Chapter 94
The Comparison of Pricing Schemes for Cloud Services

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Abstract This paper investigates subscription pricing, pay-per-use pricing, and two-part tariff from perspectives of a provider's profit, consumer surplus, and social welfare, respectively. In particular, this paper extends previous studies on pricing schemes to two-part tariff in addition to subscription pricing and pay-per-use pricing. This paper shows that two-part tariff is more efficient than the other two pricing from a provider's, consumers' and social point of view.

Keywords Cloud computing · Service models · Pricing scheme · Two-part tariff · Subscription pricing · Pay-per-use pricing

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94.1 Introduction

Cloud service can be regarded as services in utility computing, where computing services are delivered in a manner similar to traditional utilities such as water, electricity, gas, and telephony [1]. So, as in other utility services, pricing schemes from a provider's standpoint plays a pivotal role in market expansion [2, 3]. So far, studies on the managerial aspect of cloud computing is far from sufficient [4]. Thus, right pricing schemes for cloud services is a critical challenge because user demand, provider's profit, and social welfare vary with the service models and pricing schemes [2, 3].

This paper investigates subscription pricing, pay-per-use pricing, and two-part tariff from perspectives of a provider's profit, consumer surplus, and social welfare, respectively. In particular, this paper extends previous studies of Chun and Choi [4] and Song [5] and to two-part tariff price scheme. The result shows that two-part tariff is more efficient than the other two pricing models such as subscription and pay-per-use pricing from a provider's, consumers' and social point of view.

This paper is organized as follows: Sect. 94.2 discusses service models and price schemes in cloud computing. Section 94.3 investigates right pricing schemes for cloud services using a theoretical analysis and discusses implications. Section 94.4 presents conclusions.

94.2 Cloud Service Pricing

As more providers are starting to offer cloud services, how to determine the right price for users is now becoming increasingly critical for cloud providers. This is because pricing is able to regulate the supply and demand of computing services and thus affects both providers (who supply the services) and users (who demand the services) respectively [2].

There are many different potential pricing policies available to cloud content providers. In subscription pricing, users pay on a recurring basis to access software as an online service [2]. The customer subscribes to use a preselected combination of service units for a fixed price and a longer time frame, usually monthly or yearly [6]. In pay-per-use pricing, users only have to pay for what they use. While pay-per-use pricing could achieve the social efficiency, it is not easily acceptable for users who want to control their budgets [3].

94.3 The Model

This paper investigates subscription pricing, pay-per-use pricing, and two-part tariff from perspectives of a provider's profit, consumer surplus, and social welfare, respectively.

Our study differentiates itself from the previous ones as follows: First, we analyze two-part tariff in addition to subscription pricing and pay-per-use pricing. Second, we consider the cost structure of a provider as Chun and Choi [5]s model. The marginal cost of providing cloud services might affect the choice of pricing schemes by a provider.

For simplicity, we assume that there is a monopoly provider of cloud service. The cost of providing the service has both fixed and variable cost elements and is expressed as $cq + f$, where c and f are the marginal cost and fixed, respectively, and q is the quantity of service consumption. We can assume that $f = 0$ without loss of generality.

The provider chooses the pricing scheme $T(q) = A + pq$, where A is the lump-sum price and p is the unit price. The pricing scheme is subscription pricing when $p = 0$ and $A > 0$, pay-per-use pricing when $p > 0$ and $A = 0$, and two-part tariff when $p > 0$ and $A > 0$. The provider profit can be expressed as

$$\pi = (AN + pQ) - cQ,$$

where N is the number of consumers purchasing service and Q is the total quantity of service consumption.

Let us turn to the demand side. We assume that Consumer u has the net utility or surplus $S_u(q) = V_u(q) - T(q)$ when she purchases q unit of service and 0 does not buy at all, where $V_u(q)$ is the total value and $T(q)$ is the payment. The parameter u represents the type of a consumer. We assume that u is uniformly distributed along [0, U] with unit height, i.e., u ∈ [0, U]. So, the total number of consumers is U.

For simplicity of analysis, we assume that $V_u(q)$ has the specific form

$$V_u(q) = \left\{u^2 - (u-q)^2\right\}/2.$$

where $V_u(0) = 0$, $V_u'(q) > 0$, and $V_u''(q) < 0$. By maximizing her utility, Consumer u shows a downward sloping linear demand.

$$\begin{aligned} &\max_q S_u = \max_q \left[\left\{u^2 - (u-q)^2\right\}/2 - (A + pq)\right], \text{ and} \\ &q(p) = u - p \end{aligned} \tag{94.1}$$

where u is interpreted as the maximum willingness to pay for the service. Note that the consumption of service occurs only when $u \geq p$.

By inserting (94.1) into the expression of $S_u(q)$, we have the surplus of Consumer u.

$$S_u(p, A) = (u - p)^2/2 - A \tag{94.2}$$

94.3.1 Subscription Pricing

Under subscription pricing, price does not depend on the amount of consumption, so $p = 0$ and $A > 0$. From (94.1) and (94.2), it follows that

$$q = u \quad \text{and} \quad S_u = u^2/2 - A.$$

A consumer purchases cloud service when her surplus is nonnegative.

$$u^2/2 - A \geq 0, \text{ or } \quad u \geq (2A)^{1/2}.$$

Since u is uniformly distributed along [0, U], the number of consumers who purchase service is

$$N = U - (2A)^{1/2}.$$

The total quantity of service can be obtained by summing up the quantity of service consumption across all the consumers.

$$Q = \int_{(2A)^{1/2}}^{U} u du = U^2/2 - A$$

and the profit of the provider is given as follows.

$$\begin{aligned} \pi &= AN - cQ \\ &= A\left\{U - (2A)^{1/2}\right\} - c(U^2/2 - A). \end{aligned}$$

From the first order condition ($d\pi/dA = 0$), we have the optimal subscription price as follows.

$$A^S = 2(U + c)^2/9. \tag{94.3}$$

Note that superscript S is used to denote 'subscription pricing'. The marginal consumer who is indifferent from buying and not buying is

$$u^S = (2A^S)^{1/2} = 2(U + c)/3.$$

Using (94.3), the number of consumers, the quantity of service use, the profit of the provider, and the consumer surplus at the equilibrium can be easily calculated.

$$N^S = (U - 2c)/3,$$
$$Q^S = (5U + 2c)(U - 2c)/18, \text{ and}$$
$$\pi^S = (4U + c)(U - 2c)^2/54.$$

The consumer surplus and the social welfare can be obtained accordingly.

$$CS^S = \int_{2(U+c)/3}^{U} S_u du = (7U + 4c)(U - 2c)^2/162,$$

and

$$\begin{aligned} SW^S &= CS^S + \pi^S \\ &= (19U + 7c)(U - 2c)^2/162. \end{aligned}$$

The equilibrium exists when the maximum willingness to pay is sufficiently larger than the marginal cost of providing service, or

$$U \geq 2c. \tag{94.4}$$

We assume that (94.4) holds throughout this paper.

94.3.2 Pay Per Use Pricing

Next, turn to pay per use pricing. Since $p > 0$ and $A = 0$, we have

$$q = u - p \quad \text{and} \quad S_u = (u - p)^2/2.$$

The purchase occurs when $q = u - p \geq 0$, or $u \geq p$. The number of consumers purchasing service, the total quantity of service consumption, and the profit of the provider can be calculated similarly to the case of subscription pricing.

$$N = U - p,$$
$$Q = \int_p^U (u - p)du = (U - p)^2/2, \text{ and}$$
$$\begin{aligned} \pi &= pQ - cQ \\ &= (p - c)\left\{(U - p)^2/2\right\}. \end{aligned}$$

The first order condition ($d\pi/dp = 0$) generates the optimal pay per use price.

$$p^P = (U + 2c)/3.$$

Superscript P is used to denote 'pay-per-use pricing'. The marginal consumer who is indifferent from buying and not buying is

$$u^P = p^P = (U + 2c)/3.$$

From this, the number of consumers purchasing service, the quantity of service consumption, the profit of the provider, the consumer surplus, and the social welfare at the equilibrium can be derived as follows.

$$\begin{aligned} N^P &= 2(U-c)/3, \\ Q^P &= 2(U-c)^2/9, \\ \pi^P &= 2(U-c)^3/27, \\ CS^P &= \int_{(U+2c)/3}^{U} S_u du = 4(U-c)^3/81, \text{ and} \\ SW^P &= 10(U-c)^3/81. \end{aligned}$$

94.3.3 Two-Part Tariff

In case of two-part tariff, it holds that $p > 0$ and $A > 0$. It follows that

$$q = u - p \quad \text{and} \quad S_u = (u-p)^2/2 - A.$$

The condition that a consumer purchase service is given by

$$(u-p)^2/2 - A \geq 0, \text{ or } \quad u \geq p + (2A)^{1/2}.$$

The number of consumers purchasing service, the total quantity of service consumption, and the profit of the provider are given as follows.

$$\begin{aligned} N &= U - p - (2A)^{1/2}, \\ Q &= \int_{p+(2A)^{1/2}}^{U} (u-p)du = (U-p)^2/2 - A, \text{ and} \\ \pi &= (AN + pQ) - cQ \\ &= A\left\{U - p - (2A)^{1/2}\right\} + (p-c)\left\{(U-p)^2/2 - A\right\}. \end{aligned}$$

By simultaneously solving the first order conditions ($d\pi/dA = 0$, $d\pi/dp = 0$), we have the optimal two-part tariff.

$$A^T = 2(U-c)^2/25, \text{ and } \quad p^T = (U + 4c)/5,$$

To denote 'two-part tariff', we use superscript T. The marginal consumer who is indifferent from buying and not buying is

$$u^T = p^T + (2A^T)^{1/2} = (3U + 2c)/5.$$

From this, the number of consumers, the quantity of service use, the profit of the provider, the consumer surplus, and the social welfare at the equilibrium can be calculated as follows:

$$\begin{aligned} N^T &= 2(U-c)/5, \\ Q^T &= 6(U-c)^2/25, \\ \pi^T &= 2(U-c)^3/25, \\ CS^P &= \int_{(3U+2c)/5}^{U} S_u du = 6(U-c)^3/125, \text{ and} \\ SW^T &= 16(U-c)^3/125. \end{aligned}$$

94.3.4 Comparisons

Let us examine which pricing scheme maximizes the provider's profit. By comparing π^i's (i = S, P, T) we obtain the following proposition.

Proposition 1 *The profit of the monopoly provider is maximum under two-part tariff and minimum (under)subscription pricing, that is,*

$$\pi^S \leq \pi^P < \pi^T.$$

The equality holds only when the marginal cost of providing service is zero.

Proof From (94.4),

$$\begin{aligned} \pi^P - \pi^S &= c(3U^2 - 8c^2)/54 \geq 0, \text{ and} \\ \pi^T - \pi^P &= 4(U-c)^3/675 > 0. \end{aligned}$$

It holds that $\pi^P = \pi^S$ when $c = 0$. □

The merit of subscription pricing from provider's perspective is to receive much revenue from the consumers with low willingness to pay. On the contrary, the provider can obtain a large amount of revenue from the consumers with high willingness to pay under pay-per-use pricing. As shown in the fact that $\pi^P = \pi^S$ when $c = 0$, the provider can make equal revenues from either pricing by optimizing lump-sum and unit prices. However, the quantity of consumption is too large under subscription pricing compared to the other pricing schemes

($Q^P < Q^T < Q^S$). When the marginal cost of providing service is non-negligible, the profit from subscription pricing is least among all the pricing schemes. Two-part tariff balances the revenue from high-end consumers and that from low-end consumers and maximizes the profit of the provider.

Let us turn to the consumer surplus and social welfare. The calculation is straightforward, so we propose the following proposition without a proof.

Proposition 2 *Consumer surplus is highest under pay-per-use pricing and lowest under subscription pricing, that is,*

$$CS^S < CS^T < CS^P.$$

Low-end consumers prefer pay-per-use pricing to subscription pricing because the former better reflect the actual amount of her consumption. On the other hand, high-end consumers prefer subscription pricing to pay-per-use pricing because the former makes her payment constant regardless of the actual amount of her consumption. The preference for two-part tariff lies in between.

As a result, the marginal consumer who is indifferent from buying and not buying under pay-per-use pricing (u^P) does not purchase service under two-part tariff. Similarly, the marginal consumer who is indifferent from buying and not buying under two-part tariff (u^T) does not purchase service under subscription pricing. It follows that $u^P < u^T < u^S$ and $N^S < N^T < N^P$. Under pay-per-use pricing, the largest size of consumers is served and the consumer surplus is highest. Under subscription pricing, the consumers with low willingness to pay cannot purchase the service due to the high level of initial payment (A^S).

Taking the above two propositions together into account, we propose the following proposition. The proof is straightforward and can be omitted.

94.3.5 Discussion and Implications

Our predictions are that the cloud service models with sizable marginal costs such as IaaS and PaaS tend to be coupled with pay-per-use pricing, and the others with subscription pricing. Pay-per-use pricing is general among IaaS and PaaS and subscription pricing is often used SaaS offerings. The cost structure of service providers cannot fully explain the reality, but is one of the important determinants of pricing schemes.

Despite its economic performance, two-part tariff is not common in the cloud computing industry. One explanation would be the complexity of implementation. However, we expect that two-part tariff would become more popular among service providers as the market competition get fiercer and the profit margin grows narrower.

94.4 Conclusion

In this paper, we investigates subscription pricing, pay-per-use pricing, and two-part tariff from perspectives of a provider's profit, consumer surplus, and social welfare, respectively. This paper shows that two-part tariff is more efficient than the other two pricing from a provider's, consumers' and social point of view.

Our main results are first, the profit of the monopoly provider is maximum under two-part tariff and minimum (under) subscription pricing. Second, consumer surplus is highest under pay-per-use pricing and lowest under subscription pricing.

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