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Peer-to-Peer Sharing in the E-Commerce Market

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Abstract

This study focuses on the e-commerce market and analyzes the pricing behavior of a peer-to-peer platform that intermediates transactions between consumers (individuals). We consider two types of fee rates charged by a platform to consumers. Each consumer type is represented by two vectors, and consumers act depending on the values of these vectors. We investigate how the platform's profit, price of goods, and fee rate are affected by whether the platform charges the fee rate to sellers or buyers. The results indicate that, first, the platform's equilibrium profit is equivalent regardless of whether a fee rate is imposed on sellers or buyers. Second, consumer surplus and social welfare are also equivalent. Finally, the equilibrium price and equilibrium fee rate result in contrasting ones depending on whether sellers or buyers pay the fee. Specifically, when the cost of supply on the seller side increases, the fee rate falls in both cases; however, the price of goods increases more if a platform charges a fee rate to the buyers rather than the sellers.

Keywords: sharing economy, peer-to-peer, e-commerce, fee, platform

JEL Classifications: L81, L11, D21

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1 Introduction

Recently, widespread use of the Internet and smartphones has enabled collaborative consumption, or product sharing, among consumers on a large scale. Accordingly, business known as the "sharing economy" has grown rapidly. The sharing economy represents new economic vitalization activities that allow underutilized assets[1] owned by individuals to become available to others through Internet platforms.

Traditional business is centered on business-to-consumer transactions, in which companies sell products or services to consumers, and business-to-business transactions, in which companies provide products or services to other companies. By contrast, the sharing economy is based on peer-to-peer (P2P), in which consumers trade with each other. Thus, Internet companies do not provide products or services directly to consumers. Rather, they are platforms that provide a place to match people who have underutilized assets with people who would like to use those assets. The sharing economy is characterized by the fact that people can not only be users but also providers of services by utilizing their own assets.

Sharing economy services have been developed in diverse areas. Some examples include Airbnb, which provides private lodging services, and Uber, which provides ride-sharing services. This study focuses on e-commerce (EC), which allows people to buy and sell goods online. It involves platforms such as eBay (United States) and Mercari (Japan) that act as intermediaries in buying and selling the goods. In the EC market, individuals can assume the roles of both sellers and buyers. For example, someone who bought a camera on eBay or Mercari could sell an unwanted item of clothing on the same platform. We suggest that this captures the characteristics of the sharing economy.

This study aims to understand the pricing behavior of a P2P platform that intermediates transactions between consumers (individuals). Therefore, we consider two types of fee rates charged by an EC platform to individuals who provide their own good (hereafter called the "seller's case") and who purchase goods (hereafter called the "buyer's case"). Consumers can participate as buyers and sellers simultaneously. In this environment, we investigate how the

[1]These include intangible assets such as skills and time.

platform's profit, price of goods, and fee rate are affected by whether the platform charges the fee rate to sellers or buyers.

Each consumer type is represented by two types of vectors acting as a buyer and seller. The vector values vary from consumer to consumer. Depending on the value of the buyer's type, consumers decide how many goods to demand from the platform. Consumers initially own one unit of a good and may also choose to supply it to the platform. They decide whether or not to sell the good depending on the value of the seller's type. When consumers provide the good to a platform, they can increase their income; however, they can increase their utility if they do not provide the good. Each consumer decides how to allocate their total income, which consists of their original income and revenues from providing the good to the EC platform between two consumption goods: the goods traded on the EC platform (hereafter "EC goods") and a numéraire good, which we refer to as general consumption.

The model is represented as a two-stage game. In the first stage, the platform chooses the fee rate to impose on consumers based on profit maximization. In the second stage, the consumers choose whether to participate as buyers, sellers, or both. The price of EC goods is determined to clear the market, that is, to ensure that the supplied and the demanded EC goods are equal. This game is solved by backward induction.

We find that the platform's equilibrium profit is equivalent regardless of whether the fee rate is imposed on sellers or buyers. Similarly, consumer surplus and social welfare are equivalent in the cases of sellers and buyers. However, the equilibrium price and equilibrium fee rate result in contrasting ones depending on the seller's and buyer's cases. Specifically, we obtain an interesting result: When the seller's supply cost increases, the fee rate falls in both cases, but the price of EC goods increases more when a platform charges the fee rate to the buyers rather than the sellers.

1.1 Literature Review

This study is related to the literature on platforms. A well-known traditional platform model is Armstrong (2006). Other studies include, for instance, the analysis of credit card payments

(Chakravorti & Roson, 2006; Guthrie & Wright, 2007; Rochet & Tirole, 2003), media platforms such as newspapers and television(Anderson & Gabszewicz, 2006; Ferrando et al., 2008; Gabszewicz et al., 2001), and intermediary service providers such as dating agencies and real estate agents(Caillaud & Jullien, 2001, 2003). In these models, the sellers and buyers participating in the market are assumed to belong to completely different groups. However, as mentioned above, in the sharing economy, consumers can participate as both sellers and buyers; therefore, it is unlikely that sellers and buyers are entirely different. Previous platform studies have not dealt with analyses that incorporate elements of the "sharing economy."

This is a relatively new field of research, as economic analysis of a sharing economy has been conducted only recently. Among such studies, the P2P rental market for car-sharing and lodging-sharing has been well analyzed, but few models have addressed the P2P selling market. In the P2P rental market, individuals rent out their owned products in the sharing market when they are not using them. In other words, they trade within the product's capacity. In the P2P selling market, individuals provide all their unwanted goods to the sharing market (they do not use the goods themselves).

A study on the P2P selling market by Gazé & Vaubourg (2011) is similar to ours in terms of the ideas. They define electronic platforms (e.g., eBay) as two-sided markets where two agent groups can switch from one side of the market to the other. That is, an agent who participates as a seller (buyer) in the first period can switch to a buyer (seller) in the next period on the same platform. They investigate how mobility affects the equilibrium price and platforms' profit when side-switching is possible. The results demonstrate that platforms generate more profits through side-switching when the group with the highest mobility rate has the lowest externality parameters. However, there are two major issues with their study. First, it does not consider market equilibrium. It only considers the price that the platform charges agents ("fee rate" in our model) and does not mention anything about transactions between sellers and buyers. In contrast, we consider the transaction price of EC goods for sellers and buyers, which is determined through a market-clearing mechanism (i.e., the price at which supply is equal to demand). Second, in their model, agents' mobility rates are given exogenously.[2] This implies that the agents do not know whether they will stay in the first group or switch to the other. Although our study does not consider side-switching, the choice of whether consumers will be buyers or sellers is made simultaneously and endogenously.

Another study related to the P2P selling market is Feng et al. (2019). They examine how a firm should decide on the production and quality of its products when used goods are traded among consumers through a secondary market platform. In their model, consumers choose whether to buy products from the firm in the first period, and holders and non-holders trade used products in the secondary market in the second period. In contrast, our study considers an environment where all consumers already own the good. In addition, unlike our study, they do not consider much of what happens within the market.

Various studies have been conducted on P2P rental markets. The pioneering study on the sharing economy by Filippas et al. (2020) investigates market equilibrium in both the short-run case, where ownership decisions are fixed, and the long-run case, where ownership decisions can change.[3] In their model, only different types of consumers exist within the economy—owners and non-owners of a good—and no platform exists. In contrast, we examine an environment where both consumers and a platform exist in the EC market.

Other studies regarding the P2P rental market explore how the market entry of individual providers affects existing firms (Einav et al., 2016), how a product manufacturer or retailer should choose its retail price or product quality (Jiang & Tian, 2018; Weber, 2016), and how the presence or absence of P2P rentals affects ownership and usage (Benjaafar et al., 2019). These studies do not address the issue of how a platform chooses its fee rate and how this choice is likely to affect the product price because the fee rate collected by the platform is given exogenously.[4] In contrast, our study considers a market where the EC platform can affect the

[2] They conclude that endogenous mobility rates need to be considered.

[3] Zennyo (2023) is a recent study on the P2P rental market that uses this model. He analyzes the impact of the P2P rental market on a firm's product variety and design.

[4] Benjaafar et al. (2019) argue that a fee rate typically does not vary among markets where the platforms operate. Jiang & Tian (2018) similarly argue that, in practice, sharing platforms charge a fixed percentage fee for different products.

final price of EC goods by endogenously determining its fee rate.

Our study is based on the work of Gal-Or (2018). Her study also concerns the P2P rental market and investigates the nature of competition between a P2P platform (Airbnb) and a traditional lodging provider (hotel). Similar to our study, she considers an environment where individuals already have housing, and both the lodging platform and hotel affect the final lodging price. Her model characterizes two types of equilibria: partial coverage, which arises when the demand for lodging during a vacation is relatively low compared to supply, and full coverage, which arises when the demand for lodging during a vacation is relatively high compared to supply. In other words, in partial coverage, a segment of individuals choose to exit the lodging market completely; in full coverage, all individuals in the economy participate in some form of the lodging market. Our model is for the sharing of goods and differs significantly from her study, which is modeled on the sharing of housing space in private lodgings, in terms of both the real market and business structure. Therefore, we rework the economic model from the structure of supply and demand to match the observations of reality and do not merely extend or utilize her model.

This study focuses on the P2P selling market. Herein, individuals' motivation to share or trade their goods differs from that in the P2P renting market, where transactions are made within the product's capacity. In the model, individuals provide their own good to the sharing market based on the idea that "the good that is no longer needed by them may be useful and valuable to other individuals." Furthermore, our objective is to answer a (universal) question—"How do results vary depending on the subject on which a platform charges its fee rate?"—which has been surprisingly overlooked in existing studies.

The remainder of this paper is organized as follows: Section 2 presents our model. Section 3 analyzes the case in which the seller pays the fee, and Section 4 analyzes the case in which the buyer pays the fee. Section 5 presents the results of our model analysis. Section 6 discusses social welfare, and Section 7 concludes this paper.

2 Model

We consider an economy where individuals are continuous and represent the type of each individual using two vectors, (t_b, t_s). t_b and t_s represent the types when an individual participates in the EC market as a buyer and seller, respectively. This implies that the same individual has two types. The values of t_b and t_s differ for each of the individuals, but include the special cases in which $t_b = t_s$ happens to hold.

Assumption 1 *t_b and t_s are uniformly and independently distributed on [0, 1].*

t_b denotes the valuation level of EC goods when the individual participates in the market as a buyer. If t_b is large, the individual values the EC goods highly and therefore buys many EC goods. However, if t_b is small, the individual values the EC goods less and does not buy many EC goods; instead, the individual spends more money on other goods.

t_s denotes the valuation level of the good owned by an individual who participates in the market as a seller. Each individual initially owns one unit of a good, which is a composite good. For example, an individual owns a combination of different goods, such as books they finished reading, furniture they no longer need (but can still use), and T-shirts. The individual can decide whether to sell this composite good. For a large t_s, the individual believes that their good is valuable to themselves; thus, they consume all the good themselves instead of selling it. However, for a small t_s, the individual believes that their good is not valuable to themselves, so they sell all the good on an EC platform. That is, if the individual sells their good, it leads to income; if they do not sell the good, it leads to utility.

We express an individual's initial income as I per capita. If initial income I is considerably small, individuals who want to buy many goods on the EC platform cannot buy them; hence, we assume that it is sufficiently large to be an interior solution. When an individual provides their own good to the EC platform, the price of the EC goods is denoted by p. We assume a single platform in the economy. The platform collects fees from the seller or buyer as an intermediary fee. In this model, the fee rate to be collected from sellers is $d_s \geq 0$ and that to be collected from buyers is $d_b \geq 0$.[5] Therefore, in the seller's case, the individual receives the net price of $(1 - d_s)p$ per unit of the good provided on the EC platform. In the buyer's case, the individual pays the fee when purchasing goods on the EC platform; thus, the payment per unit of goods is $(1 + d_b)p$. We also assume that individuals cannot trade without participating in the platform.

Individual utility can be derived from three different sources. First, the individual derives utility from the purchase (consumption) of $x \geq 0$ units of EC goods, as follows:

$$u(x) = \begin{cases} \alpha x & \text{if } x \leq t_b, \\ \alpha t_b & \text{if } x > t_b, \end{cases}$$

where $\alpha \geq 0$ represents the utility from the consumption per unit of goods. Figure 1 illustrates this utility function. Considering concave utility, we use the utility function shown in this figure for simplification. As the individual wants to purchase EC goods up to t_b, their utility increases to that point; however, as the individual does not want to purchase EC goods more than t_b, their utility is constant at t_b.

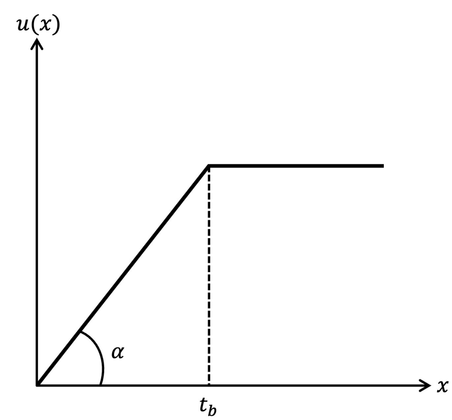


Figure 1: Individual's utility from e-commerce goods

Second, the individual derives utility from self-consumption if they consume their own good

[5]According to online sites, eBay deducts a fee of about 13–17% from sellers, whereas Mercari deducts a 10% fee of the sales price from sellers (neither collects a fee rate from buyers). See https://www.ebay.co.jp/start/business/business-fee/ (July 31, 2024) and https://help.jp.mercari.com/guide/articles/65/ (July 31, 2024). In this study, we examine the buyer's case as a benchmark to compare with the seller's case. By comparing these cases, we can see how the outcomes change depending on whether a platform collects its fee rate from sellers or buyers.

without selling it: $v(t_s) = kt_s$, where $k \geq 0$.[6] Finally, the individual derives utility from consuming all other goods. We use a numéraire good, the price of which is normalized to one. The general consumption[7] is $z \geq 0$, and the utility per unit is standardized to one.

Therefore, individuals' budget constraints can be written as follows:

$$\begin{cases} I + \{(1 - d_s)p - c\} = px + z & \text{if sell,} \\ I = px + z & \text{if not sell,} \end{cases}$$

in the seller's case, where individuals pay the fee d_s ($d_b = 0$), and

$$\begin{cases} I + p - c = \{(1 + d_b)px\} + z & \text{if sell,} \\ I = \{(1 + d_b)px\} + z & \text{if not sell,} \end{cases}$$

in the buyer's case, where individuals pay the fee d_b ($d_s = 0$). The total income of an individual who decides to provide the good they own on the platform can be expressed as $I + \{(1 - d_s)p - c\}$ in the seller's case and $I + p - c$ in the buyer's case. Here, $c \geq 0$ designates the unit cost (e.g., shipping cost) incurred by the individual to supply their good. However, if an individual decides not to provide the good to the platform, they will not earn additional income in either case. In addition, the individual must decide how to allocate their income between the consumption of EC goods and general consumption. When the individual purchases x units of EC goods from the platform, they pay px in the seller's case and $\{(1 + d_b)px\}$ in the buyer's case.

The total utility of an individual of type (t_b, t_s) depends on their decision-making on whether to provide the good to the sharing economy EC platform (acting as a seller) and whether to purchase EC goods (acting as a buyer). This can be formulated as follows:

$$U = u(x) + z,$$

when choosing to participate in the EC market as both a buyer and seller, and

$$U = u(x) + v(t_s) + z,$$

when choosing to participate in the EC market as only a buyer.

[6] If the individual sells one unit of their own good, the utility from self-consumption is zero.

[7] It refers to goods bought outside of the EC platform.

This model is presented as a two-stage game. In the first stage, the platform chooses its fee rate d_s or d_b based on profit maximization. In the second stage, individuals choose whether to participate as buyers (choose how many EC goods to purchase), sellers (choose whether to sell their good), or both buyers and sellers. The price of EC goods p is determined to clear the market, that is, to ensure that the supply and demand of EC goods are equal.

We now make the following assumption.

Assumption 2 $\alpha \geq \dfrac{k+2c}{2}$.

If α is too small, that is, the utility from EC goods is too small, it implies that the platform is not attractive and nobody will demand EC goods. Consequently, the market disappears. The above assumption is made to rule out such cases.[8]

Finally, Table 1 summarizes the parameters presented in this section.

Table 1: Parameters of the model

Parameters	Explanation
t_b	Type of an individual who participates as a buyer
t_s	Type of an individual who participates as a seller
I	Initial income of an individual
p	Price of e-commerce (EC) goods
d_s	Fee rate to be collected from a seller
d_b	Fee rate to be collected from a buyer
x	Quantity of EC goods purchased by an individual
α	Utility from EC goods
k	Degree of utility from self-consumption
z	Quantity of the numéraire good
c	Supply cost of an individual who acts as a seller

3 Equilibrium in the Seller's Case

We begin by analyzing the seller's case. Proceeding through backward induction, we successively solve the second and first stages.

[8]We further explain this assumption in Lemma 1 and Lemma 2.

3.1 Second-stage analysis

The demand for an individual $x_s^*(t_b)$ in equilibrium is as follows:

$$x_s^*(t_b) = \begin{cases} t_b & \text{if } p \leq \alpha, \\ 0 & \text{if } p > \alpha. \end{cases}$$

That is, the individual decides how much to demand by comparing the price p of EC goods with utility α the individual derives from them. As the individual wants EC goods up to t_b, their demand can increase to the point where x is equal to t_b when $p \leq \alpha$ (naturally, their utility also increases). Therefore, at equilibrium, $x_s^*(t_b) = t_b$. When $p > \alpha$, the individual does not purchase (even if they want the EC goods up to t_b); thus, $x_s^*(t_b) = 0$ in equilibrium.

We now divide our discussion into two cases: $p \leq \alpha$ and $p > \alpha$.

In the former case, the individual participates in the EC market because $x_s^*(t_b) = t_b$ holds. The total utility of an individual can be formulated as follows:

$$U(t_b, t_s) = u(x_s^*) + z = \alpha t_b + I + \{(1 - d_s)p - c\} - pt_b, \tag{1}$$

when participating in the EC market as both a buyer and seller, and

$$U(t_b, t_s) = u(x_s^*) + v(t_s) + z = \alpha t_b + kt_s + I - pt_b, \tag{2}$$

when participating in the EC market as only a buyer. Therefore, the equation determining the threshold individual $\bar{t}_s$ (i.e., the marginal supplier) who is indifferent between selling or not selling their owned good is

$$\bar{t}_s = \frac{(1 - d_s)p - c}{k}. \tag{3}$$

In segment $t_s > \bar{t}_s$ individuals choose to participate as only buyers. These individuals do not participate as sellers because their utility from consumption is higher than selling their own good. By contrast, individuals in segment $t_s \leq \bar{t}_s$ are both buyers and sellers. For these individuals, the utility is higher to sell than to consume their own good; thus, they also participate as sellers. Figure 2 illustrates the participation of individuals in the EC market.

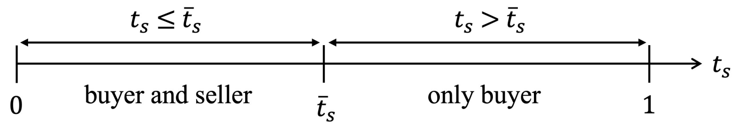


Figure 2: Participation of individuals in the e-commerce market

Individuals with $t_s \leq \bar{t}_s$ sell one unit of the good they own; hence, the total supply is $\bar{t}_s$. In addition, each individual purchases t_b units of EC goods, implying that the total demand is $\int_0^1 x_s^*(t_b)dt_b = \int_0^1 t_b dt_b = \frac{1}{2}$.[9] Hence, the price p_s of the EC goods that clear the market satisfies the following equation:

$$\bar{t}_s = \frac{1}{2}; \quad \text{thus,} \quad p_s = \frac{k + 2c}{2(1 - d_s)}. \tag{4}$$

In the latter case ($p > \alpha$), the individual participating as a buyer does not buy EC goods because $x_s^*(t_b) = 0$. Consequently, excess supply arises, and equilibrium is not established.

3.2 First-stage analysis

The platform chooses fee rate d_s to maximize the following profit:

$$\max_{d_s} \Pi_s = \begin{cases} \dfrac{(k + 2c)d_s}{4(1 - d_s)} & \text{if } p_s \leq \alpha, \\ 0 & \text{if } p_s > \alpha. \end{cases} \tag{5}$$

When $p_s \leq \alpha$, the platform earns positive profit because individuals participate and trade in the EC market. However, when $p_s > \alpha$, the platform's profit is zero because no one buys goods in the EC market.

Differentiating Equation (5) with respect to fee rate d_s shows that the platform's profit function is monotonically increasing in d_s. The more the platform raises its fee rate, the more profitable it will be; however, if the fee is too pricey, the sellers do not provide their good. Therefore, the platform determines its fee rate based on the constraint that $p_s \leq \alpha$. As the profit increases in d_s, the platform chooses the highest possible fee rate that satisfies this constraint.

[9] Based on Assumption 1, the total demand can be represented by an integral because individuals are uniformly distributed.

Lemma 1 *The fee rate in equilibrium is as follows:* [10]

$$d_s^* = 1 - \frac{k + 2c}{2\alpha}. \tag{6}$$

Proof. First, we prove that for p_s, there exists some $\bar{d}_s$ such that $p_s \leq \alpha \Leftrightarrow d_s \leq \bar{d}_s$ and $p_s > \alpha \Leftrightarrow d_s > \bar{d}_s$. We can obtain $\bar{d}_s$ by solving for $p_s = \alpha$; hence, $\bar{d}_s = 1 - \frac{k+2c}{2\alpha}$. From Equation (4), the price of EC goods increases monotonically in d_s. Thus, we can draw the graph in Figure 3. In this figure, it is trivial that $p_s \leq \alpha$ when d_s is less than or equal to $\bar{d}_s$ and $p_s > \alpha$ when d_s is greater than $\bar{d}_s$.

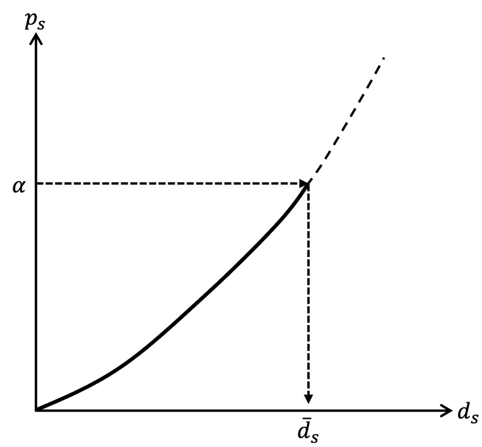


Figure 3: Price of e-commerce goods

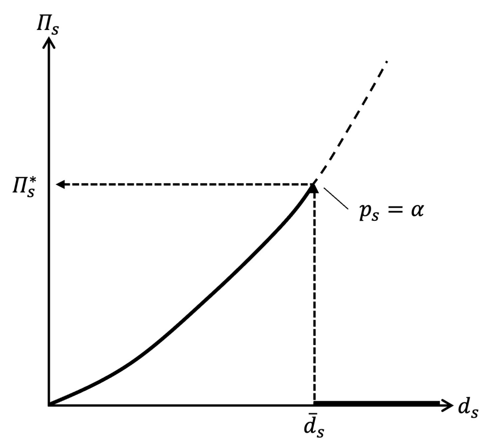


Figure 4: Platform's profit

Then, we prove that the relationship in Equation (5) holds. As mentioned previously, when $p_s \leq \alpha$, the platform's profit increases monotonically in d_s. Thus, we can draw the graph, as shown in Figure 4. Here, using each of the proofs above and based on the figure, we find that Π_s is positive when $p_s \leq \alpha \Leftrightarrow d_s \leq \bar{d}_s$, and Π_s is zero when $p_s > \alpha \Leftrightarrow d_s > \bar{d}_s$. Hence, $\bar{d}_s$ equals the equilibrium fee rate d_s^*. **Q.E.D.**

By substituting the equilibrium variable d_s^* into the threshold individual and price of the EC goods, we can obtain

$$\bar{t}_s^* = \frac{1}{2} \quad \text{and} \quad p_s^* = \alpha. \tag{7}$$

[10] d_s^* never exceeds one and is non-negative, i.e., $1 \geq d_s^* \geq 0$. From Equation (6), this is shown as $1 \geq \frac{k+2c}{2\alpha}$ from Assumption 2. In other words, α must be greater than $\frac{k+2c}{2}$ because d_s^* is not negative. If this condition is not satisfied, demand will be zero, even when $d_s^* = 0$.

The profit of the EC platform in equilibrium is

$$\Pi_s^* = \frac{2\alpha - (k + 2c)}{4}. \tag{8}$$

4 Equilibrium in the Buyer's Case

Next, we analyze the buyer's case. As the method of analysis is similar to the seller's case, we mainly describe the parts that differ between them.

4.1 Second-stage analysis

The demand for an individual $x_b^*(t_b)$ in equilibrium is as follows:

$$x_b^*(t_b) = \begin{cases} t_b & \text{if } p \leq \frac{\alpha}{1+d_b} \iff (1+d_b)p \leq \alpha, \\ 0 & \text{if } p > \frac{\alpha}{1+d_b} \iff (1+d_b)p > \alpha. \end{cases}$$

This case differs from the seller's case as $(1+d_b)p$ is the price of EC goods. As in the previous section, when $(1 + d_b)p \leq \alpha$, the individual demands up to $x = t_b$, and thus $x_b^*(t_b) = t_b$ in equilibrium. However, when $(1 + d_b)p > \alpha$, there is no demand, and thus $x_b^*(t_b) = 0$ in equilibrium.

We now divide our discussion into two cases: $(1 + d_b)p \leq \alpha$ and $(1 + d_b)p > \alpha$.

In the former case, the individual participates in the EC market because $x_b^*(t_b) = t_b$ holds. The total utility of an individual can be formulated as follows:

$$U(t_b, t_s) = u(x_b^*) + z = \alpha t_b + I + p - c - \{(1 + d_b)pt_b\}, \tag{9}$$

when participating in the EC market as both a buyer and seller, and

$$U(t_b, t_s) = u(x_b^*) + v(t_s) + z = \alpha t_b + kt_s + I - \{(1 + d_b)pt_b\}, \tag{10}$$

when participating in the EC market as only a buyer. Therefore, the threshold individual $\bar{t}_s$ is given by

$$\bar{t}_s = \frac{p - c}{k}, \tag{11}$$

and the part that differs from the seller's case is that fee rate d_b does not appear in $\bar{t}_s$.

The descriptions of the segments, supply, and demand are similar to those described in the previous section. Hence, the price p_b of EC goods that clear the market satisfies the following equation:

$$\bar{t}_s = \frac{1}{2}; \quad \text{thus,} \quad p_b = \frac{k+2c}{2}. \tag{12}$$

The point here is that p_b is independent of fee rate d_b, in contrast to the seller's case.

In the latter case ($(1+d_b)p > \alpha$), the individual does not buy EC goods because $x_b^*(t_b) = 0$.

4.2 First-stage analysis

The platform chooses fee rate d_b to maximize the following profit:

$$\max_{d_b} \Pi_b = \begin{cases} \dfrac{(k+2c)d_b}{4} & \text{if } p_b \leq \frac{\alpha}{1+d_b}, \\ 0 & \text{if } p_b > \frac{\alpha}{1+d_b}. \end{cases} \tag{13}$$

When $p_b \leq \frac{\alpha}{1+d_b}$, the platform earns a positive profit because individuals participate and trade in the EC market. However, when $p_b > \frac{\alpha}{1+d_b}$, the platform's profit is zero because no one buys the goods in the EC market.

Differentiating Equation (13) with respect to fee rate d_b shows that the platform's profit function is monotonically increasing in d_b. The more the platform raises its fee rate, the more profitable it will be. However, if the fee is too pricey, buyers do not purchase EC goods. Therefore, the platform determines its fee rate based on the constraint that $p_b \leq \frac{\alpha}{1+d_b}$. As the profit increases in d_b, the platform chooses the highest possible fee rate that satisfies this constraint.

Lemma 2 *The fee rate in equilibrium is as follows:* [11]

$$d_b^* = \frac{2\alpha}{k+2c} - 1. \tag{14}$$

Proof. First, we prove that for p_b, there exists some $\bar{d}_b$ such that $p_b \leq \frac{\alpha}{1+d_b} \Leftrightarrow d_b \leq \bar{d}_b$ and $p_b > \frac{\alpha}{1+d_b} \Leftrightarrow d_b > \bar{d}_b$. We can obtain $\bar{d}_b$ by solving for $p_b = \frac{\alpha}{1+d_b}$; hence, $\bar{d}_b = \frac{2\alpha}{k+2c} - 1$. The

[11] d_b^* is allowed to exceed one and is non-negative, i.e., $d_b^* \geq 0$. From Equation (14), this is shown as $\frac{2\alpha}{k+2c} \geq 1$ from Assumption 2. Similar to the seller's case, because d_b^* is not negative, α must be greater than $\frac{k+2c}{2}$ and if this condition is not satisfied, demand will be zero, even when $d_b^* = 0$.

effective price $(1 + d_b)p_b$ of EC goods monotonically increases in d_b, as shown in Figure 5. In the figure, it is trivial that $p_b \leq \frac{\alpha}{1+d_b}$ when d_b is less than or equal to $\bar{d}_b$ and $p_b > \frac{\alpha}{1+d_b}$ when d_b is greater than $\bar{d}_b$.

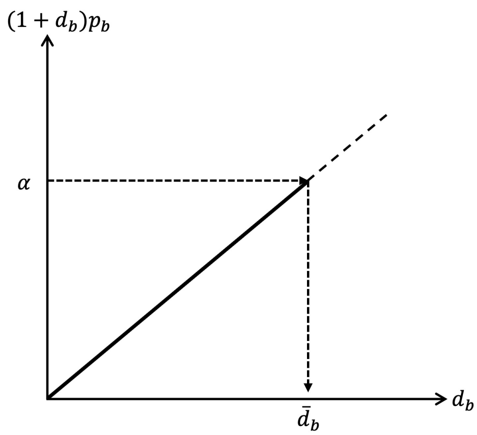


Figure 5: Price of e-commerce goods

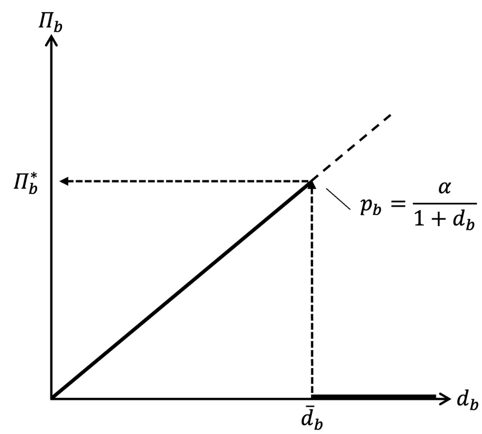


Figure 6: Platform's profit

Then, we prove that the relationship in Equation (13) holds. As mentioned previously, when $p_b \leq \frac{\alpha}{1+d_b}$, the platform's profit increases monotonically in d_b. Thus, we can draw the graph in Figure 6. Here, using each of the proofs above, the figure shows that Π_b is positive when $p_b \leq \frac{\alpha}{1+d_b} \Leftrightarrow d_b \leq \bar{d}_b$, and Π_b is zero when $p_b > \frac{\alpha}{1+d_b} \Leftrightarrow d_b > \bar{d}_b$. Hence, $\bar{d}_b$ equals the equilibrium fee rate d_b^*. **Q.E.D.**

As the threshold individual and price of the EC goods are constant, these equilibrium values are the same as those in Equation (12):

$$\bar{t}_s^* = \frac{1}{2} \quad \text{and} \quad p_b^* = \frac{k + 2c}{2}. \tag{15}$$

By substituting equilibrium variable d_b^* into Equation (13), we can obtain the profit of the EC platform in equilibrium as follows:

$$\Pi_b^* = \frac{2\alpha - (k + 2c)}{4}. \tag{16}$$

5 Results

Based on the previous two sections, we propose the following:

Proposition 1 *The platform's equilibrium profit is equivalent regardless of whether the fee rate is charged to the seller or buyer.*

Proof. By Equations (8) and (16). **Q.E.D.**

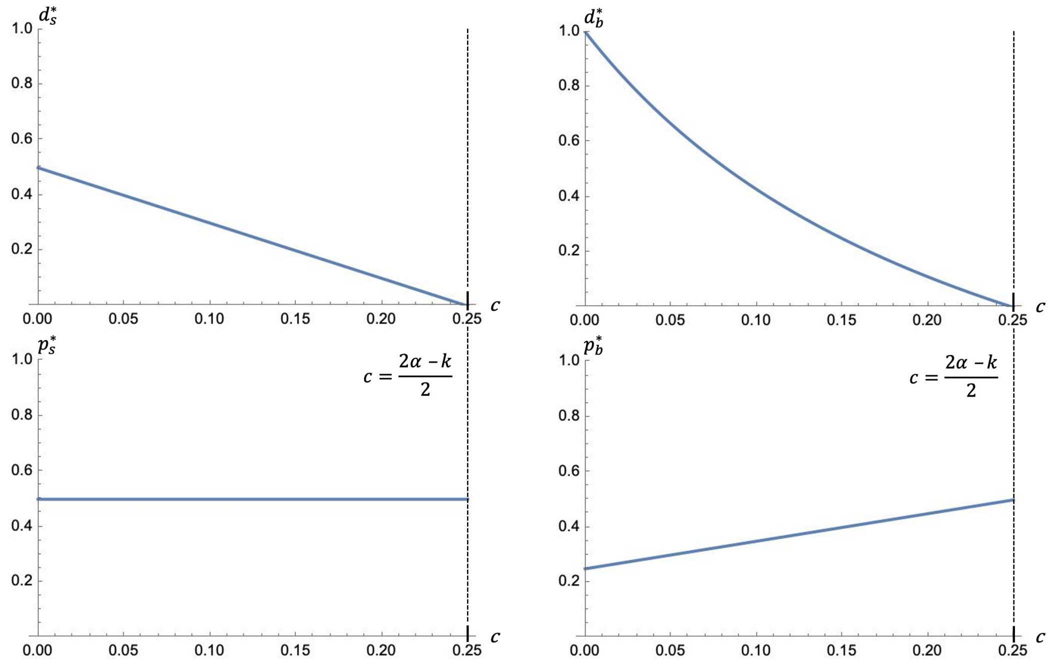
The reason for this equivalence is that the effective prices of EC goods, p_s^* in the seller's case and $(1 + d_b^*)p_b^*$ in the buyer's case, are the same at α.

Proposition 2 *In the seller's case, as c increases, d_s^* decreases, and p_s^* is constant. In the buyer's case, as c increases, d_b^* decreases, and p_b^* increases.*

Proof. By Equations (6) and (14) and Equations (7) and (15), respectively. **Q.E.D.**

Figure 7 illustrates the movement of fee rates and EC goods prices when c increases. If the seller's cost of supply c increases, sellers do not provide as much of their own good; then, the platform lowers its fee rate and allows sellers to provide it.

However, interestingly, the price of EC goods is constant in the seller's case and increases in the buyer's case, even though the seller's supply cost increases. In the seller's case, sellers reduce their supply if the cost of supply c increases. In response, the platform directly lowers its fee rate so that supply and demand are equal. Therefore, the price of EC goods is not affected. By contrast, in the buyer's case, sellers raise the price per the increase in supply cost c, but buyers do not buy EC goods if the price is higher. Therefore, the platform is forced to lower its fee rate. In other words, the fee rate is lowered by the indirect effect of increasing the prices of EC goods.



(a) The seller's case

(b) The buyer's case

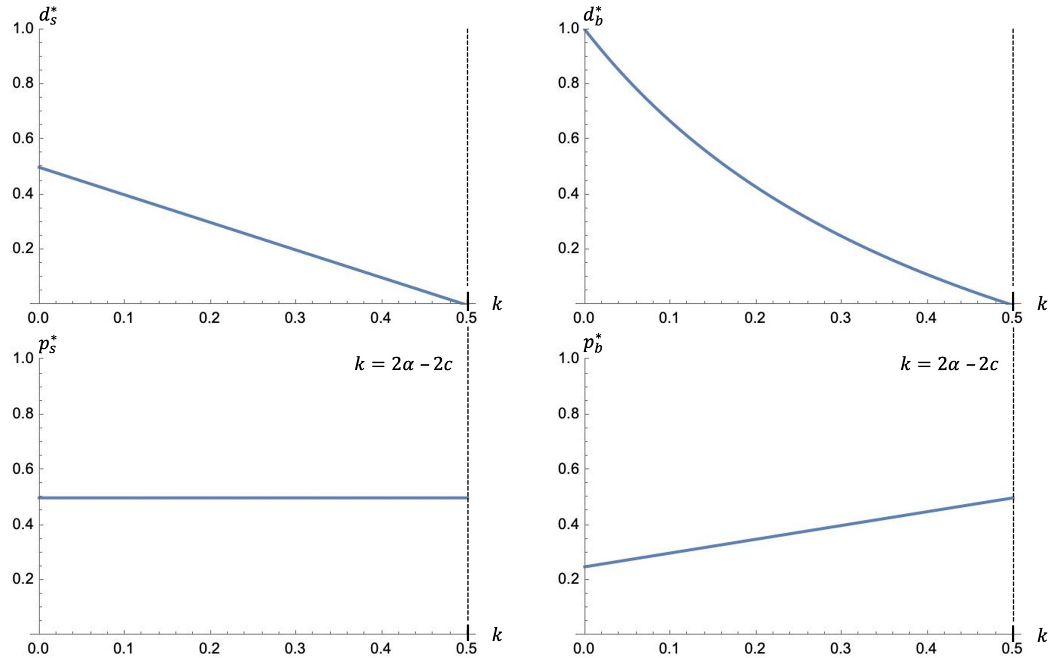
Figure 7: Movement of fee rates and e-commerce goods prices when c increases (by Assumption 2, $c \geq \frac{2\alpha-k}{2}$)

Other propositions include the following: We first examine utility k derived from individuals' consumption of their owned good.

Proposition 3 *In the seller's case, as k increases, d_s^* decreases, and p_s^* is constant. In the buyer's case, as k increases, d_b^* decreases, and p_b^* increases.*

Proof. By Equations (6) and (14) and Equations (7) and (15), respectively. **Q.E.D.**

Figure 8 illustrates the movement of fee rates and EC goods prices when k increases. In other words, k implies the opportunity cost of self-consumption; thus, this proposition is similar to Proposition 2, which represents the seller's opportunity cost. Therefore, a detailed explanation is omitted.



(a) The seller's case

(b) The buyer's case

Figure 8: Movement of fee rates and e-commerce goods prices when k increases (by Assumption 2, $k \geq 2\alpha - 2c$)

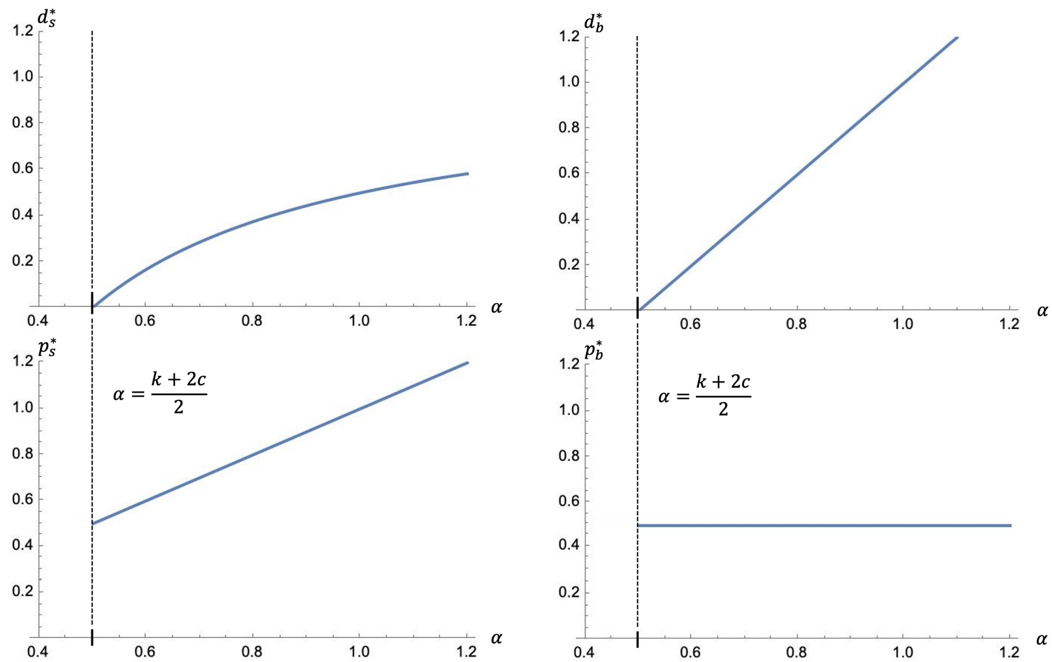
We then examine utility α derived from the individuals' consumption of EC goods.

Proposition 4 *In the seller's case, as α increases, d_s^* increases but never exceeds 1, and p_s^* increases. In the buyer's case, as α increases, d_b^* increases and can be greater than 1, and p_b^* is constant.*

Proof. By Equations (6) and (14) and Equations (7) and (15), respectively. **Q.E.D.**

Figure 9 illustrates the movement of fee rates and EC goods prices when α increases. If utility α derived from an EC platform (i.e., the attractiveness of the platform) increases, the platform raises its fee rate. However, the price of EC goods increases in the seller's case and remains constant in the buyer's case.

Buyers purchase more EC goods if utility α from a platform increases. In response, the platform raises its fee rate so that supply and demand are equal. In the seller's case, the price of EC goods increases because sellers pass on the increase in fee rate to the price. The profit for the platform is obtained from "price × fee rate × demand," and therefore, the increase in fee rate is superficially controlled. By contrast, in the buyer's case, the price of EC goods is constant because the increase in fee rate is not passed on to the price. The platform must raise its fee rate directly to earn the same profit as in the seller's case; thus, the increase in the fee rate is more drastic than in the seller's case.



(a) The seller's case

(b) The buyer's case

Figure 9: Movement of fee rates and e-commerce goods prices when α increases (by Assumption 2, $\alpha \geq \frac{k+2c}{2}$)

Propositions 2–4 confirm the movement of fee rates and EC goods prices when the respective parameters increase. We now turn to the level of fee rates and EC goods prices.

Proposition 5 *The equilibrium fee rate and equilibrium price of EC goods in the seller's and buyer's cases are compared as follows:*

(i) The platform's fee rate is higher in the buyer's case than in the seller's case (i.e., $d_b^* \geq d_s^*$).

(ii) The price of EC goods is higher in the seller's case than in the buyer's case (i.e., $p_s^* \geq p_b^*$).

Proof. First, we prove (i). To prove that $d_b^* \geq d_s^*$, we show that the difference between these equilibrium values is greater than or equal to zero. This can be expressed as follows:

$$d_b^* - d_s^* = \left(\frac{2\alpha}{k+2c} - 1\right) - \left(1 - \frac{k+2c}{2\alpha}\right) = \frac{k+2c}{2\alpha}\left(\frac{2\alpha}{k+2c} - 1\right)^2 \geq 0.$$

Clearly, $\frac{k+2c}{2\alpha} > 0$ and $\left(\frac{2\alpha}{k+2c} - 1\right)^2 \geq 0$. The above equation holds with equality if $\frac{2\alpha}{k+2c} = 1$; that is, $\alpha = \frac{k+2c}{2}$, which is the boundary case of Assumption 2. Hence, $d_b^* \geq d_s^*$.

Next, we prove (ii). We demonstrate that $p_s^* \geq p_b^*$ for all $c \in [0, \frac{2\alpha-k}{2}]$. When $c = \frac{2\alpha-k}{2}$, from Equations (7) and (15), $p_s^* = p_b^* = \alpha$. For $[0, \frac{2\alpha-k}{2}]$, p_s^* is constant by Equation (7), and p_b^* increases in c by Equation (15). Hence, $p_s^* \geq p_b^*$. **Q.E.D.**

The proposition indicates that in the seller's case, the price of EC goods is high and the fee rate is low; in the buyer's case, the price of EC goods is low and the fee rate is high. In the seller's case, sellers do not provide their good unless the price is sufficiently high to cover the fee charged. The platform sets its fee rate low to account for the higher price of EC goods. By contrast, in the buyer's case, buyers do not purchase EC goods unless the price is low because they have to pay a fee. The platform sets its fee rate high because of the lower price of EC goods.

6 Social Welfare

In this section, we discuss the platform surplus, consumer surplus, and social welfare in equilibrium.

First, we consider the seller's case. Platform surplus (PS_s) is expressed as follows:

$$PS_s = \frac{2\alpha - (k+2c)}{4}, \tag{17}$$

which is the same as Π_s^*. Consumer (individual) surplus[12] (CS_s) can be expressed as follows:

$$CS_s = \int_0^1 \alpha x_s^*(t_b) dt_b + \int_{\bar{t}_s}^1 k t_s dt_s + \int_0^{\bar{t}_s} z_s^*(t_b) dt_b + \int_{\bar{t}_s}^1 z_s^*(t_b) dt_b = I + \frac{5k}{8}, \tag{18}$$

where z_s^* denotes the equilibrium value of z_s. The first and second terms are the utilities of EC goods and self-consumption, respectively. Moreover, the third (buyers and sellers) and fourth

[12] Consumer surplus in this model is the sum of the buyer's surplus and *seller's surplus*. Note that consumer surplus differs from general consumer surplus, which we learn about in standard textbooks because it includes the seller's surplus. See the Appendix for a derivation of consumer surplus.

(only buyers) terms are the utility of general consumption. Social welfare is defined as the sum of consumer surplus and platform surplus. Therefore, social welfare (W_s) is

$$W_s = \frac{2\alpha - (k + 2c)}{4} + I + \frac{5k}{8}. \tag{19}$$

Second, we consider the buyer's case. Platform surplus (PS_b) is expressed as follows:

$$PS_b = \frac{2\alpha - (k + 2c)}{4}, \tag{20}$$

which is the same as Π_b^*. Consumer (individual) surplus (CS_b) is expressed as follows:

$$CS_b = \int_0^1 \alpha x_b^*(t_b)dt_b + \int_{\bar{t}_s}^1 kt_s dt_s + \int_0^{\bar{t}_s} z_b^*(t_b)dt_b + \int_{\bar{t}_s}^1 z_b^*(t_b)dt_b = I + \frac{5k}{8}, \tag{21}$$

where z_b^* denotes the equilibrium value of z_b. Therefore, social welfare (W_b) is

$$W_b = \frac{2\alpha - (k + 2c)}{4} + I + \frac{5k}{8}. \tag{22}$$

Finally, we propose the following:

Proposition 6 *Consumer surplus and social welfare are equivalent regardless of whether the fee rate is charged to the seller or buyer.*

Proof. By Equations (18) and (21) and Equations (19) and (22), respectively. **Q.E.D.**

7 Conclusion

This study investigates the pricing behavior of a P2P platform that intermediates transactions between consumers (individuals). To explain this environment, we focus on the EC market, which captures the characteristics of the sharing economy.

The results allow us to understand how the platform's profit, price of EC goods, and fee rate are affected by whether a P2P platform charges a fee rate to sellers or buyers. We find that the platform's equilibrium profit is equivalent regardless of whether the fee rate is imposed on sellers or buyers. The reason for this equivalence is that the effective prices of EC goods are the same in the seller's and buyer's cases. Similarly, consumer surplus and social welfare

are equivalent in both cases. However, the equilibrium price and equilibrium fee rate result in contrasting ones depending on the seller's and buyer's cases. Specifically, we obtain an interesting result: When the seller's supply cost increases, the fee rate falls in both cases, but the price of EC goods increases more when a platform charges the fee rate to the buyers rather than the sellers. This is because the price movements behind the decrease in fee rates differ in both cases, as confirmed in Section 5.

Moreover, the equilibrium fee rate is higher in the buyer's case, and the equilibrium price is higher in the seller's case. For example, in the seller's case, the platform can attract more participants by setting a lower fee rate, which it collects from the participants. However, it faces a tradeoff as the transaction price of goods tends to be higher. Given that eBay and Mercari chose the seller's case, it is suggested that these EC platforms prioritize increased participation.

We conclude by discussing how this research can be developed in the future. First, our model deals only with full coverage. That is, the total demand is fixed. However, it is unlikely that all will participate as buyers, given that some individuals may not purchase the goods provided on the EC platform. Therefore, it is necessary to investigate cases in which demand changes elastically. Second, the analysis does not consider the network effects of the platform. We believe that (positive) network effects exist on P2P platforms, including EC platforms such as eBay and Mercari. This is because, on such platforms, the more participants on the other side, the higher the probability of a successful match, which is attractive to market participants on both sides. Thus, by considering the network effect, providing a clearer explanation of the impact of an increase in utility derived from the platform is possible.[13] Finally, for clarity, this study separately analyzes the cases in which the fee rate is imposed on sellers and buyers. However, it is also necessary to consider the case of imposing the fee rate on both sellers and buyers. Future research should pursue these proposed extensions.

[13] We tried introducing the network effect but did not observe significant changes in the model.

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Appendix: Consumer Surplus

Here, we describe only the derivation of consumer surplus for the seller's case.

Consumer surplus can be expressed using the following equation:

$$CS_s = \int_0^1 \alpha x_s^*(t_b)dt_b + \int_{\bar{t}_s}^1 kt_s dt_s + \int_0^{\bar{t}_s} z_s^*(t_b)dt_b + \int_{\bar{t}_s}^1 z_s^*(t_b)dt_b,$$

where $\bar{t}_s = \frac{1}{2}$, the utility derived from the EC goods in the first term is

$$\int_0^1 \alpha x_s^*(t_b)dt_b = \int_0^1 \alpha t_b dt_b = \frac{\alpha}{2}.$$

The utility derived from self-consumption in the second term is

$$\int_{\frac{1}{2}}^1 kt_s dt_s = \frac{3k}{8}.$$

The utility derived from a numéraire good in the third term (both buyers and sellers) is

$$\int_0^{\frac{1}{2}} z_s^*(t_b)dt_b = \int_0^{\frac{1}{2}} \left\{ I + \frac{k+2c}{2\alpha}\alpha - c - \alpha t_b \right\} dt_b = \frac{I}{2} + \frac{k}{4} - \frac{\alpha}{8}.$$

The utility derived from a numéraire good in the fourth term (only buyers) is

$$\int_{\frac{1}{2}}^1 z_s^*(t_b)dt_b = \int_{\frac{1}{2}}^1 \{I - \alpha t_b\} dt_b = \frac{4I}{8} - \frac{3\alpha}{8}.$$

The derivation of consumer surplus for the buyer's case is omitted because it is similar to the seller's case.