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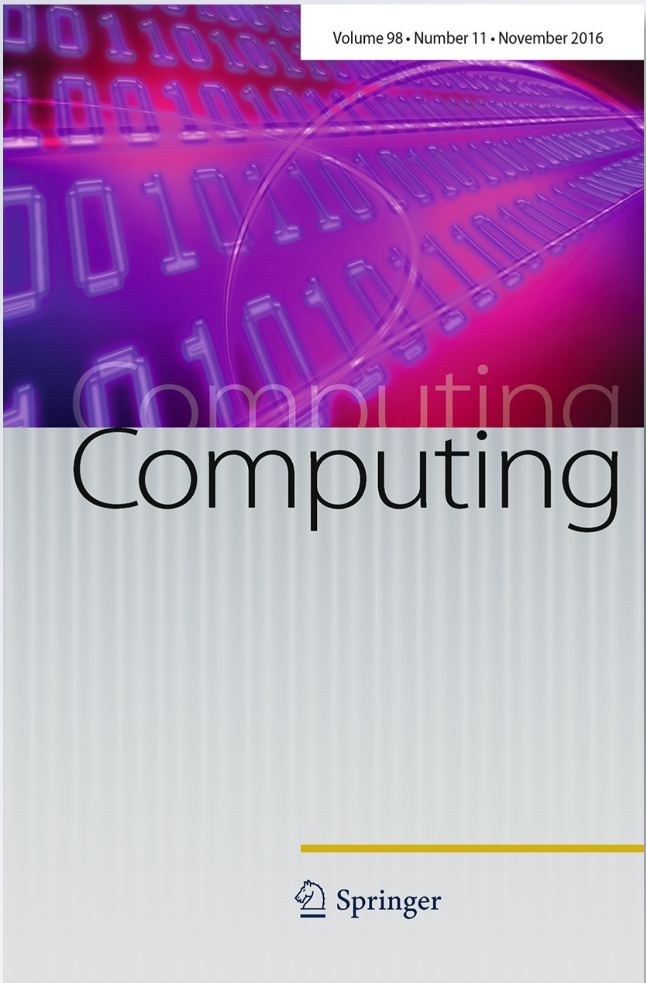

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Pricing cloud IaaS services based on a hedonic price index

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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 multi-dimensional 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

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different marketplaces. Comparing the results leads to important conclusions related to pricing policies of IaaS cloud services.

Keywords Cloud computing · Infrastructure-as-a-Service · Pricing models · Hedonic price indices

Mathematics Subject Classification Primary 91G70 · Secondary 62P20

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 Fig. 1 illustrates.

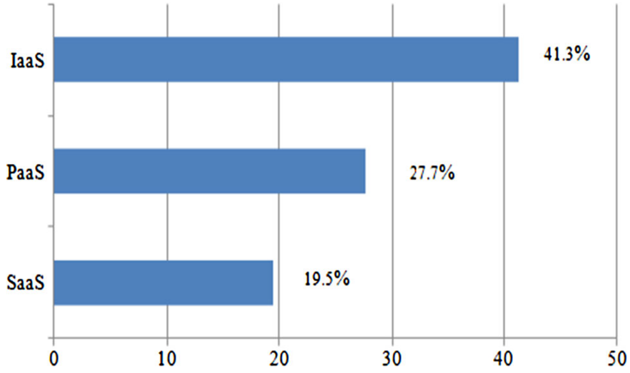

Fig. 1 Public Cloud Services—5 year (2011–2016) CAGRs (%), by model. Source: Gartner (February 2013)

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: Sect. 2 presents a brief literature review of the previous work regarding the pricing methods of cloud computing, while in Sect. 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 Sect. 4, and finally, Sect. 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 usually decide the fee for availing cloud services and 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 [10]. 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]. On the other hand, even though the cost of such services is in general nominal given a high quality and may not be a big burden for an occasional user, however businesses that need cloud services on a continuous basis at a certain fee might finally have more expenses in using them compared to owning the required infrastructure itself [10]. This is the main reason why the cloud broker is considered to be a significant part of the cloud computing business model [11]. 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 [12,13].

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 is highly applicable to IaaS services. This pricing scheme charges the users according to the resources they request such as CPU time, disk space and network traffic. Clients pay only for the required computing instances and just for the time they use them, while cloud providers balance their costs and improve their revenues.

In the case they need more resources, they simply request them from the provider [14], or the broker, who can buy on-demand instances [15]. Another fixed pricing model is based on subscription, setting a standard price for the required resources according to a longer period of subscription [15,16]. 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 [8,16]. In [10] Sharma and Thulasiram studied the effects of quality of service, rate of depreciation, rate of inflation and capital investment on the price of cloud services resulting in their own cloud pricing architecture that did the mapping between these parameters and the appropriate pricing models. Mihailescu and Teo [17] proposed such an auction-based pricing strategy for federated clouds, in which resources are shared among many cloud service providers. Bonacquisto and Modica discussed about the use of alternative auction-based mechanisms and the sale of "residual" computing capacity [18]. Rohitratana and Altmann [19] 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. [20] 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 [21] and some others based on the amount of money users are ready to pay [22]. 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 [23]. It was primarily developed seeking to capture the effect of environmental and housing attributes in the context of the housing market [24] and to adjust for quality change for automobiles [25]. In [26] 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 [27]. As far as information and communication technologies are concerned, hedonic price indices have been widely used for personal computers [28,29] taking quality changes into account and for microcomputers and printers using evidence from France [30]. A hedonic pricing approach has been also proposed in [31] 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 [23]: "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 [23,32]. Moreover, as shown in [27] 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:

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

where Pi is the price of a variety (or a model) i of the considered product and Xi 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 Nvarieties of the product (or service) the following equations must be evaluated:

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

where $bi\psi$ 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

$$\begin{aligned} P_{im} &= b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_{im}, \quad i = 1, \ldots, N \\ P_{im+1} &= b_0 + b_1 \cdot X_{1i} + b_2 \cdot X_{2i} + e_{im+1}, \quad i = 1, \ldots, N \end{aligned} \tag{3}$$

In the context of this work, the vector of characteristics Xi, 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 Cloudorado (http://www.cloudorado.com), a price comparison service of cloud computing providers. Cloudorado is also

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

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 [33]. It currently focuses on providing pricing bundles for IaaS providers. According to Cloudorado's founder, Marcin Okraszewski [34], 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 Cloudorado 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 [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.

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.

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.

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 Tranfer-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 \$3318 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

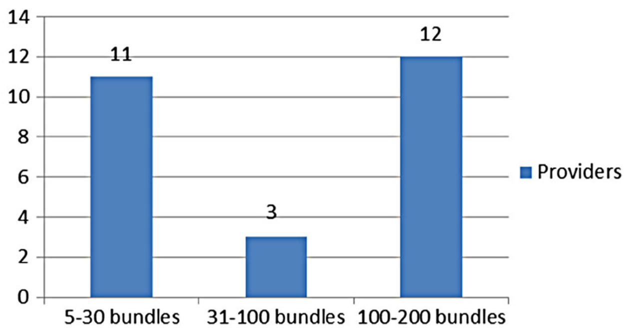

Fig. 2 Number of providers per range of price bundles

Table 2 IaaS characteristics

Characteristic	Description	Values
CPU	CPU power	2×, 4×, 6×/3×, 5×, 7×
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, 10,000
OS	Operating system of the server	Linux, Windows
Subscription	Indicates if there should be a subscription	No, yes (corresponds to 1 year subscription)

Table 3 Hedonic functions parameters (linear, exponential)

Coefficients/R^2	Linear/57.5 %	Exponential/53.7 %
Constant	130.499***	5.21***
CPU	14.532**	0.06***
Storage	0.249***	0.00***
RAM	20.434***	0.03***
OS	−16.91	−0.08***
Transfer_OUT	0.076***	0.00***
Subscription	−85.82	−0.10***

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, *n.s.* not significant

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.

In addition some non-functional factors, such as availability and reliability of resources, or the lack of fulfilling the agreements between consumers and providers, were not considered in the price model as variables. Inclusion of these characteristics constitutes an important extension of the model, since it may reveal their potential to affect the price of a cloud offering. This needs to be empirically proven through the execution of many different scenarios. According to [10] studying the effects of factors like the quality of service, the inflation rate, rate of depreciation of the resource etc. on cloud pricing helps providing a sound SLA guarantee for example. Cloudorado has updated its services with a wide range of detailed information about each cloud computing company offering 130+ distinct features that might be relevant to a cloud computing provider selection process (such as SLA, security, and certifications), but only one or two may be somehow considered qualitative or non-functional.

Seeking for the model that describes more accurately the price dynamics, as well as for comparison reasons, two models were considered, the linear and the exponential. The hedonic models' parameters were estimated by the use of ordinary least squares (OLS) and nonlinear least squares (NLS) for the linear and the exponential model, respectively. The values of the parameters are summarized in Table 3:

The calculated values for R^2 are 57.5 % for the linear model vs 53.7 % for the exponential, revealing a slightly better performance for the linear approach. However, results from both models indicate that although a great portion of the uncertainty is described they cannot adequately capture pricing dynamics. This constitutes a direction for further research and a future extension of the present work. However, a straightforward consideration is that functional factors by themselves may not be adequate to explain price dynamics and therefore non-functional factors should be included. The low proportion of uncertainty explained by the functional factors is by itself a valuable finding for the revealing of cloud services pricing dynamics and they cannot be neglected from consideration. This finding is in accordance with the limitation expressed above regarding the inclusion of non-functional requirements in the analysis. An important conclusion deriving is that the functional factors alone may be able to describe a little more than half of the uncertainty, as cloud consumers may rely more on non-functional factors, such as the brand name. It would be interesting to observe if this may change in the future, especially if the demand for cloud services increases. This provides an important suggestion to cloud providers to invest on the quality of their offered services, since hardware and software configurations are not adequate by themselves to attract customers and customer loyalty. In any case and despite the low R^2 values, results provide a measurement of the relative importance among the factors, which can provide valuable indications regarding the proposed IaaS configurations. Furthermore, most of the cloud providers are based mainly on these functional factors to derive their pricing policies, so the study of the impact of these factors is of paramount importance.

As observed, all parameters in both cases are significant for the shaping of the price. Subscription is the parameter contributing the most to the price index and ranking of parameters' effect is almost the same for both models. Moreover, the common 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, which is captured in both cases. Since the linear model performs better than the exponential, it is adopted for the rest of the analysis. Consequently, and based on the estimated parameters values, the price index function is expressed as:

$$\begin{aligned} Price\,(\$) = {} & 130.499 + 14.532 * CPU + 0.249 * Storage + 20.434 * RAM \\ & - 16.91 * OS + 0.076 * TransferOut - 85.82 * Subscription \end{aligned} \tag{4}$$

Apart from the price index constructed over the whole dataset, three more indices were developed, based on the linear hedonic model, which performed better over the specific dataset. The first index corresponds to the European offered bundles, the second to these of North America and the third to the rest of the world. Corresponding results are presented in Table 4.

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

Table 4 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

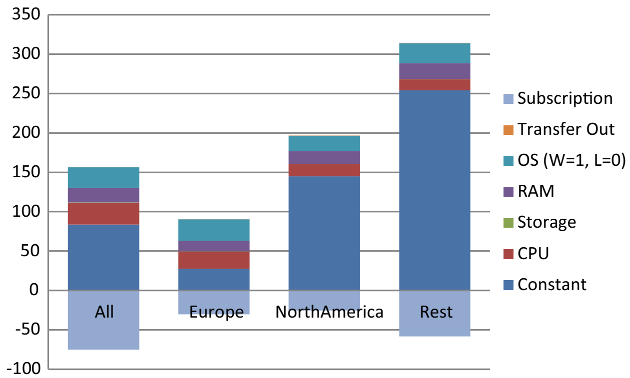

Fig. 3 Contribution of the coefficients to the shaping of price by continent

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 sizeare 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 more 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. In addition, results indicate that non-functional parameters should also be considered, since they are very probable to increase the accuracy of the models. Apart from the general price index, constructed by considering price bundles across all providers, the construction of an index for each provider would be of particular interest, mainly for comparison reasons. Finally, the periodic construction of IaaS price index is expected to reveal the dynamic nature of the services and reflect the changes in pricing schemes.

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.

References

1. Etro F (2009) The economic impact of cloud computing on business creation, employment and output in Europe. Rev Bus Econ 54(2):179–208
2. Mell P, Grance T (2011) The NIST definition of cloud computing. NIST special publication 800(145):7
3. Anderson E, Eschinger C, Wurster L, de Silva F, Contu R, Liu V, Biscotti F, Petri G, Zhang J, Yeates M (2013) Forecast overview: public cloud services, worldwide, 2011–2016, 4Q12 Update, Market analysis and statistics. Gartner Group, Inc., Connecticut, USA
4. Hurwitz J, Kaufman M, Halper DF (2012) Cloud services for dummies. IBM Limited Edition. Wiley, New York
5. Vinu Prasad G, Rao S, Prasad AS (2012) A combinatorial auction mechanism for multiple resource procurement in cloud computing. In: 12th International conference on intelligent systems design and applications (ISDA). IEEE, pp 337–344

6. Siham EK, Schlereth C, Skiera B (2012) Price comparison for infrastructure-as-a-service. ECIS (p. 61):12
7. Martens B, Walterbusch M, Teuteberg F (2012) Costing of cloud computing services: a total cost of ownership approach. In: 45th Hawaii international conference onsystem science (HICSS), 2012. IEEE, pp 1563–1572
8. Andra RS (2013) Investigating pricing and negotiation models for cloud computing. MSc in High Performance, Computing University of Edinburgh:81
9. Mitropoulou P, Filiopoulou E, Tsaroucha S, Michalakelis C, Nikolaidou M (2015) A hedonic price index for cloud computing services. In: CLOSER 2015, 5th international conference on cloud computing and services science, Lisbon, Portugal, 20–22 May 2015
10. Sharma B, Thulasiram RK, Thulasiraman P, Buyya R (2015) Clabacus: a risk-adjusted cloud resources pricing model using financial option theory. IEEE Trans Cloud Comput 3(3):332–344
11. Grivas SG, Kumar TU, Wache H (2010) Cloud broker: bringing intelligence into the cloud. In: 2010 IEEE 3rd international conference on cloud computing (CLOUD), 2010. IEEE, pp 544–545
12. Petri I, Diaz-Montes J, Zou M, Beach T, Rana O, Parashar M (2015) Market models for federated clouds. IEEE Trans Cloud Comput 3(3):398–410. doi:10.1109/TCC.2015.2415792
13. Rogers O, Cliff D (2012) A financial brokerage model for cloud computing. J Cloud Comput 1(1):1–12
14. Grossman RL (2009) The case for cloud computing. IT Prof 11(2):23–27
15. Clamp P, Cartlidge J (2013) Pricing the cloud: an adaptive brokerage for cloud computing. In: 5th International conference on advances in system simulation (SIMUL-2013). IARIA XPS Press, Venice, Citeseer, pp 113–121
16. Al-Roomi M, Al-Ebrahim S, Buqrais S, Ahmad I (2013) Cloud computing pricing models: a survey. Int J Grid Distributed Comput 6(5):93–106
17. Mihailescu M, Teo YM (2010) Dynamic resource pricing on federated clouds. In: 2010 10th IEEE/ACM international conference on cluster, cloud and grid computing (CCGrid), 2010. IEEE, pp 513–517
18. Bonacquisto P, Modica GD, Petralia G, Tomarchio O (2014) A procurement auction market to trade residual cloud computing capacity. IEEE Trans Cloud Comput 3(3):345–357. doi:10.1109/TCC.2014.2369435
19. Rohitratana J, Altmann J (2012) Impact of pricing schemes on a market for Software-as-a-Service and perpetual software. Future Gener Computer Syst 28(8):1328–1339
20. Li H, Liu J, Tang G (2011) A pricing algorithm for cloud computing resources. In: 2011 international conference on network computing and information security (NCIS), 2011. IEEE, pp 69–73
21. Rohitratana J, Altmann J (2010) Agent-based simulations of the software market under different pricing schemes for Software-as-a-Service and perpetual software. In: Altmann et al. (eds) Economics of grids, clouds, systems, and services, ser Lecture Notes in Computer Science. Springer, Berlin/Heidelberg
22. Ruiz-Agundez I, Penya YK, Bringas PG (2011) A flexible accounting model for cloud computing. In: 2011 Annual SRII global conference (SRII), 2011. IEEE, pp 277–284
23. Triplett JE (2004) Handbook on hedonic indexes and quality adjustments in price indexes. science, technology and industry working papers. OECD publishing, Paris
24. Goodman AC (1978) Hedonic prices, price indices and housing markets. J Urban Econ 5(4):471–484
25. Griliches Z (1961) Hedonic price indexes for automobiles: an econometric of quality change. In: The price statistics of the Federal Goverment. NBER, pp 173–196
26. Chanel O, Gérard-Varet L-A, Ginsburgh V (1996) The relevance of hedonic price indices. J Cult Econ 20(1):1–24
27. Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. J Political Econ 92:34–55
28. Pakes A (2002) A reconsideration of hedonic price indices with an application to PC's. National Bureau of Economic Research. No. w8715, National Bureau of Economic Research
29. Berndt ER, Griliches Z, Rappaport NJ (1995) Econometric estimates of price indexes for personal computers in the 1990's. J Econ 68(1):243–268
30. Moreau A (1996) Methodology of the price index for microcomputers and printers in France. Ind Prod Int Comp Meas Issues 99–118
31. Varoutas D, Deligiorgi K, Michalakelis C, Sphicopoulos T (2008) A hedonic approach to estimate price evolution of telecommunication services: evidence from Greece. Appl Econ Lett 15(14):1131–1134
32. Berndt ER (1991) The practice of econometrics: classic and contemporary. Addison-Wesley Publishing, Boston
33. Czarnul P (2013) An evaluation engine for dynamic ranking of cloud providers. Informatica 37(2):123

34. Okraszewski M (2015) Cloudorado launches new cloud computing comparison service. prweb.com. http://www.prweb.com/releases/cloud/computing/prweb12455967.htm. Accessed 29 Jan 2015