can result in either lower or higher ownership and usage levels, with higher ownership and usage levels more likely when the cost of ownership is high.

In Chap. 3, Baojun Jiang and Lin Tian also examine the strategic and economic impact of product sharing among consumers. Consumers buy many products but end up not fully utilizing them. A product owner's self-use values can differ over time, and in a period of low self-use value, the owner may rent out her product in a product-sharing market. Transaction costs in the sharing market have a non-monotonic effect on the manufacturer's profits, consumer surplus, and social

welfare. When the manufacturer strategically chooses its retail price, consumers' sharing of products with high marginal costs is win-win both for the firm and the consumers, whereas their sharing of products with low marginal costs can be lose-lose. Moreover, in the presence of a sharing market, the firm will find it optimal to strategically increase its quality, leading to higher profits but lower consumer surplus. Lastly, within a distribution channel framework, product sharing can sometimes benefit the downstream retailer at the expense of the upstream manufacturer.

1.2.1.2 Operational Opportunity and Challenge

In Chap. 4, Tunay Tunca builds a framework for identifying, describing and analyzing operational factors that shape the efficiency of a sharing economy. In particular, these factors are: (1) utilization of sunk and fixed costs, (2) utilization of bit-sized resources, (3) utilization of human idle time, (4) utilization of networks to lower barriers to entry into workforce and markets and (5) assigning people new operational and economic roles. Then he discusses some potential downsides and pitfalls that arise as the side effects of these operational efficiencies of the sharing economy business models and foreseeable regulatory issues that may need attention.

In Chap. 5, Siddhartha Banerjee and Ramesh Johari outline the main challenges of ridesharing platforms in various aspects such as large-scale learning, real-time stochastic control, and market design. The authors present an approach to modeling, optimizing, and reasoning about such platforms, and describe how rigorous analysis has been used with great success in designing efficient algorithms for real-time decision making, in informing the market design aspects of these platforms, and in understanding the impact of these platforms in a broader societal context.

1.2.2 Part II: Intermediary Role of a Sharing Platform

1.2.2.1 Intermediation via Pricing and Matching

The following three chapters are primarily motivated by ridesharing platforms.

In Chap. 6, Gerard Cachon, Kaitlin Daniels, and Ruben Lobel focus on two-sided pricing as a moderating mechanism. The platforms may charge consumers prices and pay individual service providers wages, conditional on market conditions. The authors study several pricing schemes, with a specific focus on a contingent pricing policy that requires wages to be a fixed commission rate of dynamic prices. Although this heuristic policy is not optimal, it is shown to generally achieve nearly the optimal profit. As labor becomes more expensive, consumers are better off with the heuristic contingent pricing policy relative to fixed pricing, because they benefit both from lower prices during normal demand and expanded access to service during peak demand.

In Chap. 7, Jiaru Bai, Rick So, Chris Tang, Xiqun Chen, and Hai Wang also study two-sided pricing in a sharing economy. They adopt a queueing model with both the supply and demand endogenously dependent on the price the platform charges its customers and the wage the platform pays its independent providers. The authors use the steady-state performance in equilibrium to characterize the optimal price, optimal wage and optimal commission rate that maximize the profit of the platform. They find that it is optimal for the platform to offer time-dependent commission rates by providing a higher rate during peak hours and a lower rate otherwise.

In Chap. 8, Yiwei Chen, Ming Hu, and Yun Zhou study the pricing and matching decisions of a platform in simultaneously managing the supply and demand. First, the authors explore how the platform could optimally set the price and wage for a single service or product in different market conditions, and provide provable performance guarantee for the fixed commission contract. Second, even with determined pricing decisions, the platform still faces the task of matching customers with suppliers. Then they consider a stochastic, dynamic model with multiple demand types to be matched with multiple supply types over a planning horizon. They characterize the optimal matching policy by determining the priorities of the demand-supply pairs, under a sufficient condition on the reward structure. Finally, they study the joint pricing and matching decision by a platform for a single service or product and take into account suppliers' and customers' forward-looking behavior. They propose a simple heuristic policy and show it is asymptotically optimal when both sides of the market have sufficiently large volumes.

1.2.2.2 Intermediation via Information and Payment

In Chap. 9, Gad Allon, Achal Bassamboo, and Eren Çil study large-scale, web-based service marketplaces, where many small service providers compete among themselves in catering to customers with diverse needs. Customers who frequent these marketplaces seek quick resolutions and thus are usually willing to trade prices with waiting times. They discuss the role of the moderating platform in facilitating information gathering, operational efficiency, and communication among agents in such service marketplaces. Perhaps surprisingly, they show that operational efficiency may be detrimental to the overall efficiency of the marketplace. Then they establish that to reap the expected gains of operational efficiency for the marketplace, the moderating platform may need to complement the operational efficiency by enabling communication among its agents.

In Chap. 10, Kostas Bimpikis and Yiangos Papanastasiou focus on the information disclosure as a moderating scheme to incentivize customers to take system-optimal actions. Crowd-sourced content in the form of online product reviews or recommendations is an integral feature of most Internet-based service platforms and marketplaces. Customers may find such information useful when deciding among potential alternatives; at the same time, the process of generating such content is mainly driven by the customers' decisions themselves. The authors

focus on a platform that can potentially incentivize the actions of self-interested customers by appropriately designing an information provision policy or a payment scheme.

In Chap. 11, Ying-Ju Chen, Costis Maglaras, and Gustavo Vulcano study an aggregated marketplace where potential buyers arrive and submit requests-for-quotes. There are independent suppliers each modeled as a queueing system that competes for these requests. Each supplier offers a bid that comprises a fixed price and a dynamic target lead time, and the cheapest supplier wins the order as long as the quote meets the buyer's willingness to pay. The authors characterize the asymptotic performance of this system as the demand and the supplier capacities grow large and obtain insights into the equilibrium behavior of the suppliers. To overcome the efficiency loss from supplier competition, they propose a compensation-while-idling mechanism that the marketplace can impose: each supplier gets monetary compensation from other suppliers during his idle time. This mechanism induces suppliers to implement the centralized solution.

1.2.2.3 Intermediation in the Presence of Self-Scheduling Suppliers

Although the self-interested behavior of individual suppliers is an indispensable feature of most of the previous chapters in Part II, the following chapters build on classical operational models such as the newsvendor model and queueing systems and focus specifically on incorporating the self-scheduling behavior of individual suppliers.

In Chap. 12, Itai Gurvich, Martin Lariviere, and Antonio Moreno study capacity management of a service provider over a horizon when its workers have the flexibility to choose when they will (or will not) work and optimize their schedules based on the offered compensation and individual availability. The authors provide an augmented newsvendor formula to capture the tradeoffs for the firm and the agents. If the firm could keep the flexibility but have direct control of agents for the same wages, it would not only generate higher profit, as it is expected, but would also provide better service levels to its customers. If the agents require a "minimum wage" to remain in the agent pool, they will have to relinquish some of their flexibility. To pay a minimum wage, the firm must restrict the number of agents that can work in some time intervals. If the pool of agents is sufficiently large relative to peak demand, the firm benefits from self-scheduling behavior of individual suppliers.

In Chap. 13, Rouba Ibrahim also focuses on the self-scheduling behavior of individual workers. When such behavior is allowed, the number of workers available in any period is uncertain. She adopts a queueing-theoretic framework to study the effective management of service systems where the number of available agents is random. She begins by surveying some theoretical results on the control of queueing systems with uncertainty in the number of servers. Then, she illustrates how to apply those theoretical results to study the problems of staffing and controlling queueing systems with self-scheduling workers and impatient, time-sensitive, customers.

1.2.3 Part III: Crowdsourcing Management

1.2.3.1 Group Buying and Crowdfunding

In Chap. 14, Ming Hu, Mengze Shi, and Jiahua Wu investigate the two popular business models, namely, online group buying and crowdfunding. The former crowdsources demand, and the latter crowdsources funds. Both share the same unique feature of an all-or-nothing mechanism, where transactions will take place only if the total number of committed purchases or pledges exceeds a specified threshold within a specified period. The authors seek to understand the impact of the all-or-nothing mechanism on consumer behavior, as well as the optimal design of such mechanisms from the perspective of third-party platforms like Groupon and Kickstarter. First, using a dataset from the online group buying industry, they empirically identify two types of threshold-induced effects on consumer behavior. Next, they study the optimal design of all-or-nothing mechanisms from two different perspectives, namely, information disclosure and pricing.

In Chap. 15, Simone Marinesi, Karan Girotra, and Serguei Netessine study group buying and its impact on a service provider. They model a capacity-constrained firm offering service to a random-sized population of strategic customers in two representative time periods, a desirable hot period and a less desirable slow period. They show that strategic consumer behavior under group buying with an all-or-nothing threshold increases the firm's profits. When threshold discounts are offered through an intermediary platform, arrangements often used in practice distort the incentives of the intermediary, and typically result in a higher discount and a lower activation threshold relative to what would be optimal for the service firm. The authors consider alternative deal designs and find that the best designs compromise the service provider's flexibility to provide customers with clear offer terms.

1.2.3.2 Crowdsourcing Contest

In Chap. 16, Laurence Ales, Soo-Haeng Cho, and Ersin Körpeoğlu present a general model framework of innovation contests, in which an organizer crowdsources solutions to an innovation-related problem from a group of independent agents. Agents, who can be heterogeneous in their ability levels, exert efforts to improve their solutions, and their solution qualities are uncertain due to the innovation and evaluation processes. The framework captures main features of a contest and encompasses several existing models in the literature. Using this framework, the authors analyze two critical decisions of the organizer: a set of awards that will be distributed to agents and whether to restrict entry to a contest or to run an open contest. They provide a taxonomy of the contest literature and discuss past and current research on innovation contests as well as a set of exciting future research directions.

1.2.4 Part IV: Context-Based Operational Problems in Sharing Economy

1.2.4.1 Bike Sharing

In Chap. 17, Mabel Chou, Qizhang Liu, Chung-Piaw Teo, and Deanna Yeo develop practical operations models to support decision making in the design and management of public bicycle-sharing systems. They develop a network flow model with proportionality constraints to estimate the flow of bicycles within the network, and to estimate the number of trips and the number of docks needed at each station. The authors also examine the impact of periodic redistribution of bicycles in the network. The same approach can be extended to incorporate the decisions of station locations, by taking into account the proportional flow constraints into a mixed-integer programming formulation. Using a set of bus transit data, they implemented this approach to identify the ideal locations for the bicycle stations in a new town of Singapore.

In Chap. 18, Daniel Freund, Shane Henderson, and David Shmoys also discuss planning methods for bike-sharing systems. They study specific questions such as decisions related to the number of docks to allocate to each station, how to rebalance the system by moving bikes to match demand, and how to expand the network. They discuss linear integer programming models, specially-tailored optimization algorithms, and simulation methods. All of these methods rely on a careful statistical analysis of bike-sharing data, which they also briefly review. This chapter is based on their 4-year collaboration with Citi Bike in New York City, and its parent company Motivate.

1.2.4.2 Vehicle Sharing

In Chap. 19, Long He, Ho-Yin Mak, and Ying Rong study the free-float model of vehicle sharing, which allows users to start and end rentals at any location within a defined service region. Compared with conventional models of vehicle sharing, the free-float model offers its users the flexibility to make one-way, two-way and multi-stop trips, and as a result, provides a more viable alternative to individual vehicle ownership. On the other hand, the flexibility of the free-float model leads to many operations management challenges that must be overcome for such vehicle sharing systems to be economically sustainable. The authors review several operations management problems in vehicle sharing including system design, vehicle repositioning, fleet sizing, dynamic pricing and reservation policy. In particular, they discuss the optimization models for service region design and fleet repositioning.

1.2.4.3 Short-Term Rental

In Chap. 20, Jun Li, Antonio Moreno, and Dennis J. Zhang study Airbnb, the largest marketplace that allows people to rent short-term lodging from property owners. One of the distinct features of such a sharing-economy marketplace is that the supply side includes individual nonprofessional decision makers, in addition to firms and professional agents. Using a data set of prices and availability of listings on Airbnb, the authors find that there exist substantial differences in the operational and financial performance of professional and nonprofessional hosts. They provide empirical evidence to explain such performance differences between professionals and nonprofessionals: nonprofessional hosts are less likely to offer contingent rates across stay dates based on the underlying demand patterns.

1.2.4.4 Online Advertising

In Chap. 21, Santiago Balseiro, Ozan Candogan, and Huseyin Gurkan study online advertising, in which impressions are sold to advertisers via real-time auctions organized by central platforms referred to as ad exchanges. Advertisers participate in the auctions run by exchanges through intermediaries which acquire impressions on their behalf. Intermediaries are specialized entities that provide targeted services for a particular segment of the market, and typically there are multiple stages of intermediation. Moreover, an advertiser may have private information, e.g., budget, targeting criterion or value attributed to an impression. First, the authors study the mechanism design problem of an intermediary who offers a contract to an advertiser with a private budget and a private targeting criterion. They characterize the optimal mechanism and establish that the presence of the intermediary results in more straightforward bidding policies. Next, they study the strategic interaction among intermediaries organized in a chain network. They characterize a subgame perfect equilibrium of the resulting game among intermediaries and show that the most profitable position in the intermediation chain depends on the underlying value distribution of the advertiser.

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Part I
Impact of Sharing Economy

Chapter 2
Peer-to-Peer Product Sharing

Saif Benjaafar, Guangwen Kong, Xiang Li, and Costas Courcoubetis

Abstract We describe an equilibrium model of peer-to-peer product sharing, or collaborative consumption, where individuals with varying usage levels make decisions about whether or not to own a homogenous product. Owners are able to generate income from renting their products to non-owners while non-owners are able to access these products through renting on as needed basis. We characterize equilibrium outcomes, including ownership and usage levels, consumer surplus, and social welfare. We compare each outcome in systems with and without collaborative consumption and examine the impact of various problem parameters. Our findings indicate that collaborative consumption can result in either lower or higher ownership and usage levels, with higher ownership and usage levels more likely when the cost of ownership is high. Our findings also indicate that consumers always benefit from collaborative consumption, with individuals who, in the absence of collaborative consumption, are indifferent between owning and not owning benefitting the most. We study both profit maximizing and social welfare maximizing platforms and compare equilibrium outcomes under both in terms of ownership, usage, and social welfare. We find that the difference in social welfare between the profit maximizing and social welfare maximizing platforms is relatively modest.

This chapter is based on the paper "Peer-to-Peer Product Sharing: Implications for Ownership, Usage and Social Welfare in the Sharing Economy", Published Online: 16 May 2018 in *Management Science*, https://doi.org/10.1287/mnsc.2017.2970

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2.1 Introduction

We are witnessing, across a wide range of domains, a shift away from the exclusive ownership and consumption of resources to one of shared use and consumption. This shift is taking advantage of innovative new ways of peer-to-peer sharing that are voluntary and enabled by internet-based exchange markets and mediation platforms. Value is derived from the fact that many resources are acquired to satisfy infrequent demand but are otherwise poorly utilized (for example, the average car in the US is used less than 5% of the time). Several successful businesses in the US and elsewhere, such as Getaround for cars, Spinlister for bikes, 3D Hubs for 3D printers, LiquidSpace for office space, MachineryLink for farm equipment and JustPark for parking, provide a proof of concept and evidence for the viability of peer-to-peer product sharing or collaborative consumption (the term we use in the rest of the chapter). These businesses and others allow owners to rent on a short-term basis poorly utilized assets and non-owners to access these assets through renting on an as-needed basis. Collectively, these businesses and other manifestations of the collaborative consumption of products and services are giving rise to what is becoming known as the sharing economy.[1]

The peer-to-peer sharing of products is not a new concept. However, recent technological advances in several areas have made it more feasible by lowering the associated search and transaction costs. These advances include the development of online marketplaces, mobile devices and platforms, electronic payments, and two-way reputation systems whereby users rate providers and providers rate users. Other drivers behind the rise of collaborative consumption are societal and include increased population density in urban areas around the world, increased concern about the environment (collaborative consumption is viewed as a more sustainable alternative to traditional modes of consumption), and increased desire for community and altruism among the young and educated.

Collaborative consumption has the potential of increasing access while reducing investments in resources and infrastructure. In turn, this could have the twin benefit of improving consumer welfare (individuals who may not otherwise afford a product now have an opportunity to use it) while reducing societal costs (externalities, such as pollution that may be associated with the production, distribution, use, and disposal of the product). It also has the potential of providing a source of net income for owners by monetizing poorly utilized assets, which are in some cases also expensive and rapidly depreciating. Take cars for example. The availability of a sharing option could lead some to forego car ownership in favor

[1]The term sharing economy has been used to refer to businesses that enable the foregoing of ownership in favor of "on-demand" access. In several cases, this involves a single entity that owns the physical assets (e.g., Zipcar for short term car rentals). It also encompasses the peer-to-peer provisioning of services (e.g., Uber for transportation services, TaskRabbit for errands, and Postmates for small deliveries). For further discussion and additional examples, see Botsman and Rogers (2010), Malhotra and Van Alstyne (2014), Cusumano (2014), and Chase (2015).

of on-demand access. In turn, this could result in a corresponding reduction in congestion and emissions and, eventually, in reduced investments in roads and parking infrastructure. However, increased collaborative consumption may have other consequences, some of which may be undesirable. For example, greater access to cars could increase car usage and, therefore, lead to more congestion and pollution if it is not accompanied by a sufficient reduction in the numbers of cars.[2] It could also lead to speculative investments in cars and price inflation, or affect the availability and pricing of other modes of public transport, such as taxis, buses, and trains.

Collaborative consumption raises several important questions. How does collaborative consumption affect ownership and usage of resources? Is it necessarily the case that collaborative consumption leads to lower ownership, lower usage, or both (and therefore to improved environmental impact)? If not, what conditions would favor lower ownership, lower usage, or both? Who benefits the most from collaborative consumption among owners and renters? To what extent would a profit maximizing platform, through its choice of rental prices, improve social welfare? To what extent do frictions, such as extra wear and tear renters place on rented resources and inconvenience experienced by renters affect platform profit and social welfare?

In this chapter, we address these and other related questions. We describe an equilibrium model of peer-to-peer product sharing, where individuals with varying usage levels make decisions about whether or not to own a homogenous product. In the presence of collaborative consumption, owners are able to generate income from renting their products to non-owners while non-owners are able to access these products through renting. The matching of owners and renters is facilitated by a platform, which sets the rental price and charges a commission fee.[3] Because supply and demand can fluctuate over the short run, we allow for the possibility that an owner may not always be able to find a renter when she puts her product up for rent. Similarly, we allow for the possibility that a renter may not always be able to find a product to rent when he needs one. We refer to the uncertainty regarding the availability of renters and products as matching friction and describe a model for this uncertainty. We also account for the cost incurred by owners due to the extra

[2] An article in the New York Times (2015) notes that "The average daytime speed of cars in Manhattan's business districts has fallen to just under 8 miles per hour this year, from about 9.15 miles per hour in 2009. City officials say that car services like Uber and Lyft are partly to blame. So Mayor Bill de Blasio is proposing to cap their growth." Note that, although the peer-to-peer product sharing we consider is different from the type of product sharing enabled by Uber (which requires the involvement of the owner as a service provider), the two share similarities in that they provide non-owners with access to a product without having to own it.

[3] A variety of pricing approaches are observed in practice. Some platforms allow owners to choose their own prices. Others (e.g., DriveMycar) determine the price. There are also cases where the approach is hybrid, with owners determining a minimum acceptable price but allowing the platform to adjust it higher (e.g., Turo), or with the platform suggesting a price (e.g., JustShareIt) but allowing owners to deviate. From conversations the authors had with several industry executives, there appears to be a push toward platform pricing, with several platforms investing in the development of sophisticated pricing engines to support owners.