PROFIT-MAXIMIZING PRICING FOR CLOUD SERVICES

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Abstract

This study presents a typology of pricing schemes for cloud services and develops a decision model based on the perspectives of both cloud providers and corporate customers to maximize the total profit for cloud providers. The model is operationalized with an illustration using real pricing data.

Keywords*: Cloud services; Profit maximization; Pricing; Subscription; Pay-as-you-go*

1. Rise of Cloud Computing and Price Management

Cloud computing is one of the most significant paradigm shifts in information technology. The term “cloud” refers to the Internet, based on the way people draw the Internet in a cloud-like symbol, and is an abstraction of the complex infrastructure it hides (Erdogmus, 2009). Cloud computing has shifted the location of the infrastructure to large networked data centers, contributing to the reduction of costs by pooling hardware and software resources and providing greater flexibility and access to users (Dikaiakos et al., 2009; Vaquero et al., 2009). Business use of cloud computing is motivated by ease of use and potential cost reductions (Cusack & Ghazizadeh, 2016).

The pricing of cloud services is of great interest to both cloud providers and cloud customers. The clarity and transparency of pricing for both cloud customers and providers is one of the key factors for the commercial success of cloud services (Weinhardt, et al., 2009). However, cloud customers often pay more than required since cloud providers’ pricing strategies are designed for the interest of the providers (Mireslami, Rakai, Far, & Wang, 2017). Realizing the potential for revenue generation in the customer’s actual usage processes, innovative providers started to charge services according to actual usage rather than fixed prices (Stoppel & Roth, 2015).

Our paper will give a review of cloud pricing schemes, present a typology of pricing schemes for cloud services, and propose a profit-maximization pricing decision model for cloud providers. We develop a method to derive an optimal pricing decision for cloud providers based on the analysis of the interactions between the price, cloud demand, and cloud revenue. This paper will help cloud providers deepen their understanding of customers’ cost minimization strategies and develop a profit-maximizing price for their cloud services.

2. OVERVIEW OF PRICING SCHEMES IN CLOUD SERVICES

Pricing is a valuation process of services and products in monetary terms. In the past several decades, various pricing and revenue management techniques were introduced and added value to firms (Cross, Higbie, & Cross, 2011). For instance, customer-value-based revenue management is widely used to utilize capacity efficiently and establish profitable customer relationships (von Martens & Hilbert, 2011), and value-driven pricing is used to charge their customers according to the value created for their customers (Reen, Hellström, Wikström, & Perminova-Harikoski, 2017). Prices set in a dynamic environment is known to affect the purchase decisions of price sensitive customers (Bitran & Caldentey, 2003) and the mutually satisfying prices help build a strong relationship between the cloud customers and the cloud providers.

Price discrimination occurs when products/services are offered to different buyers at different prices. Pricing for services can be differentiated in terms of quantity, time, and quality (Lehmann & Buxmann, 2009). When using the dynamic pricing scheme, the cloud provider sets the price for the service or resource type dynamically by reflecting the fluctuating demands and resource availability. Viewing pricing as a "quick fix" and the only route to maintaining sales or protecting market share underplays the strategic importance of pricing and its long-term strategic implications (Piercy, Cravens, & Lane, 2010). Success for cloud providers can be achieved by developing adequate pricing models that provide an efficient way to allocate and valuate a variety of services (Weinhardt et al., 2009).

Yeo, Venugopal, Chu and Buyya (2010) propose charging variable prices with advanced reservation, in which case users know the exact expenses that are computed at the time of reservation. Rohitratana and Altmann (2012) use an agent-based simulation system that models the interactions between software buyers and vendors in Software-as-a-Service (SaaS) and perpetual software (PS) license markets. The simulation results show that the demand-driven pricing scheme is the best performer but is difficult to use due to imperfect knowledge about customers and competitors. As an alternative, the penetration pricing and skimming pricing were suggested as easily implementable pricing schemes.

Huang, Kauffman, and Ma (2015) investigate whether interruptible spot-price on-demand cloud services are valuable to the vendor. They note that the presence of interruptions serves as a quality differentiator between the on-demand services and reserved services. The results from the analysis of an economic model show that a hybrid strategy (fixed-price reserved services to spot-price on-demand services) outperforms a one-service-only strategy in most cases, especially when clients are sensitive to services interruptions or when task values are highly differentiated.

Different cloud providers employ different schemes and models for pricing (Al-Roomi et al., 2013) and the diversity in the pricing models makes price comparison difficult (Lehmann & Buxmann, 2009). Prices of the cloud services are based on (1) assessment base pricing, (2) price discrimination, and (3) price bundling, or combinations of these (Ojala, 2016). In assessment base pricing, customers pay for the services using pay-as-you go or subscription method. Price discrimination refers to a pricing model in which software is rented to different customers at different prices. Price bundling refers to a pricing model that includes several service items. Considering a variety of pricing options available, finding the right pricing scheme for services is challenging, but can result in significant cost savings for customers.

Youseff et al. (2008) identify the three pricing models that are used by cloud providers: tiered pricing, per-unit (pay-as-you-go) pricing, and subscription-based pricing. Tiered pricing is a threshold-volume discount in which the price will continue to decrease over time as the customer uses services more. A pay-as-you-go pricing is one of the most popular pricing schemes, in which a customer pays only for the services he/she uses without reserving a certain amount of resources that may or may not be used. The user can easily acquire resources for the changing business needs without long-term contracts. Subscription-based pricing is a pricing scheme that originated from magazine and newspaper subscription, where a subscriber pays a reduced price for a service over an extended interval of time.

Based on the current practices in the cloud computing industry, we present a 2-dimensional pricing typology in cloud computing (Figure 1). The first dimension is the pricing time unit (short and long) and the second dimension is the pricing dynamics (static and dynamic). A short pricing time unit is used for cloud providers to charge prices on a second, minute, or daily basis, and a long pricing time unit is used to charge prices on a monthly or yearly basis. In practice, pricing time units are getting shorter over time. Facing severe price competition, some cloud providers recently moved their pay-as-you-go pricing scheme from hourly billing to per second billing for some of their services. Dynamic pricing represents the change of prices based on the changing demand and resource availability. Static prices remain the same regardless of time-variant resource and demand level.

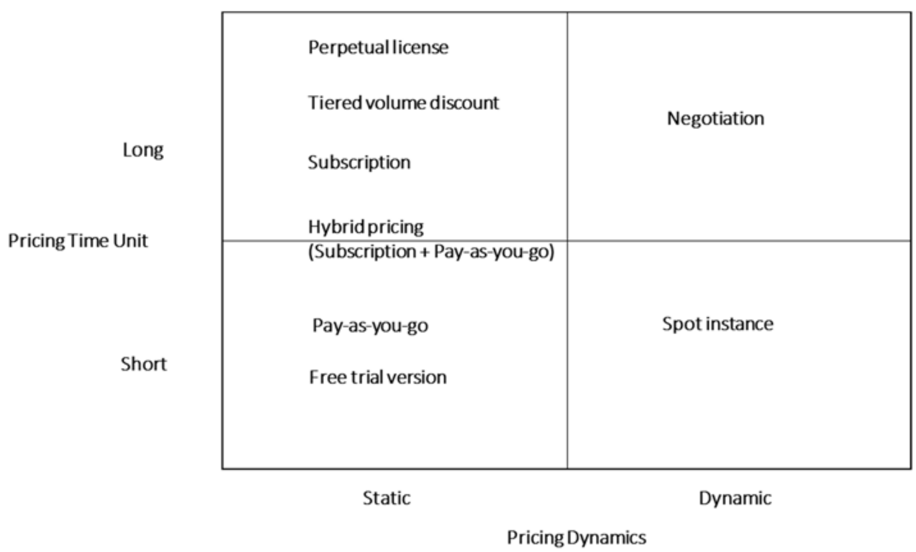

Figure 1. A Typology of Pricing Schemes

Dynamic pricing plays an important role in cloud pricing (Lehmann, & Buxmann, 2009). While its implementation is complex due to unpredictability of resource availability and computing demand, well developed dynamic pricing can increase the profit and revenue for the cloud providers as well as cost savings to the customers. There are variations of dynamic pricing such as spot instances and negotiation. Spot instances are auction-based pricing schemes to sell idle computing resources at a deep discount prices.

Spot instances have been broadly agreed upon as a significant supplement for building a full-fledged market economy for the cloud ecosystem (Abhishek, Kash, & Key, 2012). Li et al. (2016) investigate the empirical studies of cloud spot pricing indexed by major electronic libraries and argue that spot pricing plays a promising role in the sustainability of cloud resource exploitation. Cloud providers are offering various spot services. Amazon EC2 Spot instances are idle computing resources in the AWS cloud available at deep discounts compared to pay-as-you-go or subscription prices**.** Google's Preemptible VMs are a spot instance that customers can purchase at discounted prices. Microsoft Azure has offered a way to obtain and consume Azure compute at a deep discount called Low-priority VMs, allocated from their surplus compute capacity**.** However, these spot instances might terminate if other regular instances require access to those resources. Some cloud providers such as Microsoft offer negotiated prices to corporate customers for large volume long-term cloud services.

Static pricing is a pricing scheme where prices remains the same for a given period of time (short or long). In the static pricing scheme, the cloud provider sets a predefined price for each service or resource type at the beginning of the contract period. Variations of static pricing include volume discount, tiered pricing, pay-as-you-go, subscription, and hybrid pricing (a mix of subscription and pay-as-you-go). Savings from volume discounts can be realized as customers' usage increases. For example, if computing usage goes over a predetermined threshold level, one will get a scheduled volume discount for the whole usage. Some providers such as Amazon use tiered pricing, which is similar to volume discounts, but volume discounts apply to the entire usage while tiered pricing may apply to different prices for different tiers (range of usage). Subscription-based pricing is common in SaaS products such as Adobe and Salesforce.com. Subscription-based services have some benefits for service providers including stable revenue streams and reduced customer retention and acquisition costs compared to the pay-as-you-go services, the churn rate of which is a concern for many SaaS firms. Hybrid pricing is a mix of subscription and pay-as-you-go in which the cloud demand exceeding the pre-purchased subscription is transferred to the pay-as-you-go pricing. Table 1 shows the price comparison of equivalent cloud services. It is noted that their prices are highly comparable to each other.

Table 1. Pricing of Major Cloud Providers

Virtual Machine Type: US Linux	Amazon AWS OD Hourly	Google OD Hourly	Microsoft Azure OD Hourly	IBM OD Hourly	Amazon AWS OD /GB RAM	Google OD /GB RAM	Microsoft Azure OD /GB RAM	IBM OD /GB RAM
Standard 2 vCPU with Local disk	$0.133	$0.136	$0.100	$0.137	$0.018	$0.018	$0.013	$0.017
Highmem 2 vCPU no Local disk	$0.133	$0.118	$0.133	$0.179	$0.009	$0.009	$0.008	$0.011
Highcpu 2 vCPU no Local disk	$0.085	$0.071	$0.085	$0.075	$0.021	$0.039	$0.021	$0.038

Adapted from RightScale as of No. 17, 2017 (Infoworld, 2018)

An in-depth understanding of the cost components of cloud services is necessary as cost is one of the major considerations in pricing. The estimation of the total service cost requires a thorough investigation of individual cost components. Table 2 shows a list of cost categories relevant to the provision of cloud services. There are six cost categories: data center, services, hardware, software, network, and development. These cost categories are further divided into initial investment costs and recurring costs. The cost elements would vary, depending on the cloud services such as SaaS, PaaS, and IaaS. For example, the major cost elements of SaaS are costs of the data migration and management, application development, and integration. The major cost elements of IaaS are the costs of the physical computing machines, network infrastructure, installation, upgrade, and maintenance of the physical computing machines.

Table 2. Categories of Cloud Service Costs

Categories of Costs	Initial Investment Costs	Recurring Costs
Data center	Infrastructure development, Initial training, Certification	Internal technical staff, On-going training and change management, Recruiting cost
Services	Initial setup of service platforms, Advertising, Construction of customer database	On-going services, Facilities management, SLA management, Cooling cost, Electricity cost, Contract management, Data center management, Usage tracking and management, Billing systems, Service management
Hardware	Physical Computing Machines	Upgrade, Maintenance, Move, Change
Software	Virtual machine management solutions, Data management software, Application software, Operating systems, Autonomic resource management software, Middleware	VM and Application Monitor: Upgrade, Maintenance, Move, Change, Service request monitoring, Data management, Data migration
Network	Network infrastructure, Network application software, Firewall	Upgrade, Maintenance, Move, Change
Development	Service development, Infrastructure development, Server racks, Testing, Installation, Documentation	Internal technical staff, Corporate overhead cost, Collaboration with external partners, Communication costs

While most pricing studies focus on spot instances and pay-as-you-go pricing (Andrzejak, Kondo, & Yi, 2010; Ben-Yehuda, Ben-Yehuda, Schuster, & Tsafrir, 2013; Javadi, Thulasiram, & Buyya, 2011; Jin et al., 2015), a normative study on the profit maximization methods for a cloud subscription model does not exist. However, subscription pricing is widely used as well as pay-as-you-go pricing by major cloud providers such as Microsoft, Amazon, and Google. To maximize profits, a cloud provider must thoroughly understand how cloud customers make an economical decision on subscription vs pay-as-you-go and how a cloud provider's pricing will affect cloud customers' cloud purchasing decisions. The cloud provider's profit maximization efforts should take the cloud customer's cost minimization efforts into consideration for pricing. Our decision model can provide insights into how these efforts interact with each other, and how much discount must be given to customers for the cloud subscription to generate a maximum profit for the cloud provider.

3. A PROFIT MAXIMIZING PRICING DECISION MODEL

In this section, we develop a cloud pricing decision model in which a cloud provider sets the subscription price of cloud services to maximize the profit. In our decision model, cloud customers can choose the number of subscriptions and the amount of pay-as-you-go services after the cloud provider sets the prices for their subscriptions and pay-as-you-go cloud services. Since the cloud customer's purchase decision is affected by the cloud prices, combined with the fact that the cloud provider sets the price of the service, the cloud provider needs to identify the price-dependent demand function of the cloud customers. Depending on the prices, the cloud customer will choose either subscription, pay-as-you-go, or a hybrid of subscription and pay-as-you-go services to minimize the service cost. The following is the nomenclature used throughout this section.

Nomenclature

x: an actual computing demand occurring in each time unit with an exponential probability distribution function
$\lambda e^{-\lambda x}$: an exponential probability distribution function for computing demand
$1/\lambda$: mean of computing demand
p: price per subscription (the decision variable)
c: cost per subscription
S: The number of subscriptions purchased by the customer
a: price of public cloud per time unit as a pay-as-you-go option
g: cost of public cloud per time unit
t: number of time units in the subscription period

3.1 Cloud Customer Perspective

Given the prices of the subscription and pay-as-you-go services, the cloud customer tries to minimize the total cloud cost by choosing a mix of the subscription and pay-as-you-go services. The customer uses the following cost minimization function, TC_{CC}.

$$\text{Min } TC_{CC} = p \cdot S + \left(a \cdot \int_S^{\infty} \lambda e^{-\lambda x}(x - S)dx\right) \cdot t \qquad (1)$$

where p is the unit price of subscriptions, S is the number of subscriptions purchased, $p \cdot S$ is the total subscription cost, a is the price of the pay-as-you-go service per time unit, and $\left(a \cdot \int_S^{\infty} \lambda e^{-\lambda x}(x - S)dx\right) \cdot t$ is the expected total pay-as-you-go cost for the computing needs exceeding the number of subscriptions. In Equation (1), the number of subscriptions, S, is the decision variable of the cloud customer under uncertain computing needs. Equation (1) assumes that if the actual computing need exceeds the number of subscriptions purchased, the customer uses the pay-as-you-go SaaS. However, if the actual computing need is lower than the number of subscriptions purchased, there will be underutilized subscriptions. The cloud customer should increase the number of subscriptions up to the point where the marginal cost of is zero. In our study, we assume an exponential distribution of the computing demand. However, it is possible to extend the model with other types of probabilistic distributions.

Applying integration techniques, Equation (1) is transformed into Equation (2).

$$\text{Min } TC_{CC} = p \cdot S + a \cdot t \cdot \frac{1}{\lambda} e^{-\lambda S} \quad (2)$$

By differentiating Equation (2) in terms of *S*, we get:

$$\frac{dTC_{CC}}{dS} = p - a \cdot t \cdot e^{-\lambda S} \quad (3)$$

Then, the optimal number of subscriptions purchased by the cloud customer is:

$$S^* = \frac{\ln\left(\frac{p}{a \cdot t}\right)}{-\lambda} \quad (4)$$

Note that the purchase of subscription S^* depends on the price, demand level, the number of time unit (days) per subscription period, and the price of pay-as-you-go service. S^* is an input variable to the cloud provider's pricing decision model in the next section.

3.2 Cloud Provider's Perspective

A cloud provider develops its profit-maximizing pricing strategy for the cloud services offered to its customers. Pricing decisions are made under constraints of the customers' price-demand function, internal costs, and competitors' prices. Table 1 shows that the current pay-as-you-go prices are comparable among cloud providers, but the discount rates of subscriptions vary widely. For example, Microsoft offers customers 40%-70% discount for one- or two-year subscription options compared to the pay-as-you-go prices. Amazon EC2 Reserved Instances (RI) provide up to a 75% discount compared to On-Demand pricing. The discount prices of subscriptions by Microsoft and Amazon would encourage customers to choose subscriptions. However, it is not clear if the prices of the subscription are optimally set to maximize profit. Other cloud providers set the subscription prices such that there is no cost savings from the subscription. For example, as of February 2018, the pay-as-you-go price of VMware's Compute service (240GB, vRAM, 35GHz CPU) is $0.034/GB/hour, and the monthly subscription price is set at $5,978. VMware provides no discount for subscriptions to customers.

Low subscription price may boost the sales of the subscriptions, but can undermine the profit of the cloud provider. High subscription price encourages customers to choose pay-as-you-go services. Finding the optimal subscription price is a challenging task in that the optimal subscription price is derived by combining the customers' cost minimizing decision with the providers' profit maximizing decision. For a cloud provider who offers both subscription and pay-as-you-go services, the following profit maximizing function is formulated.

Max $PR_{CP} = (p - c)\cdot S + \left((a - g)\cdot \int_S^\infty \lambda e^{-\lambda x}(x - S)dx\right)\cdot t$ (5)

where p is the unit price of subscriptions, c is the unit cost of subscriptions, S is the number of subscriptions purchased by the customer, $(p - c)\cdot S$ is the profit from the sales of the subscriptions, a is the price of pay-as-you-go service per time unit, g is the cost of pay-as-you-go service per time unit, $(a - g)\cdot \int_S^\infty \lambda e^{-\lambda x}(x - S)dx$ is the profit from the sales of pay-as-you-go services. Note that the time unit of subscription is different from the time unit of the pay-as-you-go. One subscription period is equivalent to (a time unit of pay-as-you-go services multiplied by t).

Applying integration techniques, Equation (5) is transformed into Equation (6).

Max $PR_{CP} = (p - c)\cdot S + (a - g)\left(\frac{1}{\lambda}e^{-\lambda S}\right)\cdot t$ (6)

The unit price of subscriptions, p, is the decision variable in Equation (6). The number of subscriptions sold, S, is calculated in Equation (4). The cloud provider needs to find the optimal unit price of subscriptions, p^*, that yields the maximum profit. While other costs such as fixed cost can easily be taken into account, our analytical outcome would not be changed.

3.3 Determining the Subscription Price of Cloud Services to Maximize Profits

Since the cloud provider needs to find the optimal price p^* of the subscription given the cloud customer's response to the subscription price, Equation (4) is plugged into Equation (6).

Max $PR_{CP} = (p - c)\cdot \frac{\ln\left(\frac{p}{a\cdot t}\right)}{-\lambda} + (a - g)\cdot t\left(\frac{1}{\lambda}e^{-\lambda\cdot\frac{\ln\left(\frac{p}{a\cdot t}\right)}{-\lambda}}\right)$ (7)

In order to achieve the maximum profit, a cloud provider should increase the price up to the point where the marginal profit is zero. Hence, to get the optimal price of the cloud provider, differentiate Equation (7) with respect to p:

$\frac{dPR_{CP}}{dp} = \frac{-1}{\lambda}\left(1 + \ln(p) - \ln(a\cdot t) - \frac{c}{p}\right) + \frac{(a-g)}{\lambda\cdot a}$ (8)

Since there is no closed-form optimal value of p, a Newton Raphson root-finding algorithm is used. Set Equation (8) to zero and take the differential. Set Equation (8) to $f(p)$; then $f'(p)$ is:

$f(p) = \frac{-1}{\lambda}\left(1 + \ln(p) - \ln(a\cdot t) - \frac{c}{p}\right) + \frac{(a-g)}{\lambda\cdot a}$ (9)

$f'(p) = \frac{-1}{\lambda}\left(\frac{1}{p} + \frac{c}{p^2}\right)$ (10)

Since $f'(p) < 0$ for $p > 0$, there is a maximum profit in the positive price range.

An initial guess p_0 is set to the maximum subscription price.

$$p_1 = p_0 - \frac{f(p_0)}{f^{'}(p_0)} \quad (11)$$

The root finding process is repeated as:

$$p_{n+1} = p_n - \frac{f(p_n)}{f^{'}(p_n)} \quad (12)$$

until a sufficiently accurate subscription price for the root of $f(p)$ is reached.

3.4. Analysis of a Profit Maximizing Pricing Decision with an Illustrative Scenario

This section illustrates the operations of the pricing decision model discussed above and conducts sensitivity analyses to understand model behaviors of the pricing decisions by changing parameter values. As an illustration, we use the pay-as-you-go price, $0.085 per hour for Highcpu 2 vCPU no Local disk in Table 1. The base parameter values are presented below.

$1/\lambda$: 1,000 instances
c: $8.96
a: $0.085
g: $0.03
t: 732 hours

We used Equation (7) and the Newton Raphson method to identify the optimal subscription price, p. The maximum possible subscription price is $62.22 (i.e., the pay-as-you-go price * t = $0.085*732). It took four iterations of the Newton Raphson method to find the following optimal price of the subscription.

Optimal price, p^* (Price of a one-year subscription): $51.95
The discount rate of the subscription: 16.51% (i.e., ($62.22-$51.95)/ $62.22)
S (The number of subscriptions purchased by the customer): 180.46 instances
Total profit by the provider: $41369.88

Total cost by the customer: $61,320.93

Figure 2 shows the relationship between the price of the subscription and the total profit of the provider and the total cost of the customer. Note that the optimal price for the provider is $51.95. The total profit increases rapidly as the price goes up to the optimal price. However, as the price goes up beyond the optimal price, the total profit of the cloud provider declines slowly. On the other hand, the total cost of the customer continues to increase as the subscription price goes up. Figure 3 shows that the number of subscriptions declines rapidly as the price goes up. 0 subscriptions are made at the subscription price of $71.95 since the subscription price is higher than the equivalent pay-as-you-go price.

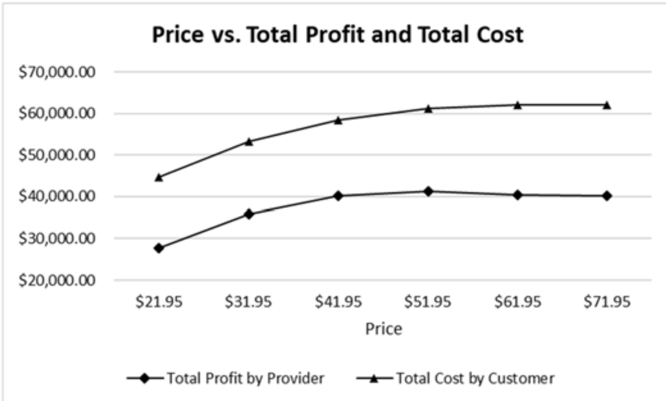

Figure 2. Subscription Price and the Total Profit of the Provider and the Customer

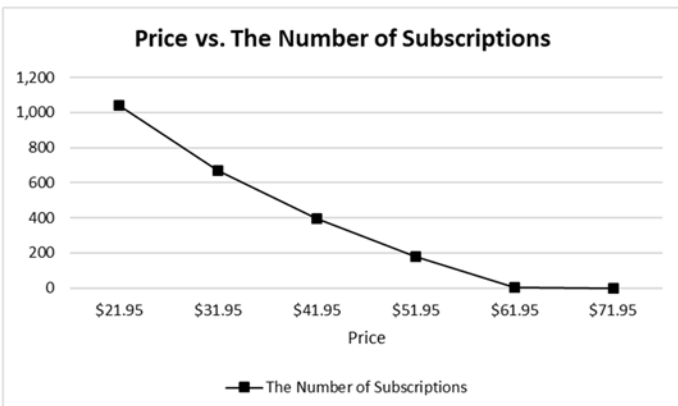

Figure 3. Subscription Price vs. the Number of Subscription

5. CONCLUSION

Cloud computing has offered many new services to enterprises and individuals. The Fourth Industrial Revolution will accelerate the growth of cloud computing due to the rapid growth of big data, the IoT, and AI applications. While a well-developed pricing strategy can affect customers' purchase intention positively and increase the company's market share, there is a paucity of studies on revenue and pricing management and therefore it is challenging for cloud providers to make informed decisions in regards to the pricing of services. Based on the current practices in the cloud computing industry, we present a 2-dimensional pricing typology in cloud computing. The first dimension is the pricing time unit (short and long) and the other dimension is the pricing dynamics (static and dynamic). A number of pricing schemes were identified and classified according this typology.

Cloud providers need to find the optimal price of the subscription given the cloud customer's response to the subscription price. The demand for the subscription depends on the price, computing demand level, the number of time unit (days) per subscription period, and the price of the pay-as-you-go services. To maximize the value of the cloud services for both the providers and the corporate cloud customers, we proposed a profit-maximizing pricing decision model. Our study is one of the first studies in the cloud pricing research area and provides a solid foundation to assess the business value of pricing decisions, moving beyond the descriptive valuation studies to value maximizing prescriptive studies, the outcomes of which should be able to guide cloud providers to plan on what discount price they should offer for subscription services.

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