Is servitization more sustainable than selling?

The impacts of pay-per-use

on revenues and aggregate usage levels

preliminary version

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Abstract

Instead of selling the product, many manufacturing firms are considering renting the product for a per-use payment - the pay-per-use (PPU) business model. Compared to selling, PPU creates a “market-expansion” effect that increases the revenue of the firm via serving consumers who stay inactive if the product is sold for a fixed selling price. PPU might also allows the firm to capture more the surplus of high-end consumers since consumers self-select themselves into different types, hence creates a positive “surplus-extraction” effect on the revenue of the firm. However, under PPU consumers use the product less and are willing to pay less for using the product. Hence, the “surplus-extraction” effect might also be negative and reduce the revenue of the firm. Via these two effects, I discuss, using a simple stylize model, the properties of the consumer base with which the firm can earn more or less revenue with PPU compared selling. I also investigate the aggregate usage level yielded by the two business models and the conditions for PPU to be win-win: the firm earns higher profit while reducing the aggregate usage level of its products.

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1 Introduction

Servitization is a family of innovating business models that sell functionality of the product rather than the product itself. One member of this family is the pay-per-use business model (PPU). Under PPU, instead of selling the products to consumers for a fixed selling price, the manufacturer charges consumers a per-use fee for each time they use the product. The “document management” service of Xeros (Xeros, 2015), for example, does not sell or lease photocopy machines to consumers but instead provides the printing service with a fee for each page that consumers print. With this service, Xeros takes care of all the operating process and charges consumers a fee for each page that covers every cost during the printing process. In the lighting industry, Philips provides the “light-per-lux” business model that charges a fee for every unit of lumix (light) that consumers use while taking care of the whole lighting system (Philips, 2011). The most famous case study of servitization is Rolls Royce. The firm earns more than 50% of its revenue from services, particularly via the TotalCare service (Rolls Royce, 2017), where the firm leases jet engines to airline consumers and manages them throughout their life cycle and charge consumers a fee for every flying hour of the engines. PPU also emerged recently in the B2C context with the car-sharing firms. Cambio, Zipcar among many others allows consumers to rent the cars and pay only for the minutes or kilometers that they drive while the insurance, gasoline, parking and maintenance costs are taken care by the firm.

Using a simple stylized model, I characterize two impacts of PPU, relative to selling, on the revenue of the firm: (i) the “market-expansion” and (ii) the “surplus-extraction” effects. While (i) is always non-negative (ii) can be positive or negative, leading to ambiguous total effect on the revenue of the firm.

Under selling, if the firm cannot discriminate its consumers, it faces a trade-off when setting price: to set a high price and sell to high-usage consumers only or to set a low price and sell to all consumers. In the first case, the firm can earn a high margin from the high-usage consumers but it has to drop the consumers of low-usage and earns nothing from them. In the second case, the firm has a
larger market and earns revenues from everybody but, due to the low price, it leaves the high-usage consumers with a positive surplus.

Under PPU, consumers do not pay the fixed selling price to own the product but pay instead a variable cost associated with the use of the product. Therefore, no consumer stays inactive in the market. No matter how low their usage rate, they can use the product under PPU for the instances of time that they derive a high utility from the usage and pay for that use only. Therefore, unless the firm already covers the whole market (in which case the “market-expansion” effect is null), PPU allows the firm to have a larger market and earns more revenue from the consumers who are inactive under selling via the “market-expansion” effect.

Also due to the per-use fee, PPU allows consumers to self-select into different types based on their usage of the product. As consequences, PPU may allow the firm to extract more surplus from high-end consumers, who otherwise use the product more often, have higher surplus but also pay the same selling price than others under selling. However, since the consumers only use the product when they derive a utility level higher than the fee but the fee must reasonably be higher than the operating cost (otherwise the firm makes no margin for the transaction), consumers may use the product less and have lower willingness-to-pay for the usage of the product. If the reduction in the usage of consumers is high, it can offset the extra revenue that the firm earns by personalizing the payments of different types of consumers. The sign of the “surplus-extraction” effect is hence ambiguous.

Therefore, the firm can earn higher revenues under PPU only if the sum of the two effects is positive; that is, both of them are positive or the “market-expansion” effect is large enough to compensate for the loss caused by the negative “surplus-extraction” effect.

On the environmental impact of the business models, PPU can lower the aggregate level of usage via reducing the usage of the consumers who buy the products under selling. However, PPU also allows more consumers to use the product, which in turn, higher the the aggregate level of usage of the business.
Thus, the impacts of PPU, relative to selling, on the environmental impacts is also ambiguous depending on the magnitudes of the two effects mentioned above.

2 Pay-per-use as a business model

An increasing number of manufacturing firms in various industries have tried to shift from business models that simply produce and sell the products to consumers to innovative business models that sell an integration of product and service rather than the product alone. These business models are called product-service-systems (PSS).

Initially, the main motivation to develop these business models is to stay competitive in the industry since competition has made it harder for the manufacturers to compete simply by making and selling high-quality products at competitive prices (Visnjic et al., 2017). In most markets, the commoditization of products leaves limited room for product differentiation and requires more innovative approaches from manufacturing firms (Tukker, 2015). Manufacturing firms have to go downstream, closer to the consumers to sell services, integrated solutions, experiences and even a results-based contract to capture value throughout the value chain.

From the mid-1990s, PSS became a popular subject for researchers engaged with sustainability and business models (Tukker, 2015). Because the new business models focus on final users’ needs rather than the products, it is expected to reduce the environmental impacts of the business and trigger changes in the behaviors of the firms and individuals that can lead to more sustainable development. With the emergence of Circular Economy as a new concept for sustainability, PSS has been touted as disruptive business models that can cut growth and development from resources dependence and pollution (Lovins et al., 2014).

Some of these PSS are simple bundles of services sold along with the products. Typical examples are warranties and maintenance services for cars or
other durable goods such as household appliances and computers. In other PPS, manufacturers sell services derived from the use of the products, treating the products as an intermediate good rather than the final product. This latter type of PSS, a “service-centric” rather than a “product-centric” business model, is hence referred to as “servitization” (Vandermerwe and Rada, 1988).

While the concept of servitization can cover multiple business models from preventive maintenance, OEM parts enforcement to software re-licensing, in this paper, I investigate one specific type of “servitization”, the pay-per-use business model to focus on the impact of this specific pricing structure.

The pay-per-use pricing structure is one of the arguments in support of the superiority of servitization on profitability and environmental impacts compared to selling. Under this pricing strategy, consumers do not pay the fixed selling price to own the product but pay instead a variable cost associated with the use of the product. From the profitability perspective, pay-per-use allows the firm to enlarge the market to consumers who would not buy the product under selling without the need to lower the purchase price that reduces profit from consumers who, under selling, would purchase the product. This practice allows the firm to extract the maximum surplus from all consumers and earn a higher profit compared to selling. From the environmental perspective, this may incentivize consumers to reduce their usage, thus lowering the environmental impact due to product use. For many products, environmental impacts are reported to be mainly emitted during the use phase rather than the production and disposal phases\(^1\), meaning that a reduction of aggregate usage will contribute significantly to lower the environmental impacts of the products.

\(^1\)Among many Life Circle Assessment studies, Costagliola et al. (2015) analyze the environmental impacts of cars over the three phases of production, use and disposal, finding that the use phase is the most critical pattern for the emissions of almost all pollutants. Elijošiute and Varžinskas (2011) apply the analysis to the case of refrigerations and find that environmental impact is the most serious in the use phase, caused by emissions into the air of the system. In another study, Muthu (2015) studies the case of washing machines and derives that the use phase causes the maximum amount of impact across various life cycle phases of the machine. The author also concludes that the use phase is the most detrimental phase of all.
However, this superiority of servitization is not clear. Financially, we can find many cases where firms tried to adopt servitization but failed or are reluctant to because of the profitability of the new business model. Interface Inc., for example, tried to adopt servitization in its business of carpet with an environmental focus. The firm proposed to the University of Texas to rent the carpet for a per-use fee while incurring all the cost of maintenance and replacement during the terms of the contract. However, the Interface’s Evergreen Services Agreement faced significant obstacles that forced the firm to stop the implementation of the project for servitization (Olivia and Quinn, 2013). Another example of a failed servitization is Better Place. The startup received almost $1 billion in funding to establish a network electric cars and charging stations in Israel and Denmark. But the firm failed to grow and went bankrupt in 2013 (Noel and Sovacool, 2016). Since consumers use the product less when they pay for every use compared to the case that they own the product, their willingness to pay can be significantly lower under servitization. Also, the unique per-use fee cannot capture all the surplus of active consumers like under selling. Consequently, the firm faces a trade-off between additional profit from tailoring the payment to different consumers and this loss of surplus that it can extract compared to the case under selling. Environmentally, while the pay-per-use pricing can incentivize consumers to reduce their individual usage, it also allows the access to use the product to consumers who would not be able to support the ownership of the product under selling. This leads to a larger number of consumers adopting and using the product, thus increasing the aggregate usage and the consequent environmental impact.

3 The literature and contribution

Related to the topic of servitization, there exists the literature on leasing and selling of durable goods. Several papers in this literature study the profitability of leasing versus selling from different perspectives, such as the effect of product depreciation rate (Desai and Purohit, 1998), competition (Desai and Purohit,
In a recent study, Agrawal et al. (2012) compare leasing versus selling, questioning whether the former is more environmentally friendly than the latter. They find that leasing can be environmentally worse than selling because the firm can remove the product from the market earlier to avoid cannibalization problems. However, studies in the durable goods literature does not provide a suitable framework to study the impact of pay-per-use pricing scheme due to their specific focus on the demand of products rather than of usages.

There exists a strand of literature on the pricing of digital goods that tackles this pricing structure. Jiang et al. (2008) study the profitability of adopting pay-per-use for a digital good relative to a fixed-price one-time purchase business model. Assuming that consumers' level of usage and marginal utility from usage are uniformly distributed and that pay-per-use incurs an inconvenience cost over the consumer, the authors compare the two pricing structures, showing that the possibility of piracy favors pay-per-use over the fixed-price structure. Using the same framework, Gurnani and Karlapalem (2001) also use a similar framework to conclude that a hybrid business model, i.e. adding the pay-per-use pricing to the fixed-price business model is more profitable than adopting each single pricing structure. They show that pay-per-use is more profitable if the cost of in-house development is large and that fixed price is more profitable otherwise. In a more recent paper, Postmus et al. (2009) assume homogeneous marginal utility from usage to study the impact of consumers' in-house development on the choice of the pricing structure of the software vendor. Gilbert et al. (2014) use the same framework, assuming that both the usage level and the marginal utility from usage follow a uniform distribution, proving that selling and renting simultaneously the product is often the optimal strategy of the firm. Balasubramanian et al. (2015) also compare pay-per-use and selling when usage on pay-per-use basis invokes a psychological cost to consumers, showing that pay-per-use is more profitable if the psychological cost is low. This strand of
the literature, however, are concerned with neither the environmental impact of different strategies nor with the operating cost of products, which is the main characteristics that distinguish physical from digital products.

Related to the choice between fixed-price selling and pay-per-use pricing, there exist also the discussion on tariff-choice biases. Some empirical studies such as Kridel et al. (1993), DellaVigna and Malmendier (2006), Lambrecht and Skiera (2006), Krämer and Wiewiorra (2012) observe a “flat-rate bias” where, on average and over time, consumers prefer a flat rate over pay-per-use tariff while they could save money with the latter one. Few other studies, in contrast, observe a “pay-per-use bias”, i.e. preference for a pay-per-use tariff even though a flat rate would be cheaper (Kridel et al., 1993; Miravete, 2003; Dowling et al., 2018). The biases found in the studies above, hence, depends on the types of products, industries and context of the markets in research. In this paper, however, the firm does not provide different pricing structures for consumers to choose. Therefore, it is not concerned with the tariff-choice-bias problem.

On the literature focusing on servitization, there are many conceptual and case studies conducted by researchers in management. Although they are very useful in defining the values of servitization for the firm and for the environment, they relied on anecdotal evidence and discrete case studies to support their argument. There are, to the best of my knowledge, surprisingly few analytical studies on the topic. Agrawal and Bellos (2017) study the impact of resource pooling on the profitability, efficiency choice and the environmental impact of servitization. They also provide the investigation of pure servitization and the hybrid business model under which the firm provide selling and servitization at the same time. Orsdemir et al. (forthcoming) take the operating cost as exogenous and investigate the durability choice of a firm facing a two-segment market. Applying the concept of life-cycle assessment to describe the

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3 see Tukker (2015) and Mont and Tukker (2006) for the review of the literature  
4 see Yang and Evans (2019) for a discussion about the sustainable potential of different types of PSS
environmental impact of product, they find ambiguous impact of servitization on profitability and environmental benefit of the firm, the win-win equilibrium depends on the firm’s relative operating efficiency, the environmental impact of product in its use phase relative to the production and disposal phases and the similarity of consumer segments. However, as I will argue in this paper, the use of their specific setting on the demand side impose that PPU and selling yields the same revenue without other distortion on the utility of consumers and the cost for operation and/or production. The mechanism they propose, therefore, can be biased upward or downward and may not predict correctly the impact of PPU on the profitability of the firm.

The papers mentioned above also rely on the introduction of a psychological cost associated with PPU. However, it is not clear that consumers receive the "ticketing effect" in many context. Since renting a car reduces significantly the time that a driver need to pack the car and the concerns about maintaining the car as well as insurance coverage, renting a car may result in a higher level of conveniences that increases the utility associated with each use. In the context of B2B businesses, many uses are intermediate outputs used to make the final product, so whether or not the user feel comfortable with the per-use fee, the utility of that unit of output should remain intact - the input to make another product or service. Furthermore, in B2B context, direct users of the product are employees of the firms, who normally don’t really count the per-use fee as much as individual consumers like in the context of the car sharing, where the "ticketing effect" is detected. Hence, in this paper I keep a symmetric utility level under the two business models for the sake of analytical tractability. The introduction of asymmetric utility will only make the result biased in the expected direction: lower utility level makes PPU less profitable and vice versa.

Unlike these works that focus more on the production side of the product, this paper stresses on the characteristics of the demand side that affect the profitability and the resulting aggregate usage of servitization compared to selling. To do that, I propose a framework in which a monopolistic manufacturer faces consumers who experience distinct instances of needs for the good at random
utility level. On the demand side, there are two segments of consumers with different usage rates of the product. Each consumer will derive a random utility level each instance they need to use the product. The distribution of the utility per use is assumed to be symmetric and independent across consumers. The manufacturer then chooses between two business model: sell products to consumers with a unique purchase price or serve the consumers when they need the functionality of the product and charge them a fee for every usage. Every time the product is used, the consumer (under selling) or the firm (under servitization) incurs an operating cost that characterizes the nature of the product. The operating cost is assumed to be the same whether it is the consumer or the firm that pays the cost.

Using this setting, I investigate different segmentations of the consumer base and shed some lights on the characteristics of the market that can make servitization more or less profitable, as well as the resulting aggregate usage of the product relative to the conventional selling model. I characterize two impacts of PPU on the profits of the firm relative to selling: the “surplus-extraction” effect and the “market-expansion” effect. While the “market-expansion” effect is always non-negative, the sign of the “surplus-extraction” effect is ambiguous. Therefore, it is not necessary that the firm earns higher profits under PPU. Only if both effects are positive or the “market-expansion” effect is large enough to compensate the negative “surplus-extraction” effect that PPU is more profitable than selling.

I also compare the level of aggregate usage resulted in the two business models. The capacity of PPU to reduce aggregate usage depends on whether it leads to market expansion (hence, more people using the product) and whether it can reduce the usage level of consumers who are willing to buy the product under selling.
4 The model

Consider a manufacturer that offers a durable product either by selling it or by PPU, i.e. providing the function of the product on a per-use basis. Under selling, the firm charges a price \( p \) for each product sold. The consumer, after purchasing the product, has to pay an operating cost \( k \) every time she uses it. Under PPU, the firm does not charge any fixed payment but a fee \( f \) for every instance that the consumer uses the product while incurring the operating cost for every usage. To focus on the key trade-offs between PPU and selling on the revenues of the firm, I assume that the operating cost is identical\(^5\) and no cost of production, neither the pooling capacity\(^6\) under both business models.

On the demand side, consumers are identified by their usage rates \( \alpha \) - the proportion of time that a consumer needs to use the product. A usage rate \( \alpha = 0 \) characterizes consumer who does not need to use the product at all and \( \alpha = 1 \) characterizes the one that needs the product all the time. At a particular instance of need, a consumer derives a random utility level \( V \). The key assumption is that a consumer only learns about the utility level that she derives from each usage instance just before the moment that it is realized. By this assumption, under selling the consumer has to form an expectation of her utility over the usage of the product and decides \textit{ex-ante} whether to buy the product before any usage instance is realized. In contrast, under PPU she can decides whether she will rent the product \textit{ex-post}; that is, after learning about the utility that she can derive of that usage instance.

Normalizing the outside option to zero, \( V \) can represent the relative value of using the manufacturer’s product compared to outside options. A high level \( V \) indicates poor alternatives to the product investigated. In cities where public transports are in bad conditions, for example, it is likely that people will often find it relatively highly satisfied using cars. In contrast, in cities where public

\(^5\)See Orsdemir et al. (forthcoming) for the discussion on the effect of the asymmetric operation cost on the analysis.

\(^6\)See Agrawal and Bellos (2015) for the discussion on the impact of pooling on profitability of servitization.
transports are well organized, the relative level of satisfaction of taking a car compared to taking public transport will be lower. A low level of \( V \) can also represent that there are many substitutes for the product while the opposite indicates that consumers do not have a real choice other than the manufacturer’s product. Also, the relative level of satisfaction may be different to different people at the same instance of time. Even though public transport is poorly organized, one may sometimes find it more interesting to go by bus when the commuting is convenient while another person does not. In another situation, the preferences of the two people may be completely reversed. Since the level of satisfaction of each usage depends on many external factors such as the weather, traffic conditions, etc., a consumer cannot predict perfectly her utility level for each usage prior to the instance of time that she needs to use the car. Therefore, characterizing the utility level of usage \( V \) as a random variable allows describing in a relevant way different situations or different industries in the economy without standardizing the alternative to every consumer in the economy.

For the sake of tractability, I assume that there are two segments of size one of consumers in the market, depending on their usage profile: high-usage and low usage consumers, identified by their usage rate \( \alpha_i \in \{\alpha_L, \alpha_H\} \). At each moment that the consumer needs to use the product, she may derive, with probability \( \frac{1}{2} \), a high utility \( v_H \) or, with probability \( \frac{1}{2} \), a low utility \( v_L \).

The manufacturer knows how the usage rates across consumer and the utilities of each use are distributed \((\alpha_H, \alpha_L, v_H, v_L)\) but cannot directly observe the level of use of a consumer or the utility level that the consumer derives from each use. Because of this, the manufacturer cannot apply first-degree price discrimination under both selling and PPU. Hence, there is one unique selling price \( p \) under selling and one unique per-use fee \( f \) under PPU.

\footnote{The results do not change qualitatively if the two segments are of different sizes or the probabilities that the consumer derives a high utility and low utility from the usage instance are different. In Section ... I provide the analysis with this setting.}
4.1 The two business models

4.1.1 Selling

Under selling, consumers buy the product at price $p$ and incur the operating cost $k$ for every usage instance. The operating cost $k$ is assumed to be smaller than $v_H$; otherwise, consumers will never use the product. Since a consumer only uses the product when the utility derive of the usage instance is higher than the operating cost, a consumer of usage rate $\alpha_i$ ($i \in \{L, H\}$) has the expected utility from buying and using the product as:

$$U_p(\alpha_i) = \alpha_i E[(V - k)^+] - p.$$

The firm can choose to sell to the high-usage segment only, to the low-usage segment only or to both. However, selling to the low-usage segment only is always dominated by the other two strategies. Therefore, under selling, the firm faces a trade-off when setting the price: set a high price to sell to the high-usage consumers or a low price to sell to both types of consumer.

If the operating cost $k$ is higher than $v_L$, i.e., $v_H > k > v_L$, only with probability $\lambda$ that a consumer derives $v_H > k$ from the usage instance. Hence, her expected utility is $U_p(\alpha_i) = \alpha_i \frac{v_H - k}{2} - p$. If the firm only sells to the high-usage segment, it sets a high price $p^H = \alpha_H \frac{v_H - k}{2}$ and earns a profit of $\pi^h_p = \alpha_H \frac{v_H - k}{2}$. If the firm sells to both segments, it sets a lower price $p^b = \alpha_L \frac{v_H - k}{2}$ and earns a profit of $\pi^b_p = \alpha_L (v_H - k)$.

If the operating cost $k$ is lower than $v_L$, i.e., $v_H > v_L > k$, the consumer always uses the product whatever the utility level ($v_H$ or $v_L$) she derives from the usage instance. In this case, the expected utility a consumer derives from buying and using the product is $U_p(\alpha) = \alpha \frac{v_H + v_L}{2} - k$. Thus, if the firm only sells to the high-usage segment, it set a high price $p^H = \alpha_H \frac{v_H + v_L}{2} - k$ and earns a profit of $\pi^h_p = \alpha_H (\frac{v_H + v_L}{2} - k)$. If the firm sells to both segments, it set a low price $p^b = \alpha_L (\frac{v_H + v_L}{2} - k)$ and earns a profit of $\pi^b_p = 2\alpha_L (\frac{v_H + v_L}{2} - k)$.

**Lemma 1.** Under selling, it is optimal to sell to both segments if the low-usage consumers have a usage rate high enough, namely if $\frac{\alpha_L}{\alpha_H} > \frac{1}{2}$. Otherwise, selling
only to high-usage segment is more profitable for the firm.

Proof.

\[ \pi_b - \pi_h > 0 \iff \begin{cases} (2\alpha_L - \alpha_H)\left(\frac{v_H + v_L}{2} - k\right) > 0 & \text{if } v_H > v_L > k \\ (2\alpha_L - \alpha_H)\frac{v_H - k}{2} > 0 & \text{otherwise} \end{cases} \iff \frac{\alpha_L}{\alpha_H} > \frac{1}{2}. \]

When setting price under selling, the firm faces a classical trade-off: on the one hand, if it sets a high price to earn high revenue for each unit of product sold, it has to give up the consumers who are not willing to pay that high price and lose a proportion of the consumer base. On the other hand, if it sets a low price to sell the product to every consumer, it will earn less from each unit of product sold. Therefore, the firm has to choose either to give up some consumers to extract all the surplus of high-usage consumers or to leave the high-usage consumers a positive surplus to cover the market.

4.1.2 Pay-per-use

Under PPU, for each usage instance of a consumer, the firm incurs the operating cost \( k \) and charges she a fee \( f \) to earn the margin \( (f-k) \). Since consumers makes decision after learning about the utility they derive from the usage instance, a consumer only uses the product if the utility derived from the usage instance is higher than the price of using it, i.e., \( V > f \). Thus, total usage of a consumer of type \( \alpha_i \) is \( \frac{\alpha_H}{2} \) if \( f > v_L \) and \( \alpha \) if \( f < v_L \). Because the firm does not charge any fixed price to purchase the product, every consumer (of usage rate \( \alpha_H \) or \( \alpha_L \)) can use the product under PPU. The aggregate usage level under PPU is then

\[
\begin{align*}
AU_f^h &= \frac{\alpha_H + \alpha_L}{2} & \text{if } f > v_L \\
AU_f^b &= \alpha_H + \alpha_L & \text{otherwise.}
\end{align*}
\]

If the operating cost is high such that \( v_L < k < v_H \), since setting \( f < k \)
yields negative margin \( f - k \), the firm will set \( f \in [k, v_H] \). To maximize its profit, the firm sets \( f = v_H \) and earns a profit of \( \pi^h_f = AU^h_f(f - k) = (\alpha_H + \alpha_L)\frac{v_H - k}{2} \).

If the operating cost is low such that \( k < v_L \), the firm has two options: either he charges the low per-use fee, \( f < v_L \) to serve both high- and low-utility usage instances or set a higher fee \( v_L < f < v_H \) and serves high-utility usage instances only. To maximize its profit, the firm will set \( f \) as large as possible in the two cases, leading to the choice of \( f_L = v_L \) or \( f_H = v_H \) and earn a profit of \( \pi^h_f = AU^h_f(f - k) = (\alpha_H + \alpha_L)(v_L - k) \) or \( \pi^h_f = AU^h_f(f - k) = (\alpha_H + \alpha_L)\frac{v_H - k}{2} \) respectively.

**Lemma 2.** Under PPU, setting a low per-use fee to serve both high-utility and low-utility usage instances is optimal if the operating cost \( k \) is low enough, namely if \( k < 2v_L - v_H \equiv \tilde{k} \). Otherwise, setting a high per-use fee to serve only the high-utility usage instances is more profitable for the firm.

**Proof.**

\[
\pi^h_f - \pi^h_f > 0 \iff (\alpha_H + \alpha_L) \left( v_L - k - \frac{v_H - k}{2} \right) > 0
\]

\[\iff k < 2v_L - v_H \equiv \tilde{k} \]

Remark that \( \tilde{k} < 0 \) if \( v_L < \frac{v_H}{2} \); that is, if the low-utility usage instances yield too small value, they become insignificant to the firm. In this case, it is optimal for the firm under PPU to set high per-use fee and serve only the high-utility usage instances. But if \( v_L > \frac{v_H}{2} \), that is, the low-utility usage instances give a high enough value, they become significant to the firm. The firm then will choose to serve these usage instance also if it can earn a high-enough margin from them, that is, if the operating cost is low enough (\( k < \tilde{k} \)).

Under PPU, the firm also faces a similar trade-off as under selling. However, the trade-off in this case depends on the values of the utility level that consumers derive from the usage instances and particularly, on the operating cost of each usage instance. If the firm can earn enough revenue from the low-utility usage...
instances (the margin that the firm earn from serving the low-utility usages instances is high), it can give up part of the margin it can earn from high-utility usage instances to serve the consumers all the time and earn higher profit from the high level of aggregate usage. However, if the revenue from the low-utility usage instances is low, it is optimal for the firm to serve only the high-utility usage instances. In this case, it gives up the revenue from low-utility usage instances but earns more margin from the high-utility usage instances by setting a higher price.

5 Comparison

In the following section, I conduct a comparison of the revenues and aggregate usage level yielded under PPU and selling to shed some lights on the impacts of PPU relative to selling on the potential of PPU.

5.1 Revenue

Relative to selling, the impacts of PPU on the revenue of the firm can be separated into two effects: the “market-expansion effect” and the “surplus-extraction effect”. Concerning market expansion, if the firm already cover the whole market under selling, PPU also cover the whole market, the “market-expansion effect” is hence zero. But if the firm does not cover the whole market under selling, since PPU allows the firm to serve consumers who are not willing to pay the fixed purchasing cost under selling, it leads to an expansion of the market, from which the firm can extract the surplus from the high-utility uses of the consumers who stay inactive if the firm sells the product.

The “surplus-extraction effect”, on the other hand, is due to the capacity of PPU to have consumers self-select into different types and pay differently. Instead of earning a fixed price $p$ from each consumer like under selling, the firm can have consumers whose usage rate is higher than the marginal consumer under selling pay more than the purchase price $p$ since they use the product
more often. However, for these consumers, the pay-per-use pricing makes them use the product less than their usage frequencies under selling. Therefore, the “surplus-extraction effect” can be positive or negative. Hence, PPU is more profitable than selling only if the sum of the two effects are positive; that is, either both of them are positive or the gain from the “market-expansion effect” can compensate for the loss from the “surplus-extraction” effect.

Proposition 1. If the firm finds it optimal to cover only the high-usage segment under selling, PPU yields a positive “market-expansion” effect by serving the whole market. However, the “surplus-extraction” effect is non-positive depends on the operating cost $k$. As a consequence, PPU yields higher revenue than selling only if $k$ is large or small enough but yields less revenue if the $k$ has medium value.

If the high-usage level $\alpha_H$ is relatively large so that the firm only sells to high-usage segment under selling ($\frac{\alpha_L}{\alpha_H} < \frac{1}{2}$), it will set a high price $p^h$ to extract all the surplus of high-usage consumers while dropping the low-usage consumers. In contrast, PPU allows the firm to serve both types of consumer, creating a positive “market-expansion” effect. However, PPU may yield lower revenue if the reduction in consumption of high-usage consumers is large so that the negative “surplus-extraction” effect offsets the “market-expansion” effect. Depending on the value of the operating cost $k$, there are three scenarios: (1i) $k > v_L$, (1ii) $\tilde{k} < k < v_L$ and (1iii) $0 < k < \tilde{k}$.

(1i) $k > v_L$

In this case, since consumers do not use the product when they only derive $v_L$ from the usage instances, the firm sets the price $p^h = \alpha_H \frac{v_L - k}{2}$ under selling to sell only to high-usage consumer $\alpha_H$. Under PPU, it sets the high per-use fee $f^h = v_H$ and earns $\alpha_i \frac{v_L - k}{2}$ from each consumer of type $\alpha_i$ ($i \in \{\alpha_L, \alpha_H\}$) for the $\alpha_i \frac{1}{2}$ proportion of time that she needs the product and derives high level of utility $v_H$ from the usage instances. Since, the firm earns the same revenue $\alpha_H \frac{v_L - k}{2}$ under both business models from each consumer of usage rate $\alpha_H$,
the “surplus-extraction” effect is zero. However, since PPU allows the firm to serve also consumers of usage rate $\alpha_L$ (who are inactive under selling) and earns a net revenue of $\alpha_L \frac{v_H - k}{2}$ from each of them, the “market-expansion effect” is positive. The sum of the two effects is hence positive, resulting in a higher revenue form the firm under PPU. In this case, because the price under selling is set to extract the maximum surplus from high-usage consumers, the firm cannot do better under PPU. However, the usage level of these consumers do not reduce under PPU due to the high operating cost. So the firm can not earn more but can assure not to lose any revenue from the high-usage consumers and profit from the capacity of PPU to expand the market to the low-usage consumers.

$\text{(1ii)} \quad \tilde{k} < k < v_L$

Since $k$ is small enough for consumers to use the product all the time under selling, the firm earns $p^h = \alpha_H (\frac{v_H + v_L}{2} - k)$ from the high-usage consumers. In contrast, Under PPU the firm finds it optimal to set $f = v_H$ to serve only high-utility uses from both types of consumers and earns $\alpha_H \frac{v_H - k}{2}$ from each high-usage consumer and $\alpha_L \frac{v_H - k}{2}$ from each low usage consumer. Compared to selling, under PPU the firm earns less from each high-usage consumer ($\alpha_H \frac{v_H - k}{2} < p^h$) but earns an additional revenue of $\alpha_L \frac{v_H - k}{2}$ by expanding the market to low-usage consumers. So even though PPU yields a negative “surplus-extraction” effect, it can still make the firm better off if the gain from the “market-expansion” effect can compensate the loss from the “surplus-extraction” effect; that is,

$$\pi_f^h > \pi_p^h \iff \frac{\alpha_L v_H - k}{2} > \left( \frac{\alpha_H v_H - k}{2} - \alpha_H \left( \frac{v_H + v_L}{2} - k \right) \right)$$

$$\iff k > v_L - \frac{\alpha_L (v_H - v_L)}{\alpha_H - \alpha_L}.$$
(1iii) \( 0 < k < \bar{k} \)

Under selling, the firm sets the price \( p^h = \alpha_H \left( \frac{v_H + v_L}{2} - k \right) \) to serve the high-usage consumers \( \alpha_H \) while under PPU, it sets \( f = v_L \) to serve both high- and low-utility usage instances from both types of consumers. Under PPU, the firm then earns \( \alpha_H (v_L - k) \) from each high-usage consumer and \( \alpha_L (v_L - k) \) from each low usage consumer. The “market-expansion” effect therefore equals \( \alpha_L (v_L - k) > 0 \) while the “surplus-extraction” effect is \( \alpha_H (v_L - k) - \alpha_H \left( \frac{v_H + v_L}{2} - k \right) = \alpha_H \frac{v_L - v_H}{2} < 0 \). Thus, PPU yields higher revenue than selling if the “market-expansion” effect can offset the “surplus-extraction” effect; that is,

\[
\pi^h_f > \pi^h_p \iff \alpha_L (v_L - k) > \left| \alpha_H \frac{v_L - v_H}{2} \right| \\
\iff k < v_L - \frac{\alpha_H}{2\alpha_L} (v_H - v_L) \equiv k_1.
\]

In this case, since an increase in \( k \) of one unit reduces the “market-expansion” effect by \( \alpha_L \) while it has no effect on the “surplus-extraction” effect, the former effect can compensate the latter only if \( k \) is small enough. However, since \( \frac{\alpha_L}{\alpha_H} < \frac{1}{2} \), we can rearrange the expression of \( k_1 \) to obtain \( k_1 > \frac{5}{4} v_L - v_H > \bar{k} \). Therefore, PPU yields higher profit than selling for all \( k < \bar{k} \) if \( \frac{\alpha_L}{\alpha_H} < \frac{1}{2} \).

**Proposition 2.** If the firm finds it optimal to cover both segments under selling, PPU yields a null “market-expansion” effect. However, since the firm gives up a proportion of surplus of high-usage consumers by setting a low selling price, PPU can yield higher revenue if it results in a positive “surplus-extraction” effect by extracting this portion of surplus. As a consequence, PPU yields higher revenue if the operating cost \( k \) is higher than a certain threshold.

If the high-usage level \( \alpha_H \) is relatively small so that the firm sells to both segments \( \frac{\alpha_L}{\alpha_H} > \frac{1}{2} \), it sets the price \( p^h \) to extract all the surplus from low-usage consumers and leave a positive surplus for high-usage consumers. Since the firm already covers the whole market under selling, the “market-expansion” effect is null. Hence, to investigate the profitability of PPU, we can analyze the “surplus-extraction” effect alone. By the same analogy as above, depending on the value
of the operating cost $k$, there are three scenarios: (2i) $k > v_L$, (2ii) $\tilde{k} < k < v_L$ and (2iii) $0 < k < \tilde{k}$.

(2i) $k > v_L$

Under selling, the firm earns $p_b = \alpha_L \frac{v_H - k}{2}$ from each high-usage consumer while under PPU, with the per-use fee $f = v_H$ the firm earns $\alpha_H \frac{v_H - k}{2}$. From each low-usage consumer, the firm earns the same revenue $\frac{\alpha_H}{2}(v_H - k)$ under both business models. The “surplus-extraction” effect is hence $\frac{\alpha_H}{2}(v_H - k) - \frac{\alpha_L}{2}(v_H - k) > 0$. Therefore, PPU yields higher revenue than selling.

(2ii) $\tilde{k} < k < v_L$

Under selling, the firm sets the price $p_b = \alpha_L \frac{v_H + v_L}{2} - k$ while under PPU, it sets $f = v_H$ to serve only high-utility uses from both types of consumers. The “surplus-extraction” effect is then $\frac{\alpha_H}{2}(v_H - k) + \frac{\alpha_L}{2}(v_H - k) - 2p_b$. Therefore, PPU yields higher revenue if and only if the “surplus-extraction” effect is positive; that is

$$\pi_f^b > \pi_p^b \iff \frac{\alpha_H}{2}(v_H - k) + \frac{\alpha_L}{2}(v_H - k) - 2\alpha_L \frac{v_H + v_L}{2} - k > 0$$
$$\iff k > v_L - \frac{\alpha_H - \alpha_L}{3\alpha_L - \alpha_H}(v_H - v_L).$$

In this case, the firm under PPU earns a higher revenue by discriminating the two types of consumers and can have the high-usage consumers pays more than the price under selling. However, similar to case (1ii), since the firm only serves high-utility usage instances under PPU while consumers use the product even for low-utility usage instances under selling, the firm under PPU loses the proportion of surplus created by these usage instances. Therefore, if $k$ is large enough, the surplus created by low-utility usages instances is small, meaning that the loss from low-utility uses under PPU is small and can be compensated by the gain from discriminating consumers.
Under selling, the firm sets the price \( p^b = \alpha_L(\frac{v_H + v_L}{2} - k) \) while under PPU, it sets \( f = v_L \) to serve both high- and low-utility usage instances. From a low-usage consumer, the firm earns less revenue under PPU than under selling \( (\alpha_L(v_L - k) < p^b) \). But since consumers self-select under PPU, the firm may earn more revenue from the high-usage consumers. The “surplus-extraction” effect is then \( \frac{\alpha_H}{2}(v_L - k) + \frac{\alpha_L}{2}(v_L - k) - 2p^b \). PPU yields higher revenue if the “surplus-extraction” effect is positive; that is

\[
\pi^b_f > \pi^b_p \iff \alpha_H(v_L - k) + \alpha_L(v_L - k) - 2\alpha_L(\frac{v_H + v_L}{2} - k) > 0 \\
\iff k < v_L - \frac{\alpha_L}{\alpha_H - \alpha_L}(v_H - v_L) \equiv k_2.
\]

In this case, because the firm under PPU sets \( f = v_L \), it cannot extract all the surplus of consumer when they derive high utility level from uses while it can partially captures this surplus under selling. However, under PPU consumers self-select themselves into different types, which can allow the firm to capture more the surplus of high-usage consumers. Hence, the sign of the “surplus-extraction” effect depends the trade-off above. Noting that for each unit less of the operating cost \( k \), the firm earns \( \alpha_H - \alpha_L \) more from a high-usage consumer, PPU can yield more revenue than selling only if the operating cost is low enough \( (k < k_2) \) so that the gain from capturing more the surplus of high-usage consumers can compensate for the loss in capturing less the surplus of low-usage consumers.

The results of Proposition 1 and 2 is summarized in Figure 1. We can observe that, in case the “market-expansion” effect is null, it is more difficult for PPU to yield higher revenue than selling. In the other case, since the “market-expansion” effect is positive, it is sufficient to have the “surplus-extraction” effect not too negative.

Large operating cost represents sophisticated products that requires special competences to operate. This is the case of B2B business in which the product is the whole system of technology and machine that requires trained employee to
operate. In this case the firm face a big trade-off if is sells the product. Due to the large operating cost, consumers only use the product when they derive high satisfaction from the product. This feature reduce the utility that consumers receive and increase the gap between the willingness-to-pay between the 2 types of consumers. Therefore, if the firm covers the whole market, it has to set the selling price low enough, making selling less profitable. Meanwhile, the firm can serve both types of consumers under PPU without dealing with this trade off.

For products that are easier to use (hence, low operating cost relative to the utility derived from usage), consumers will use it all the time and hence, enjoy a large utility from buying and selling the product. In this case, the trade off that the firm faces under selling is not as critical as in the case above, selling to both high- and low- usage consumer do not require the firm to reduce much the selling price. In this case, the trade-off when setting price turn to the PPU business model. It has to choose either to serve only high-utility instance of use with a high per use fee or to serve both with a low per-use fee. This is pretty much the case of washing machine (PPU by Homie or Bundles), coffee machine (PPU by Bundles) and cars (renting by many firms). In this case, due to the trade-off in PPU, the firm that adopt PPU can reduce the usage level of consumers, which leads to a reduction in surplus of consumer that the firm can extract. Therefore, it is harder for PPU to yield higher revenue without expanding the market.

5.2 Aggregate usage

If the operating cost $k$ is higher than $v_L$, only high-utility uses are realized under both selling and PPU. The level of aggregate usage under selling is then $\frac{\alpha}{2}$ if the firm sells only to the high-usage segment and $\frac{\alpha - \alpha v_L}{2}$ if it sells to both segments. Compared to selling, PPU results in the level of aggregate usage $\frac{\alpha v_L}{2}$ since it always serves all the high-utility uses of both types of consumers. Because PPU does not reduce the usage of consumers who are also active under selling, if PPU leads to market expansion, it necessarily increase the level of aggregate
Figure 1: Optimal business model

usage.

In case $2v_L - v_H < k < v_L$, because consumers who buy the product use it all the time under selling but the firm only serves the high-utility uses under PPU, it still yields a lower aggregate usage level even in case it leads to market expansion. The reason is that, in this case, high usage rate $\alpha_H$ is large enough for the firm to sell to only high-usage segmentation. Under selling, high-usage consumers use the product all the time since the operating cost $k$ is smaller than the low utility per use $v_L$. The aggregate usage level is then $\alpha_H$. Under PPU, both types of consumers are served. However, since the firm sets $f = v_H$, only high-utility uses are served, leading to the aggregate usage level $\frac{\alpha_H - \alpha_L}{2}$. Because $\alpha_H > \alpha_L$, the level of aggregate usage is lower under PPU than under selling.

If $k < 2v_L - v_H$, under both selling and PPU consumers are served all the time - for both high- and low-utility uses. Hence, similar to the case that $k > v_L$, PPU does not reduce the usage level of consumers who buy the product under
Figure 2: Levels of aggregate usage of the two business models

selling. Therefore, whenever PPU leads to market expansion, it also results in a higher level of aggregate usage. Otherwise, both business model results in the same level of aggregate usage.

The comparison of aggregate usage levels resulted in the two business models are represented in Figure 2.

5.3 PPU as win-win business model

In this section, I investigate the conditions for PPU to be a win-win business model; that is, for it to yield both higher revenue for the firm and lower aggregate usage level of the products. Putting together the comparison of revenue and the resulted levels of aggregate usage in Figure 3, we can observe that we do not necessarily obtain a win-win situation with PPU. When PPU yields higher revenue than selling, it can result in higher, equal or lower level of aggregate usage, depending on the segmentation of the market under selling. We can have a win-win situation with PPU only if the operating cost is lower than $v_L$ but
higher than a certain threshold. In this case, the two business models yields the same aggregate usage whether or not PPU leads to market expansion. The second-best situation is that the firm earns higher profit with PPU while the resulted level of aggregate usage does not change. In the top-left and bottom-left corner of Figure 3, while PPU is more profitable for the firm, it can result in a higher level of aggregate usage. This is the case when PPU lead to market expansion while does not reduce the usage level of the high-usage consumers.

6 Discussion and concluding remarks

Even though there exists anecdotal evidences that PPU can be both more profitable and environmentally friendly than selling, many firms also failed to adopt PPU in a sustainable way. In this paper, I compare the pay-per-use (PPU) business model to the traditional selling on two aspects: revenue of the firm and the resulting aggregate usage as a proxy for the environmental impact caused
by the business. For this purpose, I build an analytical model to analyze the
two business models, selling and PPU, when the firm faces a consumer base
with different characteristics established by two dimensions: the usage rates of
consumers and the utility levels that they derive from the service provided by
using the product. I investigate the key assumption that consumers are uncer-
tain about the utility that they can derive from each usage instance when making
decision to buy the product under selling while they can learn about the util-
ity derived from a specific usage instances when deciding whether to rent the
product under PPU.

Under this assumption, the effect of PPU the revenue of the firm relative
to selling can be separated into two effects: the “market-expansion” and the
“surplus-extraction” effects. By charging consumers a per-use fee for every time
they use the product only, the firm can give access to the consumers who would
remain inactive under selling due to the fixed selling price. Unless the firm can
cover the whole market under selling by charging a low selling price, PPU can
always expand the market two the low-usage consumers and earn some revenue
from them. PPU, hence, creates a non-negative “market-expansion” effect that
can increase the revenue of the firm.

Also due to the pricing structure, under PPU consumers self-select them-

selves into different types and pay differently according to their types. In case
the firm has to charge a low selling price under selling, they do not extract all
the surplus of the high-usage consumers. In this situation, the firm can earn
more from PPU by extracting more the surplus of these consumers. However,
because the firm has to set the per-use fee higher than the operating cost and
consumers use the product only if they derive a utility higher than the cost
they pay (the per-use fee under PPU or the operating cost under selling), PPU
may reduce the usage of these consumers. As a consequence, these consumers
have a lower willingness-to-pay under PPU than under selling. Thus, the sign of
the “surplus-extraction” effect is ambiguous and the firm earns higher revenue
under PPU only if the “market-expansion” effect can compensate for the loss
from the “surplus-extraction” effect if the latter is negative.
The negative “surplus-extraction” effect is due to the decline in usage of consumers when they switch from purchasing the product to renting it by a per-use payment. Empirical studies such as Peter Muheim & Partner (1999) for example, estimates that people in Switzerland who previously owned cars but sold them when they switched to carsharing reduced their average vehicle miles traveled by 18%. Shaheen and Sperling (1998) report even a larger reduction, about 33 to 50% in Switzerland, 37% in the Netherlands and 58% in Germany. Even though the magnitude of the reduction vary greater among studies, it is likely that the switch from ownership to a renting pay-per-use system makes consumer mindful of the cumulative costs of driving, which make them “appear to have become more judicious and selective when deciding whether to drive, take public transit, walk, bike, or even forgo a trip” (Cervero et al., 2007).

If PPU leads to market expansion, since the “market-expansion” effect is positive, a not-to-small negative “surplus-extraction” effect is sufficient for PPU to yield higher profit. Therefore, it is easier for PPU to yield higher revenue if it can lead to market expansion. In case that the firm already covers the whole market under selling, PPU can yield higher revenue only if the operating cost is high enough so that only high-utility usage instances are realized and that consumers maintain the same usage levels under both business models. In this case, the firm earn higher revenue by having consumers self-selecting themselves and the high-usage consumers pay more than the selling price they would pay under selling. However, if the operating cost is low, the firm under PPU faces a trade-off when setting the per-use fee. If the per-use fee is low, the firm can not extract all the surplus from high-utility usage instances while the firm under selling partially does. In this case, PPU yields higher revenue than selling only if the operating cost is low enough so that the firm can earn more revenue from serving the low-utility usage instances of the high-usage consumers. Since the firm earns less revenue from the low-usage consumers, the more significant is this segment compared to the high-usage segment, the harder it is for PPU to dominate selling.

This results shed light on another channel for PPU to be more profitable than
selling beside its capacity to expand the market: the capacity to have consumers pay differently according to their usage rate and pay higher than the price under selling. This paper, hence, provides some enrichment for other existing papers. In Agrawal and Bellos (2015) and Orsdemir et al. (forthcoming), the concavity of utility function impose that, without other distortions in the operating and production costs, PPU and selling yield the same profitability since the "market-expansion" and the "surplus-extraction" effect cancel each other out perfectly. In their setting, under PPU the consumer with the highest valuation for the usage of the product pays exactly the price that she would pay under selling. A consequence, all other consumers pays less under PPU than under selling, the "surplus-extraction" effect is therefore negative. So it is only by the form of the utility function that the "market-expansion" effect can compensate perfectly this loss. Therefore, Orsdemir et al. (forthcoming) conclude that the advantage in operating the product (so that the operating cost is lower) is necessary for PPU to the more profitable while in Agrawal and Bellos (2015) the advantages of PPU is yielded by the pooling capacity of the product, which leads to lower production cost and hence, higher profit for the firm.

The setting used in Balasubramanian et al. (2015)and Postmus et al. (2009), for example, can be considered as special cases of this paper: when the utility derived from the usage instances is constant, consumers maintain the same usage level under both selling and PPU. Without the effect of a negative “surplus-extraction” effect, in their setting, PPU is more profitable than selling by design since both the "surplus-extraction" and the "market-expansion" effects are positive.

The model also helps to shed some lights on the properties of the market that can make PPU a win-win business model - business model that can makes the firm more profitable while reducing the level of aggregate usage. If the operating cost is high so that consumers only use the product if they derive a high utility level of usage under both business models, PPU is more profitable than selling but it can results in a higher level of aggregate usage if it leads to market expansion. If the operating cost is lower than a certain threshold,
PPU is more profitable if it leads to market expansion. In this case, it also results in a higher level of aggregate usage. Therefore, PPU can be a win-win business model; that is, it yields higher profits and lower aggregate usage only if the operating cost is between an range of value relative to the utility levels that consumers derives from usage. In this case, PPU reduces the usage level of consumers who are willing to buy the product under selling. So even though it leads to market expansion, since the new consumers still use the product less than existent consumers, PPU can still reduce the level of aggregate usage while increasing the profits of the firm.

Even though the setting is this paper is for monopoly, it can also provide some discussions of the profitability of PPU in case there is competition. Because the profitability of PPU depends on the “market-expansion” and the “surplus-extraction” effect, we can rely on how competition influences these two effects to predict how PPU will be in the context of competition. In case that profitability of PPU depends significantly on the 'market-expansion' effect, PPU will encounter problems to be profitable since the firm has to compete with other competitors. The “surplus-extraction” effect can also be lower under competition as consumers can perceive higher payment under PPU and switch to other supplier. However, we must also count the switching cost of changing to other suppliers, particularly in case of sophisticated system of products that requires high knowledge and competences to operate. In this case, the supplier can certainly extract the surplus from these consumers as long as the high payment is still lower than the switching cost. Therefore, we can expect that if PPU is more profitable thank to the “surplus-extraction” effect more than the “market-expansion” effect, the firm may be better off under competition compared to the other case - when the “market-expansion” effect drive the profitability of the business model. This is the reason why in Balasubramanian et al. (2015) PPU makes the firm better off if in monopoly setting but worse off in duopoly setting. In their setting of competition, since only low-usage consumers use the product via PPU, the surplus-extraction effect must be low or even negative. Furthermore, since the PPU firm encounters the competition from the selling
firm and it already reach market coverage, the market-expansion effect is also null. Therefore, summing up the two effects, PPU must be less profitable.

In brief, this paper proposes a framework that allows mapping the profitability and environmental benefits of PPU relative to selling in different characteristics of the market that the firm faces and the nature of its product, characterized by the operating cost to have the product function. The model can provide a guideline for manufacturers in the transition into the new business model and also for governments and institution to predict/judge the environmental impacts of PPU in different situations.
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