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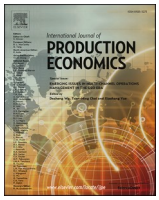

Impacts of sharing business on production, sales, and rental markets☆

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ABSTRACT

The rapid growth of the sharing economy has received much attention by recent studies. Most of them focus on the impacts on the rental markets, and sharing is seen as a perfect substitute to rental. Since evidence shows that the sharing business has also greatly affected sales markets and manufacturers, this paper attempts to bridge the gap by examining the overall effects of sharing business on rentals, sales, production, and labor employment in a differentiated product model. Renting from firms and from private owners are different in the quality instability of sharing business. By assuming heterogeneous consumers with different risk attitudes, we characterize the equilibrium for this imperfect competition market. Our results show that sharing business not only decreases the rental prices, it also decreases the retail prices. The demand for new products will decrease, and the product supplying price, production and labor employment will also decrease. If the quality of sharing business is improved, the competition between rental and sharing products becomes more severe. Both selling and rental prices will decrease, but the price of sharing business will increase. Our model suggests that for existing rental firms, increasing product heterogeneity can reduce the impacts from sharing business. For the producers, our analysis suggests to increase the replacement rate through providing innovations, to provide portable "parts" to the used products, to provide post-sale services or sustainability production, and to participate in the sharing business.

1. Introduction

"Sharing" is an old activity in human society. People rent or share their properties such as cars, homes, skills, or personal time with other people for monetary or non-monetary benefits.[1] New technologies like blockchains and big data analysis have made it possible to match a large group of people for short term leases through platforms, Apps, and distributed networks. Data from Statista shows that the total value of the global sharing economy will reach $335 billion by 2025 (Yaraghi and Ravi, 2017). The rapid growth of sharing economy companies is best illustrated by the cases of Airbnb and Uber. The statistics show the increasing valuation of Uber and Airbnb from 2014 to 2018. In 2018, the market value of Uber amounted to $76 billion, up from $72 billion the previous year.[2] In 2019, Airbnb had 4000 employees globally, and over the past year it has been working to fill out its whopping $31 billion valuation.[3] Uber went public in 2019 and Airbnb went public in 2020.

This rapid growth of sharing economy hence has a profound impact on the existing rental markets, and this is also the focus of most existing literature (e.g., Fraiberger and Sundararajan, 2015; Horton and Zeckhauser, 2016; Benjaafar et al., 2018; Jiang and Tian, 2016). However, sharing business has also greatly affected the sales markets as well as manufacturers. In the case of the automobile industry, it is anticipated that "*the increasing popularity of shared mobility will slow global vehicle sales but not reverse them …. . Through 2030, roughly a third of the expected*

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[1] See e.g., Belk (2010). Other products that can be shared are listed here: https://www.entrepreneur.com/article/335568.
[2] https://www.statista.com/statistics/831044/increasing-valuation-of-uber-and-airbnb/.
[3] https://www.inc.com/christine-lagorio/biggest-startup-ipos-2019.html.

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increase in vehicle sales from urbanization and macroeconomic growth likely will not happen because of shared mobility"[4] It is therefore necessary to analyze the overall impacts on the entire system as a result of the new sharing practice.,[5][6]

This paper attempts to bridge the gap by examining the overall effects of the sharing business on rentals, sales, production and labor employment in an imperfect competition model. Our analysis starts by treating different types of services as different products, so there are mainly three types of products: sales, rental from firms and rental from private owners. The main difference between renting from firms and private owners is the quality instability of sharing business.[7] Thus by assuming heterogeneous consumers with different risk attitudes, we can derive the market demands for the three types of products, and characterize the equilibrium for this imperfect competition market. We compare the equilibrium prices to the case without the sharing business. Finally, we address the producer's decisions and find the equilibrium product price.

Our results first show that the existence of sharing business will increase the degree of competition in the rental market. Both the selling and rental prices will decrease. The sharing business will increase the "buyers'" utilities, but there is no unambiguous conclusion for other types of consumers. When the quality insatiability of sharing business decreases, both selling and rental prices will decrease, but the price of sharing business will increase.

Next, from the perspective of the producer, we show that with sharing business, both the demand for new products and labor employment will decrease. However, this decrease of new products in the sales market will increase both the selling and rental prices but decrease the price of sharing business. Moreover, the producer will charge a lower product price when there are sharing businesses.

We use our model to address several practical strategies for the producer. First, we suggest to increase the replacement rate through providing innovations, which can increase both the demand for new products and the producer's profit. For example, nowadays[8] most new automobiles are equipped with safety devices (e.g., traction control system, rear cross-traffic alert, lane departure warning, automatic emergency braking, 360-degree camera) and connections to mobile or internet (e.g., connected mobile Apps, stolen vehicle tracking software or Apple CarPlay and Android Auto). These new devices will stimulate consumers' demand for new cars and increase car dealers' and producers' profits. Moreover, we suggest that innovations on the portable "parts" of the used products can also increase the producer's profits. Similarly, providing the post-sale services or other services that can increase the life cycle of the products or sustainability production will also increase the producer's profits but only on the stock of used products, and this can have a contrary effect on reducing the replacement rate. Finally, for shortage in demand, the producer can also participate in the sharing business by providing B2C or B2B services.

Our paper attempts to make incremental contributions to the following topics. First, most of the analytical models that have addressed the effects of sharing business focus on the rental markets (Fraiberger and Sundararajan, 2015; Einav et al., 2016; Horton and Zeckhauser, 2016; Jiang and Tian, 2016; Benjaafar et al., 2018). For example, Fraiberger and Sundararajan (2015) considered that consumers can choose to buy new products, or to rent their owned assets in a (traditional) secondary marketplace or the peer-to-peer rental marketplace. They found that the introduction of sharing would decrease ownership but increase utilization. In their model, the equilibrium prices are exogenously given as competitive prices, so there is no discussion on the interaction with other rental products, nor on the impacts on the sales market and production. Following Fraiberger and Sundararajan (2015), Horton and Zeckhauser (2016) explained how consumers divide between owners and non-owners based on their expected usage. They allowed the owners to rent their products to non-owners through P2P rental and determined the equilibrium rental rates.

In the above mentioned studies, consumers are heterogeneous in their usage levels, so rental and sharing products are treated as *homogenous* products. Differently, our paper assumes that consumers are heterogeneous in their risk attitudes. Renting from firms and from private owners are different in the quality instability of sharing business, so the two products are heterogeneous to consumers. Hence, we analyze the competition of the three products (i.e., sales, rental from firms and rental from private owners) in a differentiated product market. The inclusion of the sales market and the discussion on the impacts on production and labor employment are not seen in the above literature. Our assumption of heterogeneous consumers is similar to Wen and Siqin (2019), but their focus was on the optimal average quality level and price that a sharing platform should charge in the market.

Second, Zhao and Chen (2019) and Bernstein et al. (2018) studied the competition between sharing platforms. For example, Zhao and Chen (2019) discussed the ex-ante versus ex-post destination information models used in Didi and Uber. For Didi, drivers can acquire the passengers' destination information before receiving the orders (they called it ADI). For Uber, participants can only obtain the information after receiving the requests (they called it PDI). Intuitively, platforms can generate more revenue under the PDI model. Although our paper does not address the competition within sharing products, we analyze the cross-product competition among sharing, rentals from firms and sales, and study the impacts on production and employment, which are not addressed by these contributions.

Third, several recent papers have analyzed the effects of sharing economy from the perspectives of manufacturers (Tian and Jiang, 2018; Abhishek et al., 2019; Bellos et al., 2017; Feng et al., 2019; Jiang et al., 2018; Li et al., 2020). Manufacturers are assumed to be the retailers who can choose to sell-only, or to simultaneously sell and rent in a peer-to-peer (P2P) rental market. For example, Li et al. (2020) concluded that critical factors such as the value perception and marginal cost would determine whether manufacturers such as traditional car companies should cooperate with sharing platforms or work with rental platforms in the presence of the sharing economy. Our model also suggests that the producer should participate in the sharing business by providing B2C or B2B services to mitigate the shortage in demand. However, our model suggests that this would cause more customers to choose the sharing business, and thus cause a further shortage in sales. This explains Abhishek et al.'s (2019) results that, if a P2P market is unavoidable, the manufacturer would not necessarily be better-off by introducing its own rentals to compete against P2P.

The remainder of the paper is organized as follows. Section 2 discusses the related literature and points out the similarities and differences between the existing works and this paper. Section 3 characterizes the market demand for the three types of products: sales, rental from firms and rental from private owners. Then we compare the equilibrium prices with and without the sharing business. Section 4 describes how sharing business affects the production side. Section 5 concludes the paper with a brief discussion of management insights.

[4] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/how-shared-mobility-will-change-the-automotive-industry.

[5] https://www.journals.elsevier.com/resources-conservation-and-recycling/call-for-papers/call-for-papers-of-virtual-special-issue-on-the-sharing-econ.

[6] According to Rong et al. (2018), there is not yet much exploration of the impact of sharing economy on the sustainability of value chains …. Along with the growth of the sharing economy activities and supporting ICT, its impact on various parts of the value chain becomes evident.

[7] Some papers also noticed this potential uncertainty of products or service quality in the sharing economy. Cusumano (2015) pointed out the service variability nature of Uber, Wen and Siqin (2019) further linked the product (or service) quality uncertainties with risk considerations.

[8] https://www.kbb.com/car-news/best-car-technologies/2100004818/.

2. Related literature

This paper is related to the following four strands of literature. First, most of the analytical models that have addressed the effects of sharing business focus on the rental markets. For example, Benjaafar et al. (2018) considered the ownership choice with and without the possibility of P2P rental, with participants differing in their expected usage. They found that total ownership could increase following sharing. Einav et al. (2016) analyzed the competition between peer-to-peer sellers and rental firms. Jiang and Tian (2016) analyzed the competition between sharing business and rental firms. They showed how a rental firm strategically determines the rental prices and product quality while anticipating customers' sharing behavior. They concluded that when the firm strategically chooses its rental price, the equilibrium can be a win-win or lose-lose outcome for the rental firms and consumers, depending on the size of the marginal cost.

Second, our model is related to Zhao and Chen (2019) and Bernstein et al. (2018) who studied the competition between sharing platforms. Zhao and Chen (2019) discussed the ex-ante versus ex-post destination information models used in Didi and Uber. Bernstein et al. (2018) studied competition and multi-homing in the presence of congestion effects typically observed in the sharing economy. They found that raising prices in response to a surge in demand makes drivers and customers better off than if platforms were constrained to charge the same prices that would arise under normal demand levels. While individual drivers may have an incentive to multi-home, all players are worse off when all drivers multi-home.

Third, our model is related to recent papers that analyze the effects of a sharing economy from the perspectives of manufacturers. Tian and Jiang (2018) assumed that the product owner's self-use values can differ over time, and in a period of low self-use value, the owner may rent out the product in a product-sharing market. They found that the sharing market tends to increase the retailer's share of the gross profit margin in the channel. The existence of the sharing market tends to benefit the firms when capacity is relatively costly to build, but it is more likely to increase the retailer's profit than the manufacturer's profit.

Abhishek et al. (2019) analyzed the interaction of a peer-to-peer (P2P) rental market and the manufacturer, who can choose to sell-only, or to simultaneously sell and rent. In the latter case, the manufacturer will compete with private owners in the rental market. They concluded that consumer heterogeneity in usage rates is the driving factor for whether the manufacturer should operate in the presence of a P2P rental platform. Bellos et al. (2017) considered a manufacturer that provides car sharing and designs its product line by accounting for the trade-off between driving performance and fuel efficiency. Customers choose whether to buy, join car sharing, or rely on their outside option. They found that the manufacturer can increase the fuel efficiency of the vehicles it provides through car sharing. They concluded that "high-end" manufacturers benefit more from introducing car sharing than "low-end" manufacturers, because when high-end manufacturers introduced their own car sharing programs, they could extend their customer base without cannibalizing their existing sales. These papers presented the equilibria for different scenarios (resulted by the manufacturer's choice), and the prices are determined by demand and supply. They have not addressed the incomplete competition between the rental and sales markets as our model.

Furthermore, Jiang et al. (2018) studied the manufacturer's entry in the product-sharing market. In their model, manufacturers produce the product and sell to consumers at a retail price, and they decide how many units of the product should be put into the sharing market. They concluded that when the transaction cost for C2C sharing is high or the manufacturer's marginal cost of production is high, the manufacturer should offer enough units of the products for rental to squeeze out C2C sharing. When the transaction cost for C2C sharing and the manufacturer's marginal cost are both in the middle ranges, the manufacturer's rental services and the C2C sharing will coexist. Li et al. (2020) studied whether manufacturers like traditional car companies should cooperate with peer-to-peer platforms (sharing economy) or work with business-to-consumer platforms (rental platform) in the presence of the sharing economy. They concluded that critical factors like the value perception and marginal cost would determine whether working with business-to-consumer (B2C) platforms such as Zipcar and Togo or peer-to-peer (P2P) platforms like Turo and Getaround would be most suitable. Aw et al. (2019) also explained that perceived personalization, perceived usefulness of rating system and service personal values significantly influence perceived value and trust. Feng et al. (2019) explored how the firm should strategically decide its production and quality responses to the anticipated trade of used products among consumers through the platform. They showed that when the firm solely decides its production, the presence of a secondary market platform can increase the firm's gross profit in some situations. However, when the firm can endogenously determine product quality and production, they obtain a case in which the presence of a secondary market platform is beneficial to the firm and eventually increases product quality.

Fourth, many recent papers empirically investigate the impacts of sharing economy. For the examples of the car industry, Aw et al. (2019) empirically tested the antecedents and outcome of perceived value and trust toward on-demand ride-sharing services. Eckhardt et al. (2019) used the model of a circular road and compared the average waiting time of passengers. They pointed out the advantage of the call mechanism from the platform: the ability to tell the driver where (which direction) to go to pick up the next passenger. Schaller (2021) found that the average unoccupied time between trips for App-based ride services such as Uber and Lyft is 11 min, which is significantly longer than the average 8 min for yellow cabs.

For the examples of the hotel industry, Zervas et al. (2017) studied how Airbnb is affecting hotels. They focused on the impacts that these peer-to-peer platforms have on incumbent (rental) firms in Texas. They estimated monthly hotel room revenue as a function of Airbnb entry in the market. They suggested that in Texas, each additional 10% increase in the size of the Airbnb market resulted in a 0.39% decrease in hotel room revenue. After segmenting hotels in five industry standard price tiers (budget, economy, mid-price, upscale, and luxury), they find that the impact of Airbnb is gradually magnified as they move down the price tiers. Chain hotels will be less affected than independent hotels because chains' larger marketing budgets and stronger brands to their predictably consistent service. Quattrone et al. (2016) studied who benefits from the sharing economy facilitator Airbnb. They found an overlap between Airbnb adoption and hotel adoption. Specifically, Airbnb properties tend to be located in areas where there are hotels. But, Hotels do not tend to be in areas where there are Airbnb properties. Farronato and Fradkin (2018) investigated the welfare effects of Airbnb. To quantify the effects of the Airbnb entry, they found that Airbnb generated $41 of consumer surplus per room-night and $26 of host surplus while reducing variable hotel profits from accommodations by up to 3.7%. Cusumano (2015) and Einav et al. (2016) suggested that heterogeneity was the central problem of Airbnb listings. Mao et al. (2019) investigated the impact of delivery performance on future customer orders for an on-demand meal delivery service platform, and they concluded that delivery driver's local area knowledge and experience had significant impacts on delivery performance. i.e., there will be an inherent heterogeneity among drivers in terms of knowledge and experience.

3. The model

To examine the impacts of the sharing business, we consider an industry of a durable good[9] (e.g., car) that can be used for two periods.

[9] Other examples of durable goods that have been shared in practice include jewelries, clothes, offices, sports facilities, bikes and car parks.

After the end of period two, the product value is assumed to be zero, due to, for example, incompatibility with new technologies.[10] There are infinitely many heterogeneous consumers who are different in their risk attitudes. Following Eichner and Wagener (2009), we assume the following mean-variance utility function for each consumer:

$$V(y_k) = \mu_k - \lambda\sigma_k^2.$$

A consumer's utility from using the product k is the sum of an expected final income (μ_k) and a negative effect from variance (σ_k^2). The constant λ measures this consumer's degree of risk aversion. To simplify, we assume that each consumer has a different value of λ, and λ is uniformly distributed over [0, L] with $L > 0$.

There are three types of products in this industry: sales, rental and sharing business, which are indexed as 1, 2, 3, respectively. Here, we will distinguish between dealer and producer (or manufacturer). As will be demonstrated, the impacts on these two players are not exactly the same.

The three types of products are different in their mean and variance, whose details are described as follows.

3.1. Three types of products

For all three types of products, we assume that the single period value is V. Consumers' demands in period one are certain but their period-two demands are uncertain. There is a chance that the consumer does not need the product in period two. Let $0 < \varphi < 1$ be the probability that the product service will be needed in period two. Even when the product is not needed, we assume that there is a certain level of joy or satisfaction J ($< V$) for owning (buying) the product. In what follows, let p_k be the price of product k, with $k = 1, 2, 3$.

First, if a consumer buys the product, his expected value is μ_1 and the variance is σ_1^2, where

$$\begin{aligned}\mu_1 &= \mu_1^1 + \mu_1^2\\ &= \{V - p_1\} + \{\varphi V + (1-\varphi)J\}.\end{aligned}$$

Since the product lasts for two periods, the period-one consumer surplus is $V - p_1$. In period two, if there is a need for service (with probability φ), then the value is V; If there is no need for service (with probability $1 - \varphi$), then there is still a value J for owning the product. Although we have not explicitly assumed a holding or maintenance cost, we can use $(V - J)$ to capture the effect of holding cost. For simplification, we assume no discounting.

Next, the variance for buying the product is σ_1^2:

$$\begin{aligned}\sigma_1^2 &= \varphi(V - \mu_1^2)^2 + (1-\varphi)(J - \mu_1^2)^2\\ &= \varphi(1-\varphi)(V - J)^2.\end{aligned}$$

Here since there is no uncertainty for the period-one demand, we only calculate the deviation from the period-two mean (μ_1^2).

Second, if a consumer rents the product from the rental firm, his expected value is μ_2 and the variance is σ_2^2, where

$$\begin{aligned}\mu_2 &= \mu_2^1 + \mu_2^2\\ &= \{V - p_2\} + \varphi(V - p_2).\end{aligned}$$

Since the product lasts for two periods, the period-one consumer surplus is $V - p_2$ and the price is paid only for the period-one service. If there is a demand for service in period-two (with probability φ), then there will be a surplus $V - p_2$, where p_2 is the period-two rental price. However, if there is no demand for service (with probability $1 - \varphi$), then there is no value for the consumer and there is no need to pay.

Next, the variance for renting the product is σ_2^2:

$$\begin{aligned}\sigma_2^2 &= \varphi(V - p_2 - \mu_2^2)^2 + (1-\varphi)(0 - \mu_2^2)^2\\ &= \varphi(1-\varphi)(V - p_2)^2.\end{aligned}$$

Again, since there is no uncertainty for the period-one demand, we only calculate the deviations from the period-two mean (μ_2^2).

Third, notice first that the quality of renting from a private owner is usually less stable than renting from a rental firm. To describe this relative instability in quality, we assume that there is a chance θ that the value from usage can fall to $V - \delta$, and a probability $(1 - \theta)$ that it will remain V.

Hence the expected value for renting the product from the sharing platform is:

$$\begin{aligned}\mu_3 &= \mu_3^1 + \mu_3^2\\ &= \{\theta(V-\delta) + (1-\theta)(V) - p_3\} + \varphi\{\theta(V-\delta) + (1-\theta)(V) - p_3\}.\end{aligned}$$

p_3 is the rent charged by the private owner, and similar to p_2, the consumer needs to pay the rent every period. The terms in the first bracket are the period-one expected surplus, where there is a chance θ that the service is below the standard. If there is a demand for service in period two (with a probability φ), then there will be again an expected value: $\theta(V - \delta) + (1 - \theta)(V)$, where the period-two rental price p_3 needs to be paid again. However, if there is no demand for service (with a probability $1 - \varphi$), then there is no value and there is no need to pay.

Next, the variance for renting the product is σ_3^2:

$$\begin{aligned}\sigma_3^2 &= \theta(V-\delta-p_3-\mu_3^1)^2 + (1-\theta)(V-p_3-\mu_3^1)^2\\ &\quad +\varphi\theta((V-\delta)-p_3-\mu_3^2)^2 + \varphi(1-\theta)(V-p_3-\mu_3^2)^2 + (1-\varphi)(0-\mu_3^2)^2\\ &= \varphi(1-\varphi)(V-p_3)(V-p_3-2\delta\theta) + \delta^2\theta[\varphi(1-\varphi\theta) + (1-\theta)].\end{aligned}$$

Notice that since there is uncertainty for both periods, we need to calculate both of the deviations from the period-one mean (μ_3^1) and from the period-two mean (μ_3^2). Lemma 1 describes some useful properties about these means and variances.

Lemma 1. (1) *If $p_1 = p_2 = p_3$ and J is sufficiently big, then $\mu_1 > \mu_2 > \mu_3$ and $\sigma_1^2 < \sigma_2^2 < \sigma_3^2$.*

(2) *μ_2 and σ_2^2 decrease with p_2.*

(3) *μ_2 and σ_3^2 decrease with p_3, if $p_3 < V - \delta\theta$.*

(4) *μ_3 decreases with θ, and σ_3^2 decreases with θ, if $\delta < \frac{2\varphi(1-\varphi)(V-p_3)}{[1+\varphi-2\theta(\varphi^2+1)]}$.*

Proof. (1) The condition for $\sigma_1^2 < \sigma_2^2$ is $J > p_2$. Next, if $p_2 = p_3$, then

$$\sigma_3^2 = \sigma_2^2 - 2\delta\theta\varphi(1-\varphi)(V-p_3) + \delta^2\theta[\varphi(1-\varphi\theta) + (1-\theta)].$$

If $\theta = 0$, then we have $\sigma_3^2 = \sigma_2^2$; If $\theta = 1$, then $\sigma_3^2 = \sigma_2^2 - \delta\varphi(1-\varphi)[2(V - p_3) - \delta]$. If p_3 is not too high such that $2(V - p_3) > \delta$, then we have $\sigma_3^2 < \sigma_2^2$.

(2) $\frac{\partial\sigma_3^2}{\partial p_3} = -\varphi(1-\varphi)[2(V-p_3) - 2\delta\theta) < 0$, if $p_3 < V - \delta\theta$.

(3) $\frac{\partial\sigma_3^2}{\partial\theta} = -2\delta\varphi(1-\varphi)(V-p_3) + \delta^2[1+\varphi-2\theta(\varphi^2+1)] < 0$ if $\delta < \frac{2\varphi(1-\varphi)(V-p_3)}{[1+\varphi-2\theta(\varphi^2+1)]}$.

■

3.2. Market demands for three products

Since the selling price is usually higher than rental prices, we expect that $p_1 > p_2 \geq p_3$. Although the actual means and variances will be determined in the equilibrium, it can be expected that those who are more risk averse will buy the product, and those with the least risk

[10] To describe the trade-off between buying and renting the product, we assume that there are two periods and consumers' demands in period one are certain but their period-two demands are uncertain. In other words, periods 1 and 2 are different in the demand uncertainty. There is no specific assumption on the length of each period. Period one ends when consumers' demands for the product become uncertain.

aversion will rent the product from the sharing market.

First, given the assumption that λ is uniformly distributed over $[0, L]$, there exists a critical value λ_1 such that this consumer is indifferent between buying and renting the product from the rental firm. That is,

$$\mu_1 - \lambda_1\sigma_1^2 = \mu_2 - \lambda_1\sigma_2^2,$$

or

$$\lambda_1 = \frac{\mu_2 - \mu_1}{\sigma_2^2 - \sigma_1^2}.$$

Similarly, there exists a critical value λ_2 such that this consumer is indifferent between renting the product from the rental firm and renting from the sharing platform. That is,

$$\mu_2 - \lambda\sigma_2^2 = \mu_3 - \lambda\sigma_3^2,$$

or

$$\lambda_2 = \frac{\mu_3 - \mu_2}{\sigma_3^2 - \sigma_2^2}.$$

We find the following properties for λ_1 and λ_2.

Lemma 2. (1) *λ_1 increases with p_1, and decreases with p_2, if p_2 is sufficiently high.*
(2) *λ_2 increases with p_2, and decreases with p_3, if p_3 is sufficiently high.*
(3) *λ_2 decreases with θ, if p_3 is sufficiently high.*

Proof. (1) $\frac{\partial\lambda_1}{\partial p_1} = \frac{-\partial\mu_1/\partial p_1(\sigma_2^2-\sigma_1^2)}{(\sigma_2^2-\sigma_1^2)^2} > 0$, and $\frac{\partial\lambda_1}{\partial p_2} = \frac{-(1+\varphi)(\sigma_2^2-\sigma_1^2)+2\varphi(1-\varphi)(V-p_2)(\mu_2-\mu_1)}{(\sigma_2^2-\sigma_1^2)^2} < 0$, if p_2 is sufficiently high.

(2) $\frac{\partial\lambda_2}{\partial p_2} = \frac{-\partial\mu_2/\partial p_2(\sigma_2^2-\sigma_1^2)}{(\sigma_3^2-\sigma_2^2)^2} > 0$, and $\frac{\partial\lambda_2}{\partial p_3} = \frac{-(1+\varphi)(\sigma_3^2-\sigma_2^2)+-2\varphi(1-\varphi)(V-p_3-\delta\theta)(\mu_3-\mu_2)}{(\sigma_3^2-\sigma_2^2)^2} < 0$, if p_3 is sufficiently high.

(3) $\frac{\partial\lambda_2}{\partial\theta} = \frac{-(1+\varphi)\delta(\sigma_3^2-\sigma_2^2)-(\partial\sigma_3^2/\partial\theta)(\mu_3-\mu_2)}{(\sigma_3^2-\sigma_2^2)^2}$, which is negative if p_3 is sufficiently high such that $(V - p_3)$ is sufficiently small.

■

It is expected that those who are more risk averse will buy the product, and those with the least degrees of risk aversion will rent the product from the sharing market. Hence, we restrict to the case that $\lambda_2 < \lambda_1$. Fig. 1 shows the market demands for the three types of products.

The market demands for product 1, 2 and 3 are $(L - \lambda_1)$, $(\lambda_1 - \lambda_2)$ and $(\lambda_2 - 0)$, respectively. We assume that there will be enough amount of used product holders that are willing to provide the sharing service.[11]

Lemma 3. (1) *Product* 1's market demand decreases with p_1 *and increases with* p_2;
(2) *Product* 2's market demand decreases with p_1, *and increases with* p_1 *and* p_2;
(3) *Product* 3's demand decreases with p_3 *and increases with* p_2.

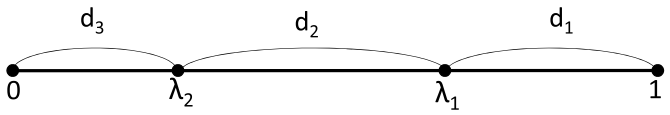

Fig. 1. Market demands for three type of products.

(4) *Product* 3's demand decreases with θ, *if p_3 is sufficiently high.*

Since λ_1 and λ_2 are nonlinear in prices, we take the first-order Taylor series approximations for these market demands at $(p_1, p_2, p_2) = (0, 0, 0)$. Let d_i denote product i's market demand, and according to Lemma 3 we have:

$$\begin{aligned} d_1 &= A - Bp_1 + Cp_2, \\ d_2 &= \alpha - \beta p_2 + \gamma p_1 + \pi p_3, \\ d_3 &= x + yp_2 - zp_3. \end{aligned}$$

We can see that the existence of sharing business will reduce the market demands for the sales and rental markets. This accords with Martucci (2016)'s observation that the sharing economy dramatically undercuts the business of taxis and rental car companies. However, some papers suggest the contrary that because of the value enhancement effect from sharing economy platform, ownership is more attractive and sharing may induce more sales (see Bellos et al. (2017), Abhishek et al. (2019), Taylor (2018), Benjaafar and Hu (2019), Gong et al. (2017), Horton and Zeckhauser (2016)).

3.3. Equilibrium prices

We now characterize the equilibrium prices for the three products. Notice that in our model, the retailer is not exactly the manufacturer, although we do not exclude the possibility that the sales market is run by the manufacturer. Let $\eta > 0$ denote the product price charged by the manufacturer. The profits for the three products are:

$$\begin{aligned} \pi_1 &= (p_1 - \eta)(A - Bp_1 + Cp_2), \\ \pi_2 &= (p_2 - \eta)(\alpha - \beta p_2 + \gamma p_1 + \pi p_3), \\ \pi_3 &= p_3(x + yp_2 - zp_3). \end{aligned}$$

Here it is assumed that the cost of sharing business is sunk and assumed to be zero. "*In many cases, the sharing economy models create an opportunity to circumvent the requirements of certain sectors. In this way, the sharing economy players have lower costs and smaller administrative burdens to contend with than the traditional players, which could give them a competitive advantage, especially if they provide the service "professionally" on a full-time basis.*" [12] We only consider the cost of buying the product from the manufacturer.

All three types of suppliers maximize their profits simultaneously, and the first order conditions (FOCs) of maximization (with respect to prices) are:

$$A + B\eta - 2Bp_1 + Cp_2 = 0, \tag{1}$$

$$\alpha + \beta\eta - 2\beta p_2 + \gamma p_1 + \pi p_3 = 0, \tag{2}$$

$$x + yp_2 - 2zp_3 = 0.$$

From equations (1) and (2), we have

$$p_1 = \frac{A + Cp_2 + B\eta}{2B} \quad \text{and} \quad p_3 = \frac{x + yp_2}{2z}.$$

Substituting them to (2), we have: $\alpha - 2\beta p_2 + \frac{\gamma A + \gamma C p_2 + \gamma B\eta}{2B} + \frac{\pi x + \pi y p_2}{2z} + \beta\eta = 0$. After calculation, we have

$$p_2^* = \frac{z[2B\alpha + A\gamma + B\gamma\eta + 2B\beta\eta] + B\pi x}{z[4B\beta - C\gamma] - B\pi y},$$

and

$$p_1^* = \frac{A + Cp_2^* + B\eta}{2B} \quad \text{and} \quad p_3^* = \frac{x + yp_2^*}{2z}.$$

[11] Suppliers in the sharing economy can generate additional incomes when their assets are currently not in use (see Bellos et al. (2017); Abhishek et al. (2019); Taylor (2018); Benjaafar and Hu (2019); Benjaafar and Pourghannad (2019)).

[12] See also https://www.pwc.com/hu/en/kiadvanyok/assets/pdf/sharing-economy-en.pdf.

Proposition 4 explains how the existence of sharing business will affect the equilibrium prices in markets 1 and 2.

Proposition 4. *The sharing business will decrease the selling and rental prices if the sharing economy is sufficiently big.*

We use Fig. 2 to illustrate this point. When there is no sharing business, the FOCs of maximization are given by

$$A^0 + B\eta - 2Bp_1 + Cp_2 = 0, \quad (3)$$

$$\alpha^0 + \beta\eta - 2\beta p_2 + \gamma p_1 + 0 = 0, \quad (4)$$

where $A^0 + \alpha^0 = L$, $A \le A^0$ and $\alpha \le \alpha^0$. From (3), we have $p_1 = \frac{A^0 + Cp_2 + B\eta}{2B}$, and

$$\widehat{p}_2 = \frac{[2B\alpha^0 + A^0\gamma + B\gamma\eta + 2B\beta\eta]}{[4B\beta - C\gamma]}.$$

The equilibrium is denoted as E^0. The lines R_1^0 and R_2^0 are the reaction functions (3) and (4), respectively.

To see the difference between p_2^* and $\widehat{p}_2$, we first check that $\partial p_2^*/\partial z < 0$, $\partial p_2^*/\partial x > 0$, and $\partial p_2^*/\partial y > 0$. With $A < A^0$ and $\alpha < \alpha^0$, $(p_2^* - \widehat{p}_2)$ will depend on the relative impacts of x, y and z.

To investigate the impacts on markets 1 and 2, we can rewrite equations (1) and (2) as follows:

$$A + B\eta - 2Bp_1 + Cp_2 = 0, \quad (1')$$

$$\left(\alpha + \frac{x\pi}{2z} + \beta\eta\right) - \left(2\beta - \frac{\pi y}{2z}\right)p_2 + \gamma p_1 = 0, \quad (2')$$

where p_3 is replaced by $\frac{x+yp_2}{2z}$. Then, in Fig. 2 the black lines describe equations (3) and (4) and the blue lines represent equation (1') and (2'). Since $A < A^0$ and $\alpha < \alpha^0$, equation (1') is at the left of equation (3). But whether $\alpha + \frac{x\pi}{2z} \gtrless \alpha^0$ will depend on the size of x (the size of sharing business). Next, the slope of equation (2') is higher than that of (3), as $2\beta - \frac{\pi y}{2z} < 2\beta$. Remind that $A + \alpha + x = L$, and hence $A + \alpha + \frac{x\pi}{2z} < L$. If x is sufficiently high (implying A and $\alpha + \frac{x\pi}{2z}$ are sufficiently low), then equation (1') and (2') will shift sufficiently to the left of equations (3) and (4). Therefore, the equilibrium prices (point E) will be smaller than the prices without the sharing business (point E^0.).

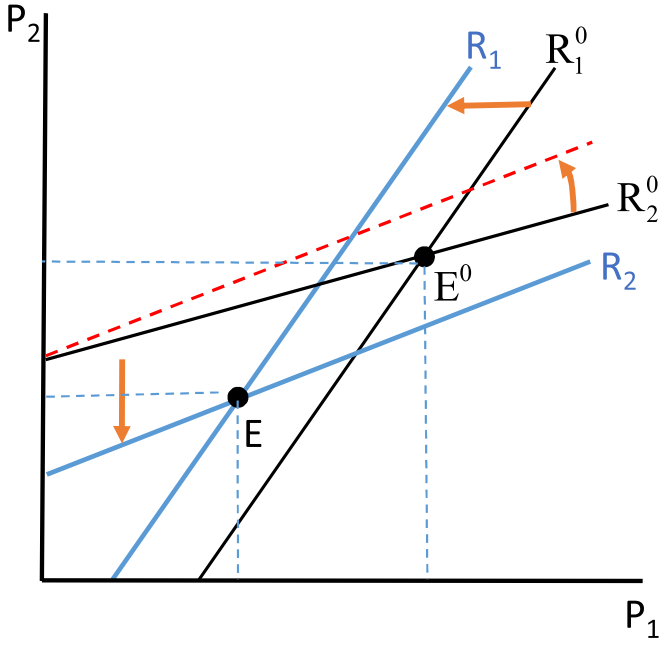

Fig. 2. Equilibrium change in P_1–P_2 diagram.

Corollary 5. *With the sharing business, the degree of competition will increase in the rental market.*

By comparing equations (3) and (4) with equation (1') and (2'), we know that the slope of equation (2') is higher than that of (4) in the $p_1 - p_2$ diagram. The slope of equation (1') is unchanged. Since the degree of competition increases with the slope, we have this conclusion.

Corollary 6. *If the rental market becomes too small, then all the equilibrium prices and profits will decrease*

When the demand for the rental market (α) becomes sufficiently small, then all three equilibrium prices will decrease. Given the total demand of L, the overall profit will decrease. Next, Proposition 7 explains how the existence of sharing business will affect the consumers in markets 1 and 2.

Proposition 7. *The sharing business will increase the buyers' utilities.*

Proof. From the assumption, those who buy the product have the utility: $\mu_1 - \lambda\sigma_1^2$. Since σ_1^2 is not related to prices and μ_1 is lower as p_1 will decrease, the utility for buying the product will increase. ■

For consumers in the rental and sharing business, we cannot make any unambiguous anticipation considering the complex combination of lower prices and lower market demand. Jiang and Tian (2016) showed that customers' benefits (from the existence of sharing economy) depend on the marginal cost, meaning that it could possibly be worse-off. However, Benjaafar et al. (2018) showed that customers always benefit.

Proposition 8. *When θ decreases, both p_1^* and p_2^* will decrease, but p_3^* will increase.*

Proof. The quality instability rate θ can be decreased if there are some screening mechanisms in the sharing market. According to Lemma 2, product 3's demand (x) decreases with θ. So when θ decreases, product 3's demand will increase. Since $\partial p_3^*/\partial x > 0$, a direct impact of this demand increase is to increase p_3^*. Indirectly, since $\partial p_2^*/\partial x > 0$, ceteris paribus, we would expect that p_2^* will also increase. However, since $A + \alpha + x = L$, when x increases, both A and α will decrease. So, the final impact on p_2^* will depend on the relative sizes of B, γ, π and z. Suppose the decrease of demand goes totally to α. Then the indirect impact on p_2^* will depend on whether $z2B > B\pi$, which is true if we assume that the cross price effects are lower than the own price effects. Thus, both p_1^* and p_2^* will decrease, but p_3^* will increase. ■

4. Impacts on production

Here we consider the impacts of the sharing business on the production side and provide several strategies for the producer. To simplify, we consider a monopolist and a simple production function as a function of labor (l):

$$O(l) = l^{\tau},$$

where $0 < \tau < 1$ measures the output elasticity of labor. With this function, we can examine the impacts on labor employment. We can easily extend this setup by adding other production factors such as capital.

To simplify the analysis, we assume that in each period, there is a replacement rate $0 < R < 1$ that a subgroup of consumers of size L from the population (S), who have owned a durable product from the previous period, will think about whether to buy new products, to rent from rental firms, or to go for the sharing business. The replacement rate can be affected by the launch of new-generation products or by the provision of post-sale services. We assume that if these consumers do not buy or

rent new products. the used products are no longer useable for them. Examples of this kind include laptops using old operating systems or mobile phones connected with 2G cellular networks.

When there is "no" sharing business, the overall market demand for new products is hence RL. The stock for used products is $(1-R)(S-L) + RL$. However, when there is sharing business, the demand for new products is only $RL(1-\lambda_2^*)$. According to Fig. 1, the demand for the sharing business is λ_2^*, so there will be only $(1-\lambda_2^*)$ are provided by rental firms and retailers which have demands for new cars. In this case, the stock for the used products reduces to $(1-R)(S-L)+RL(1-\lambda_2^*)$. Moreover, the labor employment also decreases from $\sqrt[r]{RL}$ to $\sqrt[r]{RL(1-\lambda_2^*)}$. Proposition 9 summarizes the results.

Proposition 9. *With the sharing business, both the demand for new products and the labor employment will decrease.*

Furthermore, the decrease of new products in the sales market will also affect the supply side of the sharing business. The stock of used products will reduce to $(1-R)(S-L)+RL(1-\lambda_2^*)$ and this decrease will affect the chance of bad products in the sharing platform and cause an increase in θ. According to Proposition 8, an increase in θ will increase p_1^* and p_2^*, but decrease p_3^*.

This result is contrary to some opinions (such as Bellos et al. (2017), Abhishek et al. (2019), Taylor (2018), Benjaafar and Hu (2019), Gong et al. (2017), Abhishek et al. (2016), Horton and Zeckhauser (2016)) that because of the value enhancement effect from the sharing business platform, ownership is more attractive and may induce more sales.

Corollary 10. *The decrease of new products in the sales market will increase p_1^* and p_2^*, but decrease p_3^*.*

According to Lemma 3, product 3's market demand decreases with p_3 and increases with p_2. These price effects will increase product 3's market demand, and trade-off the negative direct impact from increasing θ. Although the decrease of new products in the sales market will cause an increase in the chance of bad products in the sharing market, it will not cause the sharing market to shrink too seriously, as the price advantage (lower p_3) will attract some consumers back to this market.

Recall that the product price charged by the producer is η. So when there is no sharing business, the producer's profit is $\eta(RL) - c(\sqrt[r]{RL})$, where c is the unit labor cost. Now the producer's profit decreases to

$$\max_{\eta} \eta RL(1-\lambda_2^*) - c(\sqrt[r]{RL(1-\lambda_2^*)}). \tag{5}$$

According to Berger et al. (2018), the introduction of Uber had caused a reduction in the incomes of incumbent taxi drivers of almost 10%, and Uber, in particular, has had substantial negative impacts on workers' wages.

The equilibrium product price is determined by the FOC of maximization:

$$R(L-\lambda_2^*) - \eta R\frac{\partial\lambda_2^*}{\partial p_2^*}\frac{\partial p_2^*}{\partial \eta} + \frac{c}{r}[R(L-\lambda_2^*)]^{\frac{1-r}{r}} R\frac{\partial\lambda_2^*}{\partial p_2^*}\frac{\partial p_2^*}{\partial \eta} = 0. \tag{6}$$

Compare to the case where there is no sharing business and the FOC of maximization is only RL (not related to η). In this case, the product price will be set at the upper bound, say, $\overline{\eta}$. The interior solution for (6) will be lower than $\overline{\eta}$.

Proposition 11. *With the sharing business, the producer charges a lower product price.*

It is interesting to know whether it is profitable to cut the product price to attract more demand for new products. The answer, by the definition of maximization, is no, as the FOC in (6) has already considered the influence on boosting the demand for new products (i.e., $(L-\lambda_2^*)$).

5. Conclusion and managerial insights

"Sharing" is not new in human society, but new technologies have made it possible to match a large group of people for short term leases. The literature has noticed how the rapid growth of sharing economy can affect the existing rental markets. Our paper tries to examine the overall effects of the sharing business on the rental market, sales market, manufacturers and labor employment.

We assume that consumers are heterogeneous in their risk attitudes and renting from firms and from private owners are different in the quality instability of sharing business, and thus the two products are heterogeneous to consumers. Hence we analyze the competition of three products (i.e., sales, rental from firms and rental from private owners) in a differentiated product market. Our results show that the existence of sharing business will increase the degree of competition in the rental market. Both the selling and rental prices will decrease. The sharing business will increase the "buyers'" utilities, but there is no unambiguous conclusion for other types of consumers. When the quality insatiability of the sharing business decreases, both selling and rental prices will decrease, but the price of the sharing business will increase. Next, from the perspective of the producer, we show that with the sharing business, both the demand for new products and labor employment will decrease. However, this decrease of new product in the sales market will increase both the selling and rental prices but decrease the price of sharing business. Moreover, the producer will charge a lower product price with the presence of sharing business.

Our analysis can provide several management insights. First, as concluded in Proposition 7, the improvement of quality in sharing business can decrease both selling and rental prices and increase the sharing price. In the extreme case when θ approaches zero, renting from firms and sharing platforms become homogenous, and the competition between the two products will be more severe. We suggest that rental firms should try to increase the heterogeneity of products, which will lower the degree of competition. For example, car rental firms can provide more long-term or customized services such as cooperating with other companies. As to the sharing business, it is hard to coordinate the large number of private owners. Physically, the sharing platform can ask private owners to provide proofs for regular checks on products. For example, Uber drivers should regularly provide the criminal records and checks on car and drivers' physical and mental health. For both rental firms and sharing platforms, good feedback systems can help them understand customers' satisfaction or dissatisfaction, and improve quality.

Next, there are some approaches the producer can take to improve the profits. First, increasing the replacement rate R through providing innovations can increase the demand for new products and increase the producer's profit. For example, nowadays most new automobiles are equipped with safety devices (e.g., traction control system, rear cross-traffic alert, lane departure warning, automatic emergency braking, 360-degree camera) and connections to mobile or internet (e.g., connected mobile Apps, stolen vehicle tracking software or Apple CarPlay and android auto). Some of these devices are even required by laws. These new devices will stimulate consumers' demand for new cars and increase car dealers' and producers' profits.

Moreover, we suggest that innovations on portable "parts" to the used products can also increase the producer's profits. For example, the tire-pressure monitoring system can be added to used cars to increase driving safety. The impacts, however, are different from buying new products. Innovations that are provided only on the new product will increase the replacement rate (say, R'), so the increased demand will be $R'(L-\lambda_2^*)$. The innovative parts can be used on all of the stock of used products $((1-R)(S-L)+R(L-\lambda_2^*))$. The used product owners will be

less willing to buy new products if more newly invented products can be added to the used products to improve their quality.

Similarly, providing post-sale services[13] that can increase the life cycle of the products or sustainability production will also increase the producer's profits, but only on the stock of used products and this can have a contrary effect on reducing the replacement rate.

Finally, for the shortage in demand (i.e., $R\lambda_2^*$), the producer can also participate in the sharing business by providing B2C or B2B services. This point is also suggested by Li et al. (2020), who concluded that critical factors like the value perception and marginal cost would determine whether manufacturers like traditional car companies should cooperate with peer-to-peer platforms (sharing economy) or work with business-to-consumer platforms (rental platform) in the presence of the sharing economy. However, our model also suggests that this will cause more customers to choose the sharing business, and thus cause a further shortage in sales. This explains Abhishek et al.'s (2019) results that, if a P2P market is unavoidable, the manufacturer would not necessarily be better off by introducing its own rentals to compete against P2P.

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[13] Blaettchen et al. (2018) suggested that the new business model may affect the after-sales services for some special industries such as heavy equipment.