Pricing IaaS: A Hedonic Price Index Approach

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Abstract. Infrastructure as a Service (IaaS) is a rapidly expanding model of cloud computing. It includes control of computing resources, such as memory, computing power and storage capacity, satisfying the most fundamental IT needs for businesses on a usage-based payment model. Currently, there is an increased demand for IaaS services, which in turn feeds competition among cloud providers. As the price of cloud services depends on the supported characteristics and cloud providers do not adopt the same pricing model, the study of continuously evolving pricing schemes for such an innovative business model is a challenge. The work presented in this paper focuses on the construction of a price index based on a hedonic pricing model, emphasizing, besides basic functionality features, additional qualitative and quantitative attributes defined the Quality of Services provided. The aim of the study is to determine the importance of each feature and its effect on the final price. This is achieved by constructing the price index with data from 23 well-known IaaS cloud providers taking into account both functional and non-functional attributes of cloud computing services. In addition, a comparison of results between the present findings and our previous work is made, to assess the differences in estimates of each attribute contributory value to the shaping of IaaS pricing function.

Keywords: Cloud computing · Non-functional requirements · Infrastructure-as-a-Service · Pricing models · Hedonic price indices

1 Introduction

In recent years cloud computing has transformed ICT industry and has been established as a significant driver for cost saving and agility. Cloud services have rapidly evolved and have a profound impact on global economy and society. Cloud computing has become a popular computing architecture in IT market and it is composed of three service models:

- Infrastructure as a Service (IaaS), which includes control of fundamental computing resources, such as memory, computing power and storage capacity.
- Platform as a Service (PaaS) that provides control over the deployed applications and possibly configuration settings for developer platforms.
- Software as a Service (SaaS), which includes the use of software services accessed through a web browser or a program interface [1].

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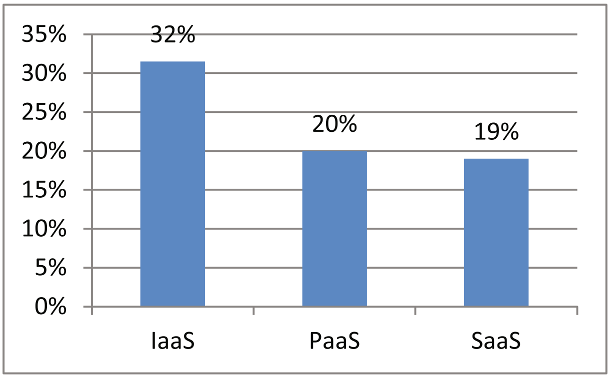

Fig. 1. Worldwide public cloud services forecast (2016–2020) [3].

This paper focuses on IaaS service, since according to Gartner Inc it is expected to present the highest growth in 2018, as shown in Fig. 1. Some key benefits of IaaS are high flexibility, usage-based payment scheme, allowing users to pay what they use as they use it, and the fact that the latest technology is always employed. This way customers can achieve a much faster service delivery [2]. Analytically, IaaS service is expected to grow up to 31.5% and it is estimated to reach $45,5 billion. On the contrary, SaaS service is expected to grow 19%, reaching $55,14 billion and PaaS service will develop 19% reaching 16,6 billion [3].

Commercial success of cloud computing is based on pricing models, provided that pricing models are transparent for both providers and clients. However, pricing schemes usually veil the prices of resources such as CPU, Memory and Storage [4]. Most cloud providers such as IBM, Amazon and Microsoft charge a prominent set of predefined packages, known as pricing bundling strategy [5]. For example Amazon offers compute optimized bundle with 16 CPUs, 122 GB of memory and 320 GB of storage for $1.33 per hour [5]. Consequently, cloud clients having specific requirements are driven to select from the predefined cloud bundles.

Customers' requirements are categorized into functional and non-functional [6]. As far as IaaS is concerned, functional requirements prescribe basic properties as computing power, memory, storage and network access speed. In addition, the Quality of Service (QoS) provided to clients is defined by non-functional requirements related to availability, security, elasticity and usability of cloud computing [7]. Both functional and non-functional features are prescribed in cloud service bundles and priced as an integrated service. However, it is important to estimate the impact of each feature, functional or non-functional, on the cloud bundle price.

Pricing efforts in existing literature often neglect the impact of non-functional client requirements, related to QoS of IaaS cloud bundles. The authors have proposed to use a hedonic pricing model for constructing a price index of IaaS, based on basic functional properties, such as CPUs, memory, storage and OS [8, 9]. Data from 23 cloud providers were collected and processed, based on information provided by Cloudorado cloud comparison engine (https://www.cloudorado.com). The study indicated that cloud pricing policies are heavily based on a subscription, while the cost of using specific resources is usually added to it. The study was based on data collected in 2014. Since then, the bundles offered by IaaS providers have been upgraded and heavily based on non-functional attributes. Thus, in this paper, the same method was applied in current data extracted by Cloudorado, emphasizing service quality attributes related to non-functional requirements, in order to construct the price index. 13 non-functional properties were added to the 4 functional ones. The hedonic pricing method indicates to which extent functional (CPU, memory, storage) and non-functional criteria affect the price [4]. The purpose of this effort is to shed some light in the manner that non-functional properties of IaaS bundles affect the price.

The rest of the paper is structured as follows: Sect. 2 presents a brief literature review of previous work based on pricing methods, while Sect. 3 is a theoretical approach of hedonic price indices. Section 4 introduces non-functional requirements on IaaS service and Sect. 5 describes price index construction by presenting the data collection process of cloud bundles, the methodology and the results. Finally Sect. 6 presents the final conclusions.

2 Literature Review

Nowadays IaaS cloud computing services demand has been increased creating in turn high competition among cloud providers who are not all pursuing the same pricing model. The study of continuously evolving pricing schemes for such an innovative business model is a really interesting task, as there are several cloud services with comparable functionality but usually available to customers at different prices.

The “pay-as-you-go” pricing scheme is commonly used to charge the users only for the services they need, paying for the required computing instances and just for the time they use them and not for what the resources value. If more IaaS resources are required during a task, customers simply ask the provider [10]. Another quite static pricing method is based on the period of subscription, meaning that a fixed price is set for a specific bundle of IaaS cloud services according to a longer period of subscription. As a consequence, users may underpay for the required resources if they use them extensively, but they might overpay if they barely need them [11]. One of the rarest fixed pricing models of cloud services is the one that is totally based on cost, but it is hard to implement. Users are offered the maximum utilization of the provider’s resources and pay for what the resources really value [12].

Although these static pricing schemes of IaaS cloud services have been used from many cloud providers in order to guarantee service level agreement, it is still inevitable to satisfy equally both the cloud vendors’ and cloud users’ requirements. This is the reason why dynamic pricing methods have been widely developed and used. In [13] an optimized fine-grained and fair pricing scheme is studied in order to derive an optimal price that satisfies both customers and providers simultaneously and also find a best-fit billing cycle to maximize social welfare. Rohitratana and Altmann [14] proposed an agent-based simulation of four different pricing models that indicated that the Demand-Driven (DD) pricing scheme was the best approach in ideal cases. A real-time pricing algorithm for cloud computing resources was introduced in [15] that analyzed some history utilization data and found the final price that was mostly beneficial for the provider because it reduced its costs, allowing at the same time resources to be used more effectively. Furthermore, there are some pricing methods that are mostly driven by competitors' prices [16] and some others based on the amount of money customers are ready to pay [17].

Apart from fixed and dynamic pricing of IaaS cloud computing services, another approach that describes price as the result of a multidimensional function shaped by the service's characteristics is the construction of price indices. Especially a price index which is based on a hedonic pricing method, takes into consideration different factors of IaaS cloud computing services trying to estimate the contributory value of each characteristic to the shaping of the total price of a service bundle. Price indices were primarily developed seeking to capture the effect of different attributes to the final pricing in the context of other areas than the cloud computing, such as the environment, the housing market or automobiles and then they have been widely used to more technological areas [18]. The hedonic pricing method has been proposed in [19] to make pricing plans more transparent among cloud providers by analyzing two price comparison methods and in [8, 9] to estimate the importance of each IaaS resource and its effect on the final price.

3 Hedonic Price Indices

Hedonic methods are regression models in which a product price is related to its characteristics, considered as a function of them, linear or non-linear. The main assumption is that a product is a bundle of characteristics and that consumers just buy bundles of characteristics instead of the product itself. A hedonic method decomposes the studied product into its characteristics obtaining estimates of the contributory value of each one.

According to the definition of [19]: "*A hedonic price index is any price index that makes use of a hedonic function. A hedonic function is a relation between the prices of different varieties of a product, such as the various models of personal computers, and the quantities of characteristics in them*". The importance of a price index is that it can be used to determine suggested prices for combinations of the characteristics that were not included, or they were not available, when the index was constructed.

These methods can be used to construct a quality-adjusted price index of a service. An informative overview of the hedonic methods and how they are constructed can be found in [18, 19].

The advantage of this method is that the necessary calculations are easy to implement. Hedonic methods are also very fast to apply but the disadvantage is that index price can change even if no new products exist, or if all prices remain the same. Among the strengths of a hedonic pricing method are that it can be used to estimate values based on actual choices and its versatility, since it can be adapted to consider several possible interactions between market goods and environmental quality.

A hedonic function, which relates a number of the product's characteristics with the corresponding price is:

$$P_i = f(X_i) \tag{1}$$

where P_i is the price of a variety (or a model) i of the considered product and X_i is a vector of characteristics associated with the specific variety. Characteristics may correspond to dummy variables, according to the concept of the study. The hedonic function is then used, for a number of different characteristics among the varieties of the product and the price index is calculated. As soon as the characteristics to be considered are determined then, for N varieties of the product (or service) the following equations must be evaluated:

$$\begin{aligned} P_i &= b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_i, \\ i &= 1, \ldots, N \end{aligned} \tag{2}$$

In this paper, the vector of characteristics X_i, corresponds to the configuration of the IaaS cloud services, including characteristics such as RAM size, number of CPUs, memory size, bandwidth etc., while in the second formulation met in the paper includes the non-functional parameters, participating as dummy variables. The description of these parameters is given in the corresponding section.

4 Non-functional Requirements of IaaS Cloud Services

This section describes all the qualitative characteristics of IaaS cloud bundles which were not considered before in the previous findings in [8, 9] and are now included in the collected price bundles in order to find their effect on the final price. There has been a growing demand and need for a more detailed IaaS cloud services selection process by considering several non-functional and functional criteria.

In general, it is commonly acceptable that non-functional requirements are very important and can be critical for the selection of an IaaS cloud computing bundle of services. This type of requirements usually specifies criteria that can be used to judge some operations of a cloud bundle, rather than specific behaviors. Cloud services selection is an important purchasing activity for many providers and nowadays consumers demand not only cheaper and fully functional services, but also high quality products, on-time delivery and excellent after-sale services. This is the reason why finding a cloud provider with the right quality services at the right price, at the right quantities and at the right time is a very difficult and challenging task. Selection of IaaS cloud services is a multiple criteria decision making (MCDM) problem involving multiple criteria that can be both qualitative and quantitative [7, 20].

Every non-functional requirement is actually an attribute of an IaaS cloud bundle. The required overall non-functional parameters of the IaaS cloud computing services include security, availability, portability, scalability and usability and each one of them constitutes a different category with corresponding attributes, as shown in Table 1. The hedonic price index of this study is constructed with data collected from the Cloudorado platform for 13 non-functional requirements [20].

Table 1. Non-functional requirements.

Requirement	Attributes	Description
Security	Encrypted Storage	*The storage volume is encrypted*
	Safe Harbor/EU Directive 95/46/EC	*The provider is compliant with EU Directive 95/46/EC on the protection of personal data. For US companies' compliance with Safe Harbor principles is checked*
Availability	Service Level Agreement (SLA) Level	*The SLA level expressed (regardless of past performance), in percentage points of availability.*
	Backup Storage	*Storage-based backup is available*
	Free Support	*Support cost is included in the price of the basic plan; any other additional support beyond the basic plan is paid*
Elasticity/scalability	Burstable CPU	*The CPU allocation can be either fixed or can burst to a higher capacity if current conditions allow it*
	Auto-scaling	*Vertical: adding more resources to a server, such as disk space, RAM or processing units. Horizontal: adding more servers*
	Resource usage Monitoring	*There are integrated monitoring solutions offered by cloud providers, so that users can monitor current resource utilization (i.e. CPU, RAM, disk, network etc.) in their cloud servers for no additional cost*
Usability/Portability	Web Interface	*A web management interface is available.*
	API	*An API management is available for automating cloud servers and interacting with them*
	One Account for All Locations	*There is one account and single interface to manage all different locations or a separate account for each location*
	Image from Cloud Server	*A provider supports creating an image from an existing VM and then deploying it to other cloud servers*
	Limited Free Trial	*A free trial of cloud services is offered for a limited period of time or for a certain amount of credit to be spent on cloud services, so that customers can use it to run tests*

5 Price Index Construction

Data collection is based on Infrastructure as a Service (IaaS) which is the most straightforward service of the service models for delivering cloud services. Cloudorado [21], a cloud computing platform that offers cloud computing comparison service was used for data collection. Cloudorado accepts customers' functional requirements of cloud computing such as compute power, storage, memory, operating system and returns a comparison of different but equivalent cloud services. In addition, the platform has been updated and supports non-functional requirements such as security, reliability and cloud management features.

The collection of cloud bundles is specified by functional and non-functional criteria, meaning that each bundle of IaaS services includes resources such as memory (RAM), storage, compute power (CPU) and operating system (OS) that constitute the functional attributes and 13 non-functional features, as described in Sect. 4. The considered values of all these features are shown in Table 2.

Table 2. The values of functional and non-functional attributes of IaaS bundles.

Requirements category	Attributes	Values
Functional requirements	CPU (v cores)	1x, 2x, 4x, 8x, 16x, 32x
	RAM (GB)	2, 4, 8, 16, 32, 64, 128, 256
	Storage (GB)	50, 100, 200, 500, 1000, 2000, 5000, 10000
	OS	Linux/Windows
Non-functional requirements	Encrypted Storage	Yes/No
	Safe Harbor/EU Directive 95/46/EC	Yes/No
	SLA	99.90%/99.95%/99.98%/99.99%/ 100%
	Backup Storage	Yes/No
	Free Support	Yes/No
	Burstable CPU	Burstable/Fixed
	Auto-scaling	None/Vertical/Horizontal/Both
	Resource usage Monitoring	Yes/No
	Web Interface	Yes/No
	API	Yes/No
	One Account for All Locations	Yes/No
	Image from Cloud Server	Yes/No
	Limited Free Trial	Yes/No

The total number of collected price instances is 806 and bundles are derived from 23 providers, shown in Table 3. The dataset was collected by selecting specific computing requirements (e.g. 2xCPU, 4 GB RAM, 50 GB Storage, Linux etc.) but these criteria were not fulfilled by all cloud providers, therefore the number of the collected price bundles of each provider may vary.

At first the price index construction is based on cloud bundles that include only functional parameters. Then, the dataset was enlarged by adding non-functional features, in order to examine and highlight the influence of non-functional requirements on

Table 3. Cloud IaaS providers.

Providers	
Microsoft Azure	Stratogen
Amazon	eApps
Google	Data Dimension
CloudSigma	CloudWare
Atlantic.net	ZippyCloud
M5	Exoscale
Elastichosts	Vps.net
Bitrefinery1	Dreamhost
Storm	Zettagrid
RackSpace	CloudSolutions
e24cloud.com	Gigenet
Joynet	

the price. The hedonic model's parameters were estimated by the use of the ordinary least squares (OLS).

5.1 Price Index Construction Based on Functional Requirements

IaaS characteristics (CPU, RAM, STORAGE and Operating System - OS) participate as independent variables in the hedonic pricing model. The operating system parameter (OS) participates as a dummy variable having the value of 0 for Linux based systems and 1 for Windows.

The price index construction estimated the following parameters and equation and the corresponding results of the hedonic pricing method are summarized in Table 4:

Table 4. The contributory value of each functional attribute.

Coefficients	Values
Constant	242,04***
CPU	21,37***
RAM	16,32***
Storage	0,09*
OS	15,12***

***p < .01, **p < .05, *p < .1, n.s. not significant.

$$\text{Price}\ (\$) = 242,04 + 21,27 * \text{CPU} + 16,32 * \text{RAM} + 0.09 * \text{STORAGE} + 15,12 * \text{OS} \quad (3)$$

The regression model accounts for a 37,1% value of R^2 indicating that the model does not succeed in describing the variance of the mode and construct an effective price index, According to the model results, the Constant, which corresponds to a fixed annually fee, contributes more to the price index, followed by the CPU and the RAM size. The operating system selection is also of importance and, finally, the storage size presents the lowest contribution to the price index, therefore it does not particularly affect the price.

5.2 Price Index Construction Based on Functional and Non-functional Requirements

In this analysis, IaaS resources (CPU, RAM, STORAGE) and the operating system (OS) attribute are the functional characteristics which participate as variables in the hedonic pricing model in combination with all the other aforementioned non-functional parameters that take part as dummy or discrete variables. The Subscription characteristic is considered to have a fixed value, meaning 'Annual Subscription' like before and the 'Web Interface' attribute is also checked but is always equal to 'Yes' since all cloud companies provide it. The estimated parameters of the price index construction are presented in descending order, as shown in Table 5.

Table 5. The contributory value of each functional and non-functional attribute.

Coefficients	Values
Constant	165,5***
Safe Harbor/EU Directive 95/46/EC	50,62***
Image from cloud server	28,28**
Burstable CPU	27,09***
One Account For All Locations	25,68***
Encrypted storage	17,30***
OS	14,24***
RAM	13,45***
CPU	11,98*
Support included	8,71*
Auto-scaling	4,07***
API	2,95*
SLA Level	1,33**
Back-up storage	1,29*
Resource usage monitoring	0,84*
Storage	0,12***
Limited free trial	0,06*

***p < .01, **p < .05, *p < .1, n.s. not significant.

The calculated R^2 value equals 73,8%, meaning that a much higher percentage of variance is described by this model. It is known that the more variance that is accounted for by the regression model the closer the data points will fall to the fitted regression line [18]. More specifically, in this case all parameters are significant and they contribute to the shaping of the price. The requirement that decides whether a cloud provider is compliant or not with EU Directive 95/46/EC on the protection of personal data or with Safe Harbor principles for US companies seems to be a crucial non-functional parameter, that justifies why security is one of the most important user concerns in the context of cloud computing. Storage does not affect the price very much, which also supports the finding of the previous price index, which was based only on functional parameters. Furthermore, the requirement of portability, in other terms the possibility to create an image from an existing VM and then deploy it to another and the existence of one account to manage all different locations, affects pricing at a high level resulting in reduction of price of the bundles by a factor of more than 25.

6 Conclusions

The work performed in this paper focuses on the construction of a price index based on a hedonic pricing model, following and updating the findings of our previous work [8, 9] focused on functional features, such as CPU, memory and storage space, by including non-functional characteristics describing the Quality of IaaS cloud computing model. The hedonic pricing method was evaluated using data from 23 IaaS cloud providers, corresponding to more than 800 price bundles taking into account 4 functional and 13 non-functional properties of cloud computing services.

The aim of this empirical study was to estimate the importance of each feature and its effect on the final price. According to the derived results and the construction of the corresponding index, apart from the constant parameter, which indicates the importance of the subscription in the pricing scheme, the high values of non-functional features indicate that they affect the price more than functional ones. Security, being represented from ‘compliance with Safe Harbor/EU Directive 95/46/EC’ and ‘encrypted storage’ attributes, and portability, consisting of ‘Image from cloud server’ and ‘One account for all locations’ are of substantial importance. In addition, the possibility of whether the CPU allocation can burst to a higher capacity or not is quite significant. However, the storage and limited free trial parameters seem to affect less the final pricing of cloud bundles of services. As a next step, we plan to investigate further the importance of non-functional features in constructing cloud bundles of service and the contribution of each of them in determining the cost for the providers themselves. It seams that non-functional features, as for example security and portability, are more costly for the providers, that functional ones, as for example storage.

The existence of a price index for the IaaS cloud services, as highlighted in this work, can provide very useful information, not only about business plans and pricing methods but also regarding the market of cloud itself and helping to guide investment. Several qualitative features of IaaS cloud bundles were included the price index construction in order to find their importance and effect on the final price. The results indicate that non-functional requirements are very important and considered critical by clients for the selection of an IaaS bundle of services. Finding a cloud provider with the right quality services at the right price, at the right quantities and at the right time is a very difficult and challenging task involving multiple criteria that can be both qualitative and quantitative.

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