

Pricing cloud IaaS services based on a Hedonic Price Index

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Abstract: Cloud computing, as an innovative business model, has experienced rapid diffusion across the international business world, offering many benefits to both the demand and the supply side of the ICT market. In particular, the public cloud approach receives more attention and the Infrastructure as a Service (IaaS) model is expected to be the fastest growing model of public cloud computing, as it is considered to be a very good solution for companies needing the control of fundamental computing resources, such as memory, computing power and storage capacity. Currently, the battle for a dominant market share grows the competition among cloud providers and leads to the development of new pricing schemes, in order to meet the market demand. However, the choice of the cheapest cloud hosting provider depends exclusively on the clients' needs and this is why prices for cloud services are a result of a multidimensional function shaped by the service's characteristics.

Into that context, this paper summarizes the findings of an initial work on the construction of a price index based on a hedonic pricing method, taking into account different factors of IaaS cloud computing services, including two of the most important players in the cloud market, Google and Microsoft Azure. The aim of this study is to provide price indices both on a continent level and globally, in an effort to investigate differences in pricing policies in different marketplaces. Comparing the results leads to important conclusions related to pricing policies of IaaS cloud services.

1 INTRODUCTION

During the recent years, cloud computing has experienced a rapid and high diffusion across the international business world as there is an increased demand for a new business model that can assist companies in responding faster and cheaper to their constituents' needs, worldwide. Cloud systems and services are being improved and developed at a fast pace, offering operational and economic benefits to both the demand and the supply side of the ICT market, contributing substantially at the same time to the creation of a global competitive environment [1].

Therefore, cloud computing is considered as a really powerful technological tool and an innovative business model, 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 and
- Software as a Service (SaaS), which includes the use of software services accessed through a web browser or a program interface [2].

In addition to these, cloud computing has also four deployment models:

- Private cloud, provisioned for exclusive use by a single organization;

- Community cloud, used exclusively by a specific community of consumers from organizations that have shared concerns;
- Public cloud, open for use by the general public and
- Hybrid cloud, which is a composition of two or more distinct cloud infrastructures [2].

Concerning the above models, public cloud computing receives more attention and the IaaS model gains increased adoption across the business world [3]. More specifically, IaaS, which is a foundational cloud delivery service and the most straightforward of the cloud models, provides flexibility and can be a very good solution for companies needing computing resources in the form of virtualized operating systems, workload management software, hardware, networking, and storage services [4]. Computational power and operating systems are delivered to the customers in an “on-demand” approach. An enterprise that migrates its IT system to IaaS may hire the required resources as needed, instead of buying them [2]. According to Gartner’s latest report about the public cloud [3], it is expected that IaaS will be the fastest growing area of public cloud computing achieving a compound annual growth rate (CAGR) of 41.3% through 2016, as Figure 1 illustrates.

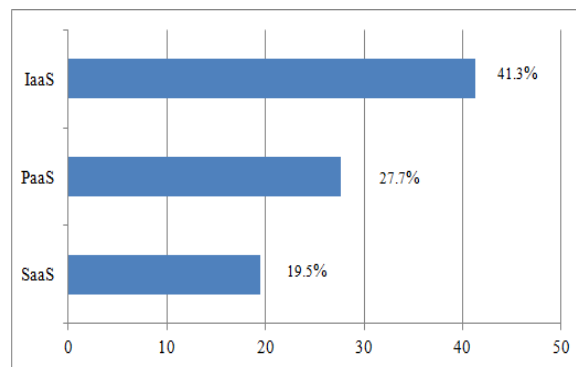


Figure 1: Public Cloud Services - five year (2011-2016) CAGRs (%), by model. Source: Gartner (February 2013)

Currently, there are several public cloud providers in the cloud market providing similar services to customers. A client's choice of which cloud company would host his infrastructure-related services in the long-term depends jointly on the price it has, the Quality-of-Service (QoS) guarantees it offers to its customers and the satisfaction of the advertised guarantees [5,6]. Cloud computing works, in general, on a “pay-as-you-go” basis, giving the option to the user to pay for what they use; meaning that the customer is charged for each computing resource (e.g. RAM, CPU, storage) separately, usually per unit-hour [7]. On the other hand, it is true that the battle for a dominant market share grows the competition among cloud companies and leads to the development of new pricing schemes in order to meet the market demand. As a result, several packages of different resources are offered in attractive tariffs and they are continually fitted to the changing preferences and increasing needs of customers. Furthermore, there is an option somewhere in the middle, as there are some cloud providers who offer predefined sets of some resources, usually memory and CPU are bundled, whereas users can select simultaneously on their own some other computing characteristics, such as storage size [7,8].

Finding the right combination of the available resources is critical for a business to achieve the best value when creating its own cloud bundle of services. As any bundle consists of various characteristics, valued differently by each consumer, there are a number of questions that arise in the cloud computing context, such as:

- How customers’ choices and preferences for IaaS affect the pricing of the corresponding resources.
- Which characteristics are truly independent from one another, while at the same time being the most important for shaping the pricing of IaaS.
- How each characteristic’s influence changes over time, or region, or in any other way.

For this reason, many cloud providers have already developed cost estimator tools, used to help customers evaluate IaaS services, deciding the most suitable combinations for their needs. They are mainly based on asking users some questions about the amount of computational power, memory, storage requirements, data transfer and they subsequently offer a monthly estimate for price for the selected bundle [4]. However, none of these tools is capable of identifying the cheapest cloud hosting provider due to the fact that this is a choice that depends exclusively on the clients’ computing needs and, furthermore, price is considered to be a multidimensional function, where many factors should be taken into account [6].

Into that context, this paper summarizes the findings of our initial work, presented in [9], seeking to describe the mechanism of pricing in the IaaS cloud market. The outcome was the construction of a price index based on a hedonic pricing method, taking into account different factors of IaaS cloud computing services. Towards this direction, the present study extends the analysis of IaaS pricing including two of the most important players in the cloud market, Google and Microsoft Azure and providing price indices globally as well as on a continent- based level. This constitutes an effort to investigate differences in pricing policies in different marketplaces, especially in USA and Europe. Comparison of the results leads to interesting conclusions related to pricing policies of IaaS cloud services.

The rest of the paper is structured as follows: Section 2 presents a brief literature review of the previous work regarding the pricing methods of cloud computing, while in Section 3 there is a theoretical approach of hedonic functions analysis and price indices. The empirical study and the evaluation of hedonic regression model together with discussion are described in Section 4, and finally, Section 5 concludes, providing directions for future research.

2 PRICING MODELS OF CLOUD COMPUTING

In the cloud computing environment, an Infrastructure-as-a-Service (IaaS) demand describes an access to system resources, mainly CPU, memory and disk. Resource allocation and offering is a really challenging task because of the existence of different pricing models. In general, cloud hosting providers must follow a suitable pricing model that does not bring any loss to neither the provider nor the consumer and tends to maximize the social surplus of the market. It is not usually easy to reach a point where both sides agree with the price set. A user is always willing to pay a lower price for the resources requested, whereas a provider should not want to go beyond the lowest price that gives him no profit [8]. This is the main reason why the cloud broker is considered to be a significant part of [the cloud computing](#) business model [10]. Being the middleman between users and providers the broker aims to succeed in settling the best financial agreement, making a profit out of this service [11].

Currently, there are many cloud vendors that follow a fixed pricing strategy, meaning that customers pay for what they use but not for what the cloud services value [5]. One of the most common pricing schemes of this category is the “pay-as-you-go” model, which charges the users for just the services they need, paying only for the required computing instances and just for the time they use them. In the case they need more resources, they simply request them from the provider [12], or the broker, who can buy on-demand instances [13]. Another fixed pricing model is based on subscription, setting a standard price for the required resources according to a longer period of subscription [14,13]. However, these static approaches of pricing have some limitations, due to the fact that they reserve computational resources in advance and it is often hard to satisfy the cloud vendors’, cloud brokers’ and cloud users’ requirements.

Hence, dynamic pricing is usually the key solution to the above problems. According to this approach, the price for each bundle of resources is based on a number of factors, such as availability, time, the service features and according to the forces of the demand and supply of a real-time market [8,14]. Mihalescu and Teo [15] proposed such an auction-based pricing strategy for federated clouds, in which resources are shared among many cloud service providers. Rohitratana and Altmann [16] used 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. Li et al [17] introduced a real-time pricing algorithm for cloud computing resources. They analyzed some history utilization data finding 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. Moreover, there are some pricing methods that are mostly driven by competitors’ prices [18] and some others based on the amount of money users are ready to pay [19]. All of the above pricing methods are fair enough for the customers’ side.

Both of the above categories of pricing models, especially the dynamic one, take into consideration some of the most important characteristics of the service. The construction of price indices is generally used for this purpose, seeking to estimate the extent to which each characteristic affects the total price of a service bundle. Among the most common and widely used approaches is the hedonic pricing method [20]. It was primarily developed seeking to capture the effect of environmental and housing attributes in the context of the housing market [21] and to adjust for quality change for automobiles [22]. In [23] a price index for paintings, based on regressions using the full set of sales, was constructed and the idea that goods are valued for their utility-bearing characteristics can be found in [24]. As far as information and communication technologies are concerned, hedonic price indices have been widely used for personal computers [25,26] taking quality changes

into account and for microcomputers and printers using evidence from France [27]. A hedonic pricing approach has been also proposed in [28] to estimate price evolution of telecommunication services based on data across Europe and in [6] Siham et al applied the hedonic pricing method in order to make cloud pricing plans more transparent.

3 HEDONIC PRICE INDICES

Hedonic methods refer to regression models in which a product's (or a service's) prices are related to product characteristics and the observed price of a product (service) is considered as a function of these characteristics. The main assumption hedonic methods are based on, is that a service is a bundle of characteristics and that consumers just buy bundles of product characteristics instead of the product itself. A hedonic method decomposes the item being researched into its constituent characteristics, and obtains estimates of the contributory value of each characteristic, provided that the composite good can be reduced to its constituent parts and that the market values those constituent parts.

According to the definition provided in [20]: "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".

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 [29,20]. Moreover, as shown in [24] consumer chooses from a large number of product varieties without having the ability to influence prices. As a consequence, consumers maximize utility and producers maximize profits. In hedonic studies it is possible to adjust the price of a service for its quality not quantity. All of them are based on some estimated coefficients that are inflicted on the characteristics of the products in two periods; m and $m + 1$. It is possible to estimate the coefficients separately, for each evaluate period of time, or consider the observations of two or all periods together and estimate a common set of coefficients, seeking to reveal the general trend.

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.

The hedonic price indices are commonly used as approximations to find how much money a consumer would need in period $m+1$ relatively to the amount of money required in period m , keeping the same level of utility. The solution to this problem is to determine the consumer's profile and his reaction to a varied and fast-changing supply of products. The main problem towards this direction is that each consumer has potentially different needs and requirements No matter what profile is decided, it will be a hypothesis and an assumption that will correspond to a specific model. In addition to this, a consumer's desire is not stable, something quite reasonable since there is a great offer as technology becomes cheaper and more attractive.

A hedonic function $f(X)$, which relates a number of the product's characteristics with the corresponding price as:

$$P_i = f(X_i) \quad (1)$$

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. 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:

$$P_i = b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_i, \quad (2)$$

$$i = 1, \dots, N$$

where b_i are the regression coefficients that have to be estimated and e_i is the regression residual of the assumed functional form. The regression coefficients value the characteristics and they are often called implicit prices,

because they indicate the prices charged and paid for an increment of one unit of the corresponding characteristic. Implicit prices are much like other prices, they are influenced by demand and by supply. In some cases the natural logarithm (ln) of the price is considered, instead of the actual value. Furthermore, the functional form of the index can be nonlinear.

In the case that the prices span between two (or more) periods of time m and $m + 1$, the equations to be evaluated are

$$P_{im} = b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_{im}, \quad (3)$$

$$i = 1, \dots, N$$

$$P_{im+1} = b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_{im+1},$$

$$i = 1, \dots, N$$

In the context of this work, the vector of characteristics X_i , corresponds to the configuration of the IaaS cloud services assumed to affect the price, including characteristics such as RAM size, number of CPUs, memory size, bandwidth etc. The description of these parameters is given in the next section. As also assumed in the relevant literature, in hedonic regression the independent variables are chosen among the ones that include performance-related product and service attributes, which represent not only value to the consumer but also resource cost to the producer.

Moreover, the functional form adopted for the evaluation of the hedonic regression is the linear, since it is usually preferred in the hedonic theory, mainly due to the fact that linear functions are easy to estimate and interpret and despite the fact that for products such as high-tech goods, the loglinear model may be used, among as it most likely reduces the problem of as prices tend to be log-normally distributed.

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.

4 PRICE INDEX CONSTRUCTION

This section describes the empirical study design, contains the evaluation of the hedonic price index methodology for cloud computing services, the construction of a corresponding index and discussion of the results.

The price index is constructed for the IaaS cloud computing, the most straightforward cloud service. Data collection was based on Clouddorado (<http://www.clouddorado.com>), a price comparison service of cloud computing providers. Clouddorado is also a price calculator for multiple cloud hosting providers, since the comparison is performed by calculating price for individually set server needs. The platform allows to preselect basic user specifications, such as required processor computing capabilities, memory or storage and returns a ranking based on that [30]. It currently focuses on providing pricing bundles for IaaS providers. According to Clouddorado's founder, Marcin Okraszewski [31], the task of comparing manually all the providers is very hard for the companies and it can take days or even weeks. This is the reason why Clouddorado is always up to date, so that businesses are able to make even better decisions and finally be successful.

. The number of the collected price bundles, shown in Table 1, is 2742, out of 26 providers, including Google and Windows Azure, which were not considered in [9].

Not surprisingly, the most popular geographical continent for providers is North America, with 21 out of the 26 to have datacenters located there, followed by Europe, with 16 providers. Australia and Asia follow with 8 providers, each one, South America with 4 providers and Africa comes last with just 1 provider.

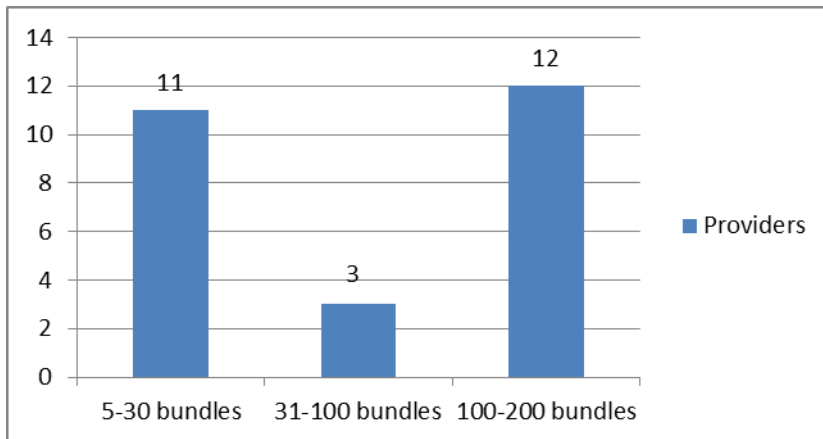
Table 1: Cloud IaaS providers

Providers	Location
Amazon	N. America, Europe, Asia, Australia, S. America
atlantic.net	N. America, Europe
Bitrefinery	N. America,
CloudSigma	N. America, Europe
Dimensiondata	N. America, Europe, Asia, Australia, S. America, Africa

eApps	N. America,
ecloud24	Europe
Elastichosts	N. America, Europe, Asia, Australia
Exoscale	Europe
GIGENET	N. America,
GOGRID	N. America, Europe
Google	N. America, Europe, Asia
HYVE	N. America, Europe, Asia
JoyentCloud	N. America, Europe
Lunacloud	Europe
M5	N. America,
Ninefold	N. America, Australia
OPENHOSTING	N. America,
Rackspace	N. America, Europe, Australia
SERVERMULE	Australia
Storm	N. America,
StratoGen	N. America, Europe, Asia
Terremark	N. America,
VPSNET	N. America, Europe, Asia, Australia, S. America
Windows Azure	N. America, Europe, Asia, Australia, S. America
Zettagrid	Australia

As mentioned above, the price bundles of the hedonic method are extracted from 26 providers. The criteria that the bundles were based on were not fulfilled by all cloud providers, therefore the number of the collected price bundles of each provider varies. Figure 2 below depicts the number of providers that correspond to a specific range of bundles.

Figure 2 Number of providers per range of price bundles



The price bundles are specified by the resources presented in Table 2, together with the considered values. These characteristics participate as variables in the hedonic pricing model.

Table 2: IaaS characteristics.

Characteristic	Description	Values
CPU	CPU power	2x, 4x, 6x / 3x, 5x, 7x
RAM	RAM size in Gigabytes (GB)	1, 4, 16, 32

Storage	Measured in GB	100, 1000
Transfer_Out	Number of bytes sent by server to Internet per month. (GB)	5, 10000
OS	Operating System of the server	Linux, Windows
Subscription	Indicates if there should be a subscription	No, Yes (corresponds to 1 year subscription)

Data correspond to the IaaS services offered by cloud providers based on different pricing models. The study started by selecting specific computing requirements (e.g. 2xCPU, 1GB RAM, 50GB Storage, 5GB Transfer-Out, Linux) but due to the fact that many of the providers (e.g. Amazon, Rackspace, GoGrid) use price bundling, the closest to each customer's needs package of resources, was considered every time (<http://www.cloudorado.com>). Prices range between \$31 and \$3,318 per month and there are observable differentiations depending on the existence of a subscription, while the duration of the subscription does not affect the price substantially. The operating system parameter (OS) and the subscription characteristics participate as dummy variables. The values for the OS are 0 for Windows and 1 for Linux and, regarding the subscription, corresponding values are 0 for no subscription and 1 for a subscription.

Among the limitations of the collected dataset is that there are a few more characteristics participating in the construction of the price bundling, which were not considered into this study. These characteristics are the Transfer In (the number of bytes received by server from the internet per month), the Time On (proportion of the day the server is available) and the option that the CPUs, the RAM and the storage can be distributed among more than one physical server. The value of the Transfer In characteristic does not contribute at a substantial level to the shaping of the pricing bundles, because many cloud providers such as Amazon and ecloud24 charge customers only for the outgoing traffic and the others include it as a small amount in the total price of services. Therefore, with no loss of generality, the Transfer In attribute was considered to be at 1GB per month. As far as Time On is concerned it was set at a level of 100% availability per day. Finally, the default offered value of non-distributed resources was considered.

The hedonic model's parameters were estimated by the use of ordinary least squares (OLS) and the derived equation is presented below:

$$Price (\$) = 83,8 + 27,7 * CPU + 0,223 * Storage + 18,7 * RAM + 25,8 * OS + 0,08 * Transfer Out - 75,3 * Subscription \quad (4)$$

The results of the hedonic pricing method are summarized in

Coefficients	Value
Constant	130,499***
CPU	14,532**
Storage	0,249***
RAM	20,434***
OS	-16,91
Transfer_OUT	0,076***
Subscription	-85,82

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

The calculated R^2 value is 57,5%, indicating that although a great portion of the uncertainty is described by the model, the linear form of the model may not be the most appropriate to describe the pricing index and alternative formulations could also be considered, which constitutes a direction for future research.

As observed, all parameters are significant and they contribute to the shaping of the price. Subscription is the parameter contributing more to the price index, followed by the CPU and the RAM size. The high value of the constant, which represents a fixed monthly fee, supports the finding that the subscription is a crucial parameter. Storage does not seem to affect the price very much. The choice of the operating system affects pricing at a high level, since Windows increases the price of the bundles by a factor of 25.79.

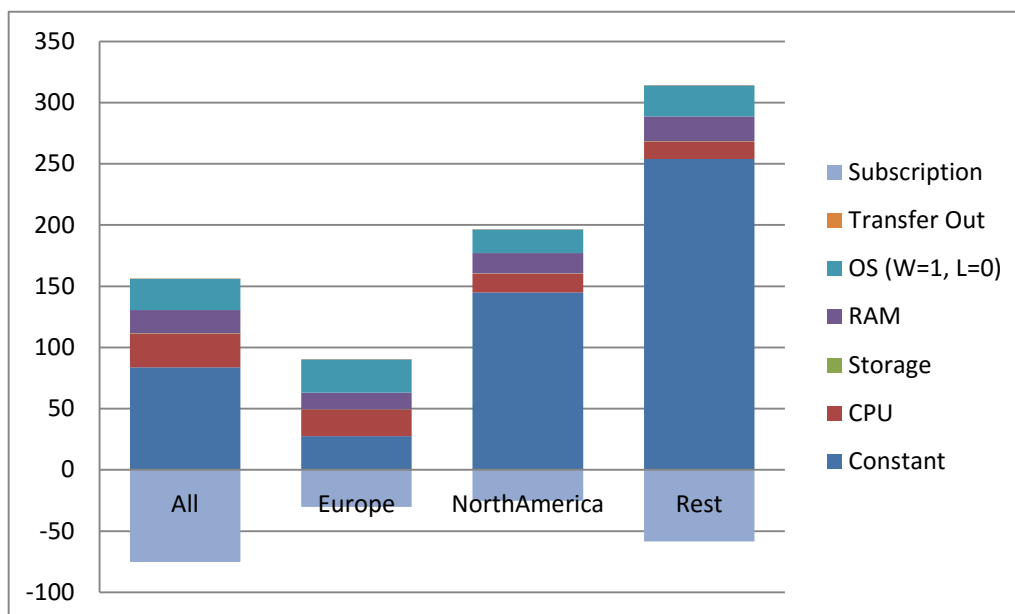
Apart from the price index over the whole dataset, three more indices were constructed, based again on the linear hedonic model. The first of them corresponds to the European offered bundles, the second to those of North America and the third to the rest of the world. Corresponding results are presented in Table 3.

Table 3: Regional Price Indices

Coefficients / R^2	Europe / 52,9%	North America / 55%	Rest / 86.3%
Constant	27.5	145	254
CPU	21,97	15.3	14.3
Storage	0.0595	0.311	0.159
RAM	13,5	16.6	20.2
OS	27,3	19.1	25.5
Transfer_OUT	0.0504	0.08	0.157
Subscription	-0.3	-25.4	-0.9

The main differences among the results of the linear hedonic model across regions and the whole dataset are graphically illustrated in Figure 3.

Figure 3 Contribution of the coefficients to the shaping of price by continent



Among the most important findings is the value of the constant and the differentiations it reveals across the datasets. More specifically, in Europe with 402 bundles in total, the constant has the lowest value equal to 27.5, whereas in North America with 544 bundles it amounts 145 and in the rest of the world where there are 288

bundles of 20 different cloud vendors its value is estimated to 254. In other terms, the standard amount of money per month that European providers impose does not affect the price of IaaS computing services as much as it does in the other continents. However, the low value of the constant may be the main reason for the low value of R^2 , indicating that Europe still lacks from a coherent way of pricing, and each provider follows its own pricing scheme. This is in accordance with the higher value of R^2 in North America, where at the same time the constant has an also higher value, as well as in the Rest of the world dataset, where R^2 has an observably higher value, together with an observably higher constant. This finding can lead to the conclusion that the cloud IaaS market is not mature yet to operate according to a competitive pricing model and the existence of a subscription is of paramount importance for the providers. For all of the continents, CPU, RAM and OS are among the most important characteristics, with the CPU having an observably higher impact in Europe, where RAM has a lower impact, as compared to the rest. As far as the storage size is concerned, this is a more important parameter mainly in North America than anywhere else. Traffic is more valued in the Rest dataset, since the *Transfer_OUT* parameter has a higher value than the other datasets.

5 CONCLUSIONS

Following an earlier work of the authors [9], a price index for the Infrastructure as a Service cloud computing services is developed, based on the hedonic pricing method and the linear model. The data were collected for a number of 26 providers, corresponding to more than 2700 price bundles. Information about cloud vendors on a continent level is also provided, together with a detailed comparison.

The results indicate that, apart from the constant parameter which indicates the importance of the subscription, a finding that is also supported by the high value of the subscription parameter, the CPU and the RAM size are also of substantial importance and significance. On the contrary, the storage and the transfer out parameters seem to affect the pricing procedure less.

As in most cases, there are some certain limitations in this work, which in turn constitute its further extension and indicate directions for future research. Among them is the use of non linear functional forms in the hedonic formulation, seeking to improve the accuracy of the pricing index. The value of R^2 achieved indicate that it would be worth testing. Apart from the general price index considering price bundles across all providers, the construction of an index for each provider would be of particular interest, mainly for comparison reasons.

The construction of price indices for the other cloud computing models, namely the software as a service (SaaS) and the Platform as a Service (PaaS), where literature has little to present, would be another important, as well as interesting, research direction.

In any case, the existence of a price index for the cloud services can provide very useful information, not only regarding the pricing schemes but also regarding the market of cloud itself and could suggest optimal pricing approaches of the cloud services.

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