A Brokering Model for the Cloud Market

Georgios Chatzithanasis[1][0000−0002−5099−4213], Evangelia Filiopoulou[1][0000−0002−2791−2582], Christos Michalakelis[1][0000−0002−4401−5058], and Maria Nikolaidou[1][0000−0002−4541−961X]

Harokopio University
Department of Informatics and Telematics
Omirou 9, PS 17778 Athens, Greece
geo.hatz@hua.gr
https://dit.hua.gr

Abstract. The cloud broker is an IT role and a business model that acts as an intermediary agent between cloud providers and end users. The exponentially increasing adoption of the IaaS market has contributed significantly to the so far growth of the Cloud Broker market. The unprecedented scenario of COVID-19 pandemic has upgraded the role and the contribution of broker to the cloud market, since cloud adoption has been further accelerated by the COVID-19 crisis. Cloud broker guarantees the availability of a given amount of resources for use at a specific time, offering pricing policies that benefit consumers and boost broker's profitability. Into that context a cloud brokering model, is introduced and described, together with a profit maximization economic model, suggesting and evaluating different pricing policies that ensure the viability of the business and boost profitability. The pricing policy that is able to lead to the maximum profit potential is also highlighted.

Keywords: Brokering Model· Pricing· Cloud Computing

1 Introduction

The Infrastructure-as-a-Service (IaaS) market has been on growth for several years and there are no indications leading to a lowering of demand in the foreseeable future [27]. In addition, the rapid global spread of COVID-19 has forced almost all sector of financial market, such as small and large businesses, healthcare and education to digitally transform. Therefore, the COVID-19 impact on cloud computing is tremendous and IaaS market is highly affected [1] [20].

The increasing adoption of IaaS market has contributed significantly to the growth of the cloud broker market which is expected to register a CAGR of 16.6% until 2024 [25]. Moreover, the unprecedented scenario of COVID-19 pandemic has upgraded the role and the contribution of broker to the cloud market, since cloud adoption has been further accelerated by the COVID-19 outbreak.

Cloud broker is an IT role and business model and acts as an intermediary between cloud providers and end users [21]. It combines and integrates multiple services into one or more new services and enhances a given service by improving some specific capability and providing value-added services to cloud consumers. Finally, the cloud broker, aims to attract consumers and increase the market share, offering higher discounts than cloud providers, reducing the cost for cloud users [9].

The cloud broker business model, is built upon ensuring economic viability and profitability, based on a proper pricing policy. The price of a service affects consumer demand and this in return affects the revenues generated by the firm [1].

Into that context a Brokering model is described and analysed. Broker initially reserves instances(VMs) from cloud providers for a specific time period, gaining a significant discount. The discount is related to the reservation time, therefore broker chooses a reservation period, combined with a price that fits the capital budget. Thence, broker leases the VMs to end-users, at a price lower than the on-demand provider's price, in order to attract more users and increase the market share. In the context of this work, a profit maximization economic model is proposed, suggesting and evaluating different pricing policies that ensure the viability of the business and boost profitability. The pricing policy that leads to the maximum profit potential is also analysed.

Broker's pricing policies are related to the corresponding policies of the providers, since they both claim a share in the cloud market. Cloud providers adopt different pricing policies under different commitment terms. The most popular is the "pay-as-you-go" pricing, referring to "on-demand" instances where users pay a fixed price for virtual machines (VMs) per billing cycle without any commitment [13]. In addition, the subscription-based policy is used for Reserved Instances (RI), where users pay a onetime upfront fee for a time period, as for example a monthly subscription.

The economic model proposes pricing policies based on cloud providers pricing schemes. The on-demand pricing is used as a reference point for the evaluation of the model. For the development of the pricing policy the price evolution over a specific time period is taken into account. This concept is rather challenging and innovative, since profit analysis is usually linked to the consumer demand for the given product or service.

The importance of the proposed methodology, which constitutes the contributions to the corresponding literature can be summarised to the following topics:

- Broker set the prices of the resources based on the prices set by cloud providers.
- The financial viability of the investment is examined.
- The profit potential of each proposed pricing policy is highlighted.
- The social surplus, in terms of the end-users and broker's surplus is estimated.

The rest of the paper is organized as follows: Section 2 presents the related work, while Section 3 describes the cloud pricing and introduces the proposed profit maximization model. Section 4 presents a case study of the model for the evaluation of the model. Finally Section 5 concludes the paper and suggests future work.

2 Related Work

There are several papers available in the relevant literature that discuss the cloud broker business model, including studies that address the broker's profit maximization.

In [22] a different kind of broker was introduced, relying on outsourcing virtual machines (VMs) to customers. Virtual Machine Planning Problem was defined that tried to address broker's profit maximization. In addition, a number of efficient smart heuristics was proposed, aiming to allocate a set of VM requests from customers into the available pre-booked ones, that maximized the broker earnings.In [26] the authors introduced two algorithms that maximize the profit of the cloud broker. Dynamic pricing was adopted to adjust users demand under Quantized Billing Cycles. In [29] a fair and priority aware pricing scheme was designed, known as Priority Pricing, aiming to address the idle resource waste.

In [28] a profit maximization problem was modeled based on optimal multi-server configuration and VM pricing. Finally, a heuristic method was introduced to address the optimization problem. In [21] the cloud broker was introduced as a novel business role between cloud providers and cloud users and was described by a a multiserver, a revenue and a cost model. In addition users' demand holds a determinant role in the broker's profit maximization problem.

It is evident that the profit maximization models of the review are strongly related to consumer demand. A different approach is presented to the present paper, based on the evolution of cloud pricing through time, aiming to fill the identified gap in the relevant literature. Amazon's pricing policy was adopted for the evaluation of the model which, according to literature, follows an important annual reduction in the on-demand price [19].

3 Problem statement

3.1 Cloud market pricing

Many companies offer Cloud Computing options and have facilitate the everyday life of IT departments but also have proven highly cost effective. The leaders in the market are the Amazon Web Services (AWS) [2], Microsoft Azure [5], IBM, and Google [23]. These providers represent the 55% of the cloud infrastructure services market, in total [3].

One of the major features of cloud computing follows the "pay-as-you-go" pricing model, where the user pays according to the amount of resources consumed [7]. However, the "pay-as-you-go" model is complex as it requires continuous monitoring of resource usage [31].

In addition, the majority of cloud providers offer two pricing schemes: the on-demand and the reserved instances. The former enable users to pay per hour computing capacity with no long-term commitments. Reserved instances (RI) pricing schemes offer users the option to reserve Virtual Machines (VMs) for a specific time period, for example one year. RI are not physical instances but rather a discount billing concept in which user purchases VMs for a fixed time period and in return providers offer significant discounts, as compared to the equivalent on-demand instances price. The amount of the discount varies according to the length of the commitment and the available payment options. It is evident that that reserved instances are cost-effective if workloads are steady, whereas on-demand instances are considered to be a more suitable solution when the workload rate is scattered. The broker of the current paper interacts with providers and purchases reserved instances and leases them to users, aiming to be profitable. Profit making is among its main objectives, hence, the following section examines a broker's profit maximization problem

3.2 Proposed Profit Maximization Model

IaaS providers usually offer resources for varying periods of time, either on demand, i.e. for a short period of time, or for a longer period. Amazon [2], for example, apart from the on-demand supply offers IaaS for a maximum period of three years. The pricing scheme is based on the assumption that the price of IaaS is reversely proportional to the reservation time. This means that the longer the time infrastructure is reserved, the lower the reservation price for the resource.

Broker has a strong incentive to reserve resources for a long time, as this can contribute to the maximization of the profit, based on the proposed methodology. Therefore, broker is assumed to reserve a quantity of infrastructure from an IaaS provider for a long period of time. Into that time frame, which constitutes the period the corresponding investment is valuated, the broker creates bundles and offers them into the marketplace for a shorter period of time, at a higher price than the price they were reserved; but definitely lower than the current on-demand price of the provider, during each period of time. It is assumed that broker will lease instances to users continuously and the resources will not be idle. In addition, the difference between the reservation price and the selling price drives the creation of the broker's revenues and the consequent profit. Figure 1 illustrates the broker model.

The above assumptions can be mathematically formulated as follows:

At the beginning of the period under evaluation, t_0, broker reserves a quantity, Q, of virtual machines, at a price of $P_{res}(t)$ per unit, for a time period t^*, at a total cost C, as presented in Equation 1.

$$C = P_{res}(t) * Q \tag{1}$$

The function $P_{res}(t)$ denotes the price that the broker pays to the provider for reserving VMs for t period of time. Without loss of generality, it can be assumed that $P_{res}(t)$ is linear:

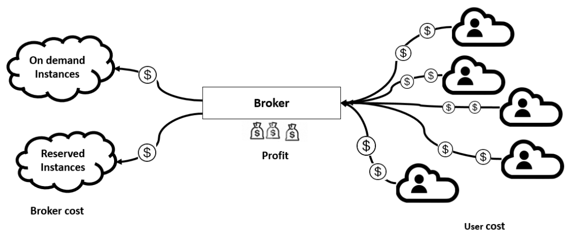

Fig. 1. Cloud Broker Overview

$$P_{res}(t) = \beta t + P_{res_0} \ , \beta < 0 \tag{2}$$

where P_{res_0} is the price of the reserved VMs for the minimum possible time period and the coefficient β describes the price decrease due to discount derived from the provider's pricing policy.

Following that, broker creates time-based bundles, Q_i, of these VMs and supplies the retail market. Each bundle, Q_i, is then reserved for time t_i at a price of $P_{sell,j}$ creating a revenue R as presented in Equation 3

$$R_i = Q_i * P_{sell,j} \tag{3}$$

The selling price $P_{sell,j}$ is reduced over time, as technology evolves and new cloud instances are introduced. The function $Psell(t)$ denotes the price reduction of the VMs for a specific time period.

$$P_{sell}(t) = \gamma t + P_{sell_0} \ , \gamma < 0 \tag{4}$$

where P_{sell_0} is the maximum price that broker sells to users an amount of VMs for the minimum reservation time and the coefficient γ denotes the price decrease due to the introduction of new cloud solutions.

Thus, the total revenue deriving by the total quantity Q is depicted in Equation 5.

$$R = \sum_{i=1}^{n} R_i = \sum_{i=1}^{n} Q_i * P_{sell,j} \tag{5}$$

In the context of this analysis, it can be assumed that the market demand for cloud resources will cover the total reserved quantity, Q. This is a quite valid assumption, since cloud services merit a continuously increasing demand and it can be also verified by performing a forecasting analysis regarding the demand for the time period t^*. The total profit, P, for the broker model is given by the following equation 6 .

$$P = R - C = \sum_{i=1}^{n} R_i - P_{res} * Q = \sum_{i-1}^{n} Q_i * P_{sell,j} - P_{res} * Q \tag{6}$$

which, in turn, corresponds to the maximization of P, within the time period under consideration, t^*.

$$\left.\begin{array}{l} \max P = \max\left(R - C\right) = \max(\sum_{i=1}^{n} R_i - P_{res} * Q) \\ \max P = \max(\sum_{i-1}^{n} Q_i * P_{sell,j} - P_{res} * Q) \\ \text{subject to: } P_{res} < P_{sell,j} < P_{ond}(t) \end{array}\right\} \text{M1}$$

where P_{ond} corresponds to the on-demand price of the provider, at time t. Broker as a for-profit business aims to gain competitive edge in the cloud market therefore, the selling price $Psell(t)$ should be highly related to provider's on-demand pricing $P_ond(t))$. Cloud providers, seeking to enhance cost-effectiveness, reduce the level of the on-demand pricing over time [19].

$$P_{ond}(t) = \delta t + P_{ond_0} \ ,\delta < 0 \tag{7}$$

Following the above statement, $P_{sell,j}$ can be expressed as a function of $P_{ond}(t)$:

$$P_{sell,j} = f(P_{ond}(t)) \tag{8}$$

Function f apart from the value of $P_{ond}(t)$ accommodates other marketing variables as well, such as competition, broker's brand name and market reputation, as well as other parameters that define the range within which broker can set $P_{sell,j}$. This function reflects the elasticity of $P_{sell,j}$ in response to $P_{ond}(t)$. In a simpler approach and without loss of generality, if the market factors are considered constant during the evaluation time, $P_{sell,j}$ can be expressed as constantly proportional to $P_{ond}(t)$ by a factor α.

$$P_{sell,j} = \alpha * P_{ond}(t),\ a \leq 1 \tag{9}$$

The inequality $\alpha \leq 1$ indicates that broker is expected to supply the resources at a lower price than the provider's on-demand price, at each time, since if this does not hold the end user would prefer to obtain resources directly by the provider itself. The value of α, in this case as well, depends on the same factors, including brand name, competition and market concentration and other specific marketing mix variables.

As far as the pricing policy is considered and based on the above analysis, the pricing strategy of broker, i.e. the level of $P_{sell,j}$ depends on a number of parameters that describe the market environment, like competition and market reputation of the broker. If no competitor exists, broker can follow a cost-based pricing approach, by placing a price cap or a price margin over the Pres. However, if other brokers operate in the market, corresponding pricing strategies should be adopted to accommodate this fact. In each case the market reputation and the brand name of the broker determines the level of P_{res} as they strongly related to the confidence of the retail market to the broker and drive their decision to reserve their IaaS from broker or from the original provider, even at a higher price. For example, a well-established broker can set a higher price, closer to the $P_{ond}(t)$ than a newcomer, or a not well-established one.

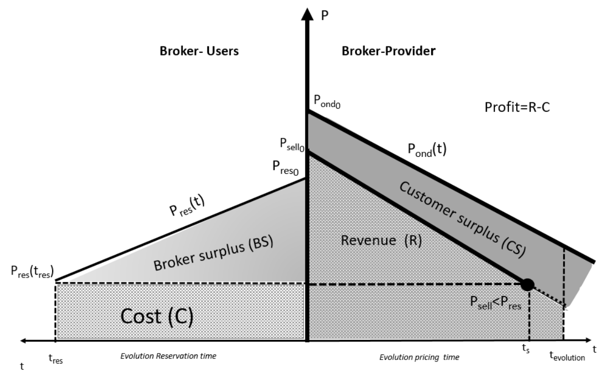

Fig. 2. Profit Maximization Model

The following figure illustrates the proposed model.

Figure 2 illustrates broker's two-fold interaction with the providers and users. Initially, broker reserves instances for time t_{res} at a price $P_{res}(t)$. Therefore area C corresponds to the cost that broker pays to the provider for RIs. RIs are a discount billing concept in which broker purchases VMs for a fixed time period and in return providers offer significant discount. The aforementioned Equation 1 is depicted in Figure 2 and describes the evolution of the reservation price, thus the area BS defines the broker surplus. Broker surplus is the monetary gain obtained by broker because resources can be purchased at a lower price according to reservation time [6].

In addition, broker leases the VMs to consumers at price $P_{sell}(t)$ and, aiming to be competitive, the selling price is lower than the on-demand price $P_{ond}(t)$ of the providers. Figure 2 also presents the evolution of the selling and on-demand pricing based on the Equations 4 and 7 respectively over time $t_{evolution}$, where $t_{evolution} = t_{res}$. Hence, area CS describes customer surplus, that is the monetary gain obtained by consumers because broker offers them resources at a lower price than the provider [6], whereas area R displays broker's revenue. Broker's profit equals to the difference between R area and cost area C. Finally, when the broker has gained a considerable profit, hypothetically at the t_s the selling price can be lower than the corresponding reservation price.

4 Case Study

4.1 Amazon Web Services-AWS

Numerous cloud providers offer various solutions, however Amazon [2] still remains the leader and has established to hold the largest market share of the cloud market [27] for several years. Amazon offers reserved and on-demand instances. On-demand instances are charged on a per-hour or per-second (minimum 60 seconds) basis with no long-term commitment. Instead, reserved instances are offered with a significant discount (up to 75%), as compared to on-demand pricing. By using reserved capacity, businesses can minimize risks, more predictably manage budgets and comply with policies that require longer-term commitments [14] [15]. In addition, Amazon's users can also choose three different RI payment options [4]: In **Full-Upfront** users need to pay in advance the total cost of the RI, but offers the largest discount. With **Partial-Upfront** users pay 50% in advance with an additional monthly cost and get lower discount compared to full-upfront. **No-Upfront** does not require payment in advance, but has a higher monthly cost and with lower discount.

More specifically, the pricing policy concerning Amazon's on-demand and reserved T3xlarge instance is presented in Table 1 [15]. T3xlarge can be purchased for 3-year term.

Table 1. Pricing of T3.XLarge instance by Amazon EC (Region(Europe),Linux)

Pricing Strategy	**Payment Option**	**Upfront** $	**Monthly** $	**Period** $	**Total** $	**Discount (%)** *
			3 Year Billing			
Compute Savings Plans	Full Upfront	1,646.40	-	-	1,646.40	67.32
Standard Reserved Instances	Partial Upfront	1,007.00	27.96	1,006.56	2,013.56	60.03
EC2 Instance Savings Plans	No Upfront	-	60.44	2,175.84	2,175.84	56.81
On-Demand Instances	-	-	139.94	5,037.84	5,037.84	0.00

* discount on the On-Demand price of the billing Period

According to Table 1 users that adopt no upfront payment for purchasing T3.XLarge instance obtain discount ranging 36.99% - 56.81% over the on-demand price. In addition, partial upfront requires users to pay almost 50% of the all upfront price plus a monthly cost, and offers a slightly higher discount (60.03%). Finally, Full Upfront option requires users to pay the entire cost of the T3.XLarge instance in advance, enjoying the largest discount (67.32%). For the implementation of the model, broker reserves the T3.XLarge instance by Amazon EC and pays in advance, using Full Upfront option at cost P_{res}=1,646.40$ for the 3-year term. According to table 1, the chosen payment option is the most advantageous solution for broker, since the broker gains the maximum discount and then can maximize the profit potential.

Amazon offers various instances, however without loss of generality, the T3.XLarge instance was chosen for the implementation of the model with an average price of all Europe regions. It is a low cost burstable general purpose instance type that provides a baseline level of CPU performance with the ability to burst CPU usage at any time for as long as required [17]. Based on the proposed model, broker's profit potential is not essentially affected by the chosen instance.

4.2 Broker Business Model

Broker represents a model that can be extended to many different markets and implementations. The proposed approach introduces a business model that aims to be profitable by investing money in reserving Amazon's VMs and selling them to end users. Broker's economic viability and profitability depend upon the pricing policy; the selling price should be at a level that will eventually cover the cost and produce profit [11].

Amazon offers RIs that can be purchased for 1-year and 3-year terms. Broker can offer RIs that can be purchased for a shorter leasing time, for example 3-month, 6-month or 18-month terms, thus providing more flexible and cheaper services than Amazon.

Based on the mathematical formulation of the problem, broker's selling price is strongly related to the on-demand price of Amazon and is expected to be lower than this. For example broker can set a selling price at a level of 15% lower than the Amazon's on-demand pricing. Hence and based on Equation 9 different prices of α can form different levels of P_{sell} and different pricing policies.

In order to examine the profit potential of the proposed pricing policies the financial viability of the investment is initially examined by conducting a break-even point analysis that can be a effective tool to lower the risk and point out the most profitable policy. A break-even point corresponds to the quantity that should be offered in order to cover the fixed and variable costs and defines the point that the investment will generate a positive return [24]. It is the point at which total cost and total revenue are equal [18].

The break-even point analysis takes into consideration the fixed cost of the investment and the proposed selling prices, described by Equation 9 and estimates the break-even point of each pricing policy. The break-even point analysis is conducted for the Amazon EC2 3-year term reserved T3.Xlarge instance as shown in Table 1 and broker choose the Full Up Front payment option.

Since the financial viability of the investment has been evaluated the profit potential is explored. Return of Investment (ROI) is adopted in order to examine the potential return from the current investment for each proposed pricing policy. ROI is a financial metric that is widely used to measure the probability of gaining a return from an investment. It is a ratio between net income (over a period) and investment costs [10].

Broker in order to be flexible and competitive in the cloud marker can modify the pricing strategy when the break-even point is reached. Three (3) pricing policies are proposed that alter broker's initial pricing policy. The proposed policies are based on the purchase intentions of the consumers and sellers in the market [30] [8]

- **Greedy Pricing:** The corresponding scenario can be adopted when the demand for cloud resources is high and the availability is low, accompanied by a low market competition. Under those circumstances, the broker can modify the pricing policy with a price similar to the initial provider. The scenario can be used when demand by end-users is high like the surge in usage that COVID-19 has caused [12].

$$P_{sell}(t) = P_{ond}(t) \tag{10}$$

- **Dynamic Pricing:** The selling price P_{sell} is reduced, following an exponential distribution over time periods. A dynamic strategy aims to locate the optimum price point at any time. It can be adopted in the case of increased availability of resources and also is indicated when the selling price is varied due to technology evolution. [8]

$$P_{sell}(t) = P_{ond}(t)/2^x x = 1, 2, 3...t, \text{time periods} \tag{11}$$

- **Spot-Low Pricing:** The specific pricing policy is inspired by Amazon Spot Instances, without including bidding. Spot instance pricing can be almost 90% cheaper than the on-demand equivalent [16]. Into this context, the broker aims to be competitive by modifying the selling price P_{sell}. The broker minimizes the coefficient α of Equation 9 and offers VMs in a highly competitive price, without having unused resources. This policy can increase the number of end-users, increase broker's market share [30] and offers minimum guaranteed profit.

$$P_{sell}(t) = \alpha * P_{ond}(t) \text{ , where } \alpha \approx 0 \tag{12}$$

4.3 Evaluation - Results

As mentioned above, the broker reserves instances from Amazon and leases them to users, seeking for a pricing policy that will boost its profitability. In order to be flexible and competitive to Amazon, it offers to users RIs for a shorter leasing timeFor demonstration reasons and without loss of generality the evaluation of the model is based on a 6-month (semester) leasing. According to the mathematical formulation of the model, the broker's selling price P_{sell} is strongly related to Amazon's on-demand price P_{ond}. According to the evolution of the market, Amazon's EC2 prices have dropped 10.5% annually during the last years [19]. However, in the current case study the annual on-demand price reduction is assumed to be equal to 8% rather than 10.5%. This is because the COVID-19 pandemic has accelerated cloud adoption, so a smaller price reduction could be expected to be adopted, as result of the resources demand increase [12]. Amazon's on-demand price currently equals to 0.1856 $ / per hour [14], hence taking into account the rate of price reduction per semester, P_{ond} price per semester was estimated.

Therefore Amazon's on-demand price per semester is estimated and presented in Table 2.

Broker chooses to lease resources from Amazon, since Amazon is the leader in the cloud market and offers numerous IaaS solutions and various payment

Table 2. Assumptions on Price Evolution

Duration (Semesters)	**Price Reduction**	**Pond/Hour**	$\mathbf{P_{ond}}$
1st	0.00 %	0.1856 $	801.79 $
2nd	4.00 %	0.1782 $	769.72 $
3rd	4.00 %	0.1708 $	737.65 $
4th	4.50 %	0.1624 $	701.57 $
5th	5.25 %	0.1527 $	659.47 $
6th	5.25 %	0.1429 $	617.38 $

options. Table 1 presents its pricing policy for T3.xlarge instance, including all the possible payment options. Based on Table 1 the most advantageous pricing policy of the T3.xlarge was selected to be evaluated within the context of the proposed model. More specifically, the chosen reserved instances is a 3-year term of T3.xlarge at a cost of 1,646.40$, adopting the Full Upfront payment option. According to Table 1 broker gains a significant discount (67.32%), which corresponds to the broker's surplus. As mentioned in the mathematical formulation section, the broker reserves Q instances, however for simplicity and demonstration reasons the present case study is based on leasing only one T3.xlarge instance.

As far as pricing is concerned, a broker seeks to set the selling prices that will help to achieve profit maximization. Its selling price, P_{sell}, is expected to be lower than Amazon's on-demand pricing and is expressed by the coefficient α of the Equation 9. Broker can set various values to α and define the corresponding pricing policies. Examining each policy the profit potential and consumer surplus are pointed out. For example if coefficient $alpha$ equals to 71.30% then broker's selling price is 28.7% lower than Amazon's on demand price. Figure 3 illustrates the selling price for a specific α and the price evolution of Amazon's on-demand price. The specific pricing policy reaches break-even point at 18 months, therefore the area IC corresponds to the investment cost, the P_{res} price. The area (P) describes broker's profit and finally area CS displays consumer surplus.

Figure 4 illustrates different pricing policies, based on different values of the coefficient $alpha$. Since the investment cost is fixed, the values of $alpha$ contribute significantly to profit maximization. The investment cost, together with the profit and the consumer surplus can be highlighted for each pricing policy.

According to Figure 4 the coefficient $alpha$ ranges between 38.40% and 100%. The pricing policy which corresponds to the minimum coefficient α (38.40%) makes the investment viable and reaches the break-even point at the end of the investment evaluation, at the end of the 36 months. Despite the fact that the selling price is 61.6% lower than Amazon and the customer surplus is the highest in this case, the broker has no profit. When the broker's selling price is equal to Amazon's on-demand price, then the $alpha$ is 100%. The investment reaches the break-even point at 15 months. This pricing policy is really advantageous and the ROI is really high (160.42%). This is justifiable, since the broker purchased the

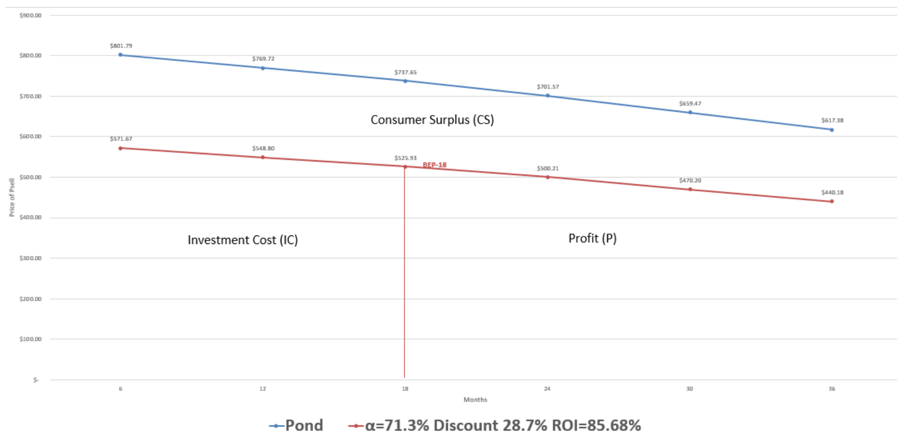

Fig. 3. Profit Model for α= 71.3%

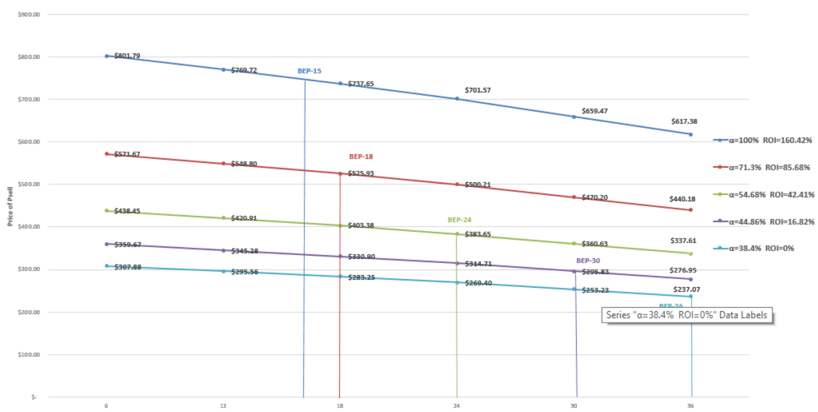

Fig. 4. Profit Maximization Model

resources at the lowest price and sells then at the maximum potential. However, in this case, consumers will prefer to purchase resources from Amazon rather than lease them from the broker, since there do not gain discount, not mentioning the effect of Amazon's brand name.

When the investment reaches the break-even point, the adopted pricing policy can be modified based on the profit potential, market competition, consumer demand and any other market parameters. Without loss of generality, the most advantageous pricing policy of Figure 4 is modified. The chosen pricing policy reaches the break-even point at 18 months and is really profitable since the ROI equals to 85.68%. Since the investment has reached the break-even point, broker can decide to modify its pricing policy. As mentioned above three pricing scenarios are applied and their profitability is examined. Figure 5 presents the modifications of the pricing policy, according to the three pricing scenarios. In addition the profits of each policy are estimated and highlighted.

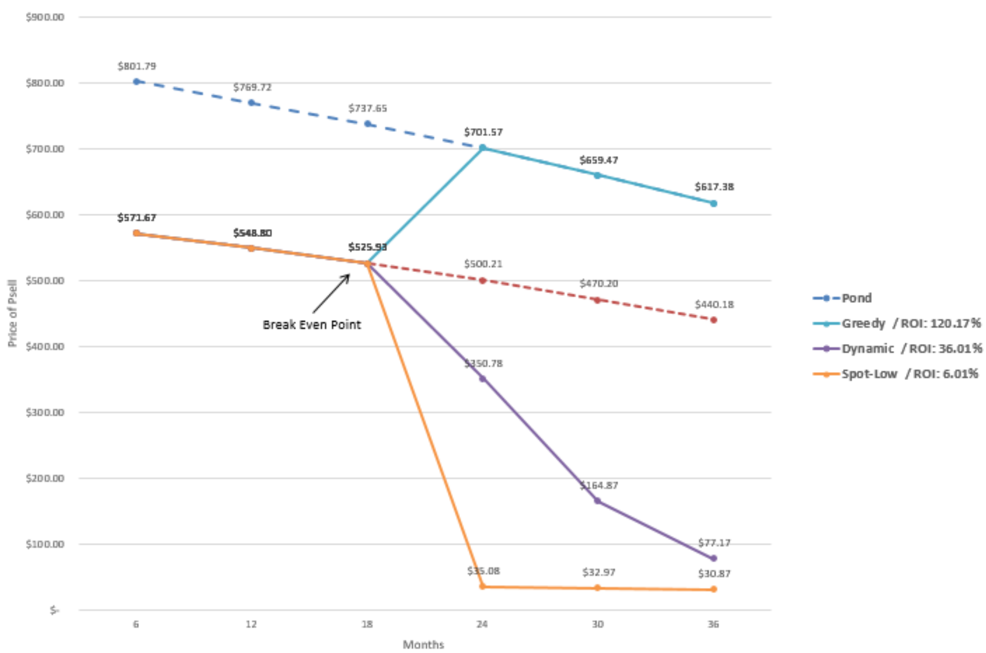

Fig. 5. Alternative pricing scenarios after the break-even point

A significantly high profit is related to the Greedy scenario. In this case Amazon and the broker sell at the same price and the estimated Return of Investment (ROI) is equal to 120%.

In the case of a competitive market, the broker needs to adopt a competition-based pricing strategy, which is mainly characterized by low retail prices. A low selling price can ensure that the investment will be profitable and broker's market share can be increased. In the Dynamic and Spot-Low scenarios, the broker drops the selling prices significantly. In the Dynamic scenario, the selling price is reduced following an exponential distribution and the ROI of the Dynamic scenario equals to 36%. Initially, the selling price is 28.7% lower then Amazon's price. Then, there is a price reduction and the selling price for the last 3 semesters is 50%, 75% and 87.5% lower than Amazon's pricing respectively. Finally, in the Spot-Low scenario, the broker offers resources at a price level of 95% lower than Amazon. In this case, its profit is limited, since the ROI equals only to 6%. However, this policy can increase significantly broker's market share and establish a share in the cloud market.

If the broker decides to keep the initial pricing policy, offering the resources at a level of 28.7% lower than Amazon on-demand pricing, profits are higher than by adopting Dynamic and Spot-Low scenarios. However, the Dynamic and Low Pricing scenarios are based on low and more flexible pricing that can increase the broker's market shares.

5 Conclusions

The exponential increasing adoption of IaaS market has significantly contributed to the growth of the cloud broker market. In addition, the unprecedented scenario of COVID19 pandemic has upgraded the role and the contribution of broker to the cloud market. Cloud broker is an IT role and business model and acts as an intermediary between cloud providers and end users [26]. The business model aims to be viable and profitable, based on a proper pricing policy.

The current paper describes a brokering model, according to which the broker initially reserves instances(VMs) from cloud providers for a specific time period, thus obtaining a significant discount. Following that, the broker leases the VMs to end-users, or even other cloud brokers, at a price lower than the on-demand provider's price. The broker can adopts different pricing policies, not only to produce profit for his sustainability but to also improve the social welfare by reducing end-user's cost. This can be achieved by providing resources at a lower price than the provider and with a flexible leasing duration.

A profit maximization model was introduced and developed based on the broker's two-fold interaction with the providers and users. For more accurate results the proposed model was implemented based on Amazon's AWS EC2 pricing policies. Initially, the broker reserves resources from cloud providers, choosing the most advantageous reservation price for 3-year terms. The reservation time and the Full Upfront payment options create a significant discount that the broker can leverage, defining broker's surplus. Then, the broker leases the resources to end-users and defines pricing policies that offer financial viability and profitability.

In order to ensure the profitability of the investment a profit maximization model was examined. Then different pricing polices were considered, estimating the profit and the consumer surplus each one generates. The broker aims to produce profit by leasing the resources at a lower price than the provider's on-demand price, in order to attract end-user not to obtain resources directly by the provider (e.g Amazon).

Based on the results, with a more adaptable and competitive pricing policy, the broker has the ability to offer significantly lower selling prices than Amazon and generate a considerable profit. It is notable to mention that even with a dramatic price drop returns profits there is a minimum profitability.

As in most cases, there some limitations in this paper. In the above case study the broker receives payments from end-users with a 6-month lease. Also, the assumption that each RI is leased for the whole duration of the study, should be replaced with a mathematical distribution that better expresses demand.

Finally,in the future the model can be applied adopting a shorter leasing periods and also calculate profit for RIs that have been obtained for a shorter duration from the provider and a different payment option such as Partial Upfront or No Upfront.

References

1. Alashhab, Z.R., Anbar, M., Singh, M.M., Leau, Y.B., Al-Sai, Z.A., Alhayja'a, S.A.: Impact of coronavirus pandemic crisis on technologies and cloud computing applications. Journal of Electronic Science and Technology p. 100059 (2020)
2. Amazon: https://aws.amazon.com, last accessed: 6.4.2021
3. Amazonmarketshare: https://www.statista.com/chart/18819/worldwide-market-share-of-leading-cloud-infrastructure-service-providers/, last accessed: 7.4.2021
4. Ambati, P., Irwin, D., Shenoy, P.: No reservations: A first look at amazon's reserved instance marketplace. In: 12th {USENIX} Workshop on Hot Topics in Cloud Computing (HotCloud 20) (2020)
5. Azure, M.: https://azure.microsoft.com/en-us/, last accessed: 6.4.2021
6. Boulding, K.E.: The concept of economic surplus. The American Economic Review **35**(5), 851–869 (1945)
7. Buyya, R., Yeo, C.S., Venugopal, S., Broberg, J., Brandic, I.: Cloud computing and emerging it platforms: Vision, hype, and reality for delivering computing as the 5th utility. Future Generation computer systems **25**(6), 599–616 (2009)
8. Elmaghraby, W., Keskinocak, P.: Dynamic pricing in the presence of inventory considerations: Research overview, current practices, and future directions. Management science **49**(10), 1287–1309 (2003)
9. Filiopoulou, E., Mitropoulou, P., Michalakelis, C., Nikolaidou, M.: The rise of cloud brokerage: Business model, profit making and cost savings. In: International Conference on the Economics of Grids, Clouds, Systems, and Services. pp. 19–32. Springer (2016)
10. Friedlob, G.T., Plewa Jr, F.J.: Understanding return on investment. John Wiley & Sons (1996)
11. Hanna, N., Dodge, H.R.: Pricing: policies and procedures. Macmillan International Higher Education (2017)
12. Impact, C.S.G.M.R..C.., to 2030, R.: https://www.reportlinker.com/p06009776/Cloud-Services-Global-Market-Report-COVID-19-Impact-and-Recovery-to.html, last accessed: 28.4.2021
13. reserved instances, A.: https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/ec2-reserved-instances.html, last accessed: 6.4.2021
14. on demand instances, A.: https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/ec2-on-demand-instances.html, last accessed: 6.4.2021
15. reserved instances, A.: https://aws.amazon.com/ec2/pricing/reserved-instances/pricing/, last accessed: 6.4.2021
16. Instances, A.E.S.: https://aws.amazon.com/ec2/spot/pricing/
17. Instances, A.E.T.: https://aws.amazon.com/ec2/instance-types/t3/
18. Kampf, R., Majerčák, P., Švagr, P.: Application of break-even point analysis. NAŠE MORE: znanstveni časopis za more i pomorstvo **63**(3 Special Issue), 126–128 (2016)
19. Llorente, I.M.: The limits to cloud price reduction. IEEE Cloud Computing **4**(3), 8–13 (2017)

20. marketsandmarket: https://www.marketsandmarkets.com/Market-Reports/covid-19-impact-on-cloud-computing-market-86614844.html
21. Mei, J., Li, K., Tong, Z., Li, Q., Li, K.: Profit maximization for cloud brokers in cloud computing. IEEE Transactions on Parallel and Distributed Systems **30**(1), 190–203 (2018)
22. Nesmachnow, S., Iturriaga, S., Dorronsoro, B.: Efficient heuristics for profit optimization of virtual cloud brokers. IEEE Computational Intelligence Magazine **10**(1), 33–43 (2015)
23. Platform, G.C.: https://azure.microsoft.com/en-us/
24. Reinhardt, U.E.: Break-even analysis for lockheed's tri star: An application of financial theory. The Journal of Finance **28**(4), 821–838 (1973)
25. Research, Markets: Cloud services brokerage market - growth, trends, covid-19 impact, and forecasts (2021 - 2026), https://www.researchandmarkets.com/reports4591657/cloud-services-brokerage-market-growth-trends
26. Saha, G., Pasumarthy, R.: Maximizing profit of cloud brokers under quantized billing cycles: a dynamic pricing strategy based on ski-rental problem. In: 2015 53rd Annual Allerton Conference on Communication, Control, and Computing (Allerton). pp. 1000–1007. IEEE (2015)
27. Share, I.M.: https://www.statista.com/statistics/258718/market-growth-forecast-of-public-it-cloud-services-worldwide/
28. Shinde, V., Patil, A., Kodre, S., Bhandari, G., et al.: Participation of cloud broker in cloud computing to achieve maximum profit. IJRAR-International Journal of Research and Analytical Reviews (IJRAR) **5**(4), 1109–1112 (2018)
29. Wang, X., Wu, S., Wang, K., Di, S., Jin, H., Yang, K., Ou, S.: Maximizing the profit of cloud broker with priority aware pricing. In: 2017 IEEE 23rd International Conference on Parallel and Distributed Systems (ICPADS). pp. 511–518. IEEE (2017)
30. White, T.B., Yuan, H.: Building trust to increase purchase intentions: The signaling impact of low pricing policies. Journal of Consumer Psychology **22**(3), 384–394 (2012)
31. Zhang, R., Wu, K., Li, M., Wang, J.: Online resource scheduling under concave pricing for cloud computing. IEEE Transactions on Parallel and Distributed Systems **27**(4), 1131–1145 (2015)