PRICE COMPARISON FOR INFRASTRUCTURE-AS-A-SERVICE

Siham El Kihal, Christian Schlereth, Bernd Skiera*

Abstract

Today's pricing of infrastructure-as-a-service is not transparent because some providers, such as Google, charge separately for each service characteristic (e.g., $50 per CPU or $15 per GB of memory per month) and let customers freely configure the service. In contrast, competitors like Amazon, Microsoft, and IBM only offer predefined bundles (e.g., 4 GB of memory, 400 GB of storage, and 2 CPUs for $140 per month). These different types of pricing plans make price comparisons very difficult.

The aim of this study is to increase price transparency among providers by proposing two price comparison methods, which provide a detailed overview of the billing situation in the infrastructure-as-a-service market. The first method is "hedonic pricing", which decomposes each provider's billing into the contributing values of the product´s characteristics. The second is a new method, called PriCo ("Pricing plan Comparison"), which in addition considers offers from competitive providers. We employ the two methods in an empirical study, which compares the pricing of the infrastructure-as-a-service providers Google, Microsoft, Amazon, IBM, and Terremark. The insights gained allow customers to better identify the best provider for their needs. The proposed methods also help providers to better understand and position their pricing in the market.

Keywords: Cloud Computing, Infrastructure-as-a-Service, Pricing, Hedonic Pricing, Pricing Plan Comparison.

* Siham El Kihal, Research Assistant, Goethe University Frankfurt, Faculty of Business and Economics, Department of Marketing, Grueneburgplatz 1, 60323 Frankfurt am Main, Germany, Tel.: ++49-69-798-33861, Fax: ++49-69-79-35001, E-Mail: elkihal@wiwi.uni-frankfurt.de
Christian Schlereth, Assistant Professor, Goethe University Frankfurt, Faculty of Business and Economics, Department of Marketing, Grueneburgplatz 1, 60323 Frankfurt am Main, Germany, Tel.: ++49-69-798-34638, Fax: ++49-69-79-35001, E-Mail: schlereth@wiwi.uni-frankfurt.de
Bernd Skiera, Chaired Professor of Electronic Commerce, Goethe University Frankfurt, Faculty of Business and Economics, Department of Marketing, Grueneburgplatz 1, 60323 Frankfurt am Main, Germany, Tel.: ++49-69-798-34649, Fax: ++49-69-79-35001, E-Mail: skiera@skiera.de

1 Introduction

Infrastructure-as-a-service (IaaS) is one of the three fundamental service layers of cloud computing, in which on-demand virtualised computing resources are provided to the customer. Computing resources are sold on-demand with limited or no upfront investment by the customers, and consumption is readily scalable to accommodate heterogeneous user requirements (Armbrust et al. 2010; Koehler, Anandasivam and Dan 2010). Customers can use the service with no long-term commitment, although they may still opt for such a plan, frequently motivated by price reductions. Services are delivered over the internet and are often fully managed by a 3rd-party provider, who realises economies of scale and cost advantages through the use of virtualised multitenant platforms. Gartner estimated that in April, 2011, the global market value of IaaS was $3.7 billion—approximately 10% of the overall cloud computing market—and predicted an increase to $10.5 billion by 2014 (Pettey and Stevens 2011).

Researchers have argued that the commercial success of cloud computing services can only be achieved if the pricing is clear and transparent to both providers and customers (Weinhardt et al. 2009; Anandasivam and Weinhardt 2010). However, looking at today's market, we observe exactly the opposite for IaaS. Two types of pricing plans are prominently used: price bundling and unbundling. Price unbundling, as exemplified by Google, charges for each computing characteristic separately and has similarities to pay-per-use pricing plans. Customers decide on the required computing characteristics (e.g., the number of CPUs and storage capacity) and are charged a specific price per unit (e.g., $50 per CPU or $15 per 100 GB of storage). Price bundling as offered by IBM, Amazon, and Microsoft uses a discrete set of predefined packages (e.g., a "Silver Instance" with 4 GB of memory, 400 GB of storage, and 2 CPUs for $140 per month or a "Gold Instance" with 16 GB of memory, 1 TB storage, and 4 CPUs for $280 per month). Therefore, customers with specific computing requirements can only choose the next best plan that fulfils their needs and thus may be forced to buy computing resources that they may not fully need. Other providers such as Terremark offer pricing plans that can be categorised as in between price bundling and unbundling because they offer bundles of CPUs and memory but let customers decide on storage requirements.

As a result, the market for IaaS resources is nontransparent, which negatively affects customers, but also providers. One indication is that web sites such as http://cloud-computing.findthebest.com exist to evaluate IaaS providers. However, these evaluations primarily focus on technical aspects such as the supported programming languages, the security and backup features, or the choice of operating system. These evaluations are not able to identify the cheapest provider, which depends on customers' computing requirements. For example, if a customer requires a high number of CPUs, he or she should choose a provider who charges a low price for CPUs. However, providers who use price bundling do not explicitly communicate the price per CPU. Thus, customers may face difficulties in evaluating the prices of composite services. The calculation of the financial benefit of moving to the cloud or changing providers is thus hardly feasible and has been cited as one of the main reasons that prevents customers from adopting cloud services (Armbrust, Fox et al. 2009; Martens and Teuteberg 2012; Püschel and Neumann 2009). Furthermore, this low transparency also negatively affects providers because they can only successfully position their pricing plans in the market if they fully understand the pricing plans of their competitors, which may be difficult to monitor.

In this study, we aim to mitigate the low transparency of prices and propose two price comparison methods. The first price comparison method is "hedonic pricing", which decomposes IaaS prices into the "hedonic prices" of its characteristics. Furthermore, we also develop a new comparison method, called PriCo ("**Pri**cing Plan **Co**mparison"), which considers the prices of competitive providers. We illustrate the use of both methods in an empirical study that analyses the prices of the five of the most important IaaS providers. Our results demonstrate that IaaS providers in fact use the low transparency of prices to differentiate their service from competitors. The results also indicate substantial differences in the billing amounts for different equipped IaaS characteristics, meaning that customers are well advised to thoroughly compare the prices based on their carefully evaluated needs.

The remainder of the paper is structured as follows: The next section presents a review of previous research on this topic. Section 3 describes both comparison methods. Section 4 applies these methods to an empirical study in an IaaS context. Finally, we draw our main conclusions from the analysis and provide managerial implications for IaaS providers and customers.

2 Previous Research

Infrastructure-as-a-service is designed to be offered as a digital value-added service. Information systems generally focus on the development and implementation of methods for requirement analysis or requirement engineering. One of the ultimate aims of information systems is to initially measure and test the perceived benefit of a business model from the customer viewpoint (Fritz, Schlereth and Figge 2011). Thereby, price transparency plays a crucial role. Based on this understanding, the following three streams of literature are relevant for this research: (1) The pricing of cloud computing resources, (2) price bundling, and (3) the use of the hedonic pricing method in information systems.

2.1 The Pricing of Cloud Computing Resources

The evolution of cloud computing over the past few years has resulted in a variety of studies focusing on its technical aspects such as security (e.g., Weinhardt et al. 2009), the technical capabilities of cloud computing (e.g, Buyya et al. 2009), or the quality assessment with service-level agreements (e.g., Marston et al. 2011). Several studies have examined the economic side of cloud computing and analysed business opportunities when moving into the cloud using a cost-benefit analysis (e.g, Armbrust et al. 2009; Püschel and Neumann 2009; Koehler, Anandasivam and Dan 2010).

Only a few studies address the pricing of cloud computing resources, and most focus on the context of software-as-a-service (SaaS). For example, Rohitratana and Altmann (2010) use an agent-based model to study the dynamics of pay-per-use pricing. Koehler et al. (2010) outline reasons why many customers prefer flat-rate over pay-per-use pricing. Anandasivam (2009) introduce a bid-pricing method for cloud computing services. A common theme in these studies is that the pricing plans, such as pay-per-use plans or flat rates, are easy to understand and compare. Lehmann and Buxmann 2009 provide a structured overview of more advanced types of pricing plans in the context of SaaS and argue that current pricing knowledge is not able to meet the challenges of other cloud computing business models and recommend further research (see Marston et al. 2011 for a similar argument).

Price bundling is a relevant type of pricing plan for infrastructure-as-a-service and has been mostly neglected. Subsequently, we describe insights from prior studies on price bundling and explain how IaaS provides a challenging context for the price-bundling literature, motivating the current study.

2.2 Price Bundling

Price bundling is a pricing strategy that markets two or more products or services as a specially priced package (Schmalensee 1984; Venkatesh and Mahajan 2009). Schmalensee (1984) distinguishes three bundling strategies: unbundling, bundling, and mixed bundling[1]. Current IaaS providers mainly apply price bundling and unbundling and no example is known to the authors in which IaaS providers employ a mixed bundling strategy. When using price bundling, providers aim to increase their profits through price differentiation by segmenting customers and also to veil the prices of the characteristics of the bundle (Venkatesh and Mahajan 2009).

[1] In case of mixed bundling, the seller offers the bundle as well as the individual items.

In their meta-analysis, Venkatesh and Mahajan (2009) summarise the conditions under which price bundling is superior to alternative pricing strategies. They suggest that price bundling should be used if variable costs are near zero or at least relatively low compared with customers' willingness to pay. They also state that price bundling is favourable if the products in the bundle are strong complements. In oligopolies, providers may benefit from using price bundling if they succeed in preventing their services from being compatible with the services of other companies (Venkatesh and Kamakura 2003; Matutes and Regibeau 1992). In the case of IaaS, we assume that these conditions are fulfilled.

Price bundling for IaaS differs from bundling in the previous literature. One common assumption is that a customer only uses one unit of a product within a bundle. In contrast with IaaS, the quantity of each characteristic may vary within the bundle, and at least one unit of each service characteristic is needed to create a meaningful service. This difference provides a new perspective on price bundling, which we investigate in this study by proposing two price comparison methods.

2.3 The Hedonic Pricing Method in Information Systems

According to the underlying theory of the hedonic pricing method, products are bundles of characteristics, or "qualities", and the market is in equilibrium, such that a product´s price consists of the implicit or "hedonic" prices of its characteristics (Lancaster 1972; Rosen 1974). Griliches (1961) popularised the use of the hedonic pricing method and constructed a quality-adjusted price index for cars. Rosen (1974) built a formal, competitive, general equilibrium model in which consumers demand a single product based on the composition of its characteristics. This model has been prominently used to compare the prices of many durable and nondurable goods (e.g., Goodman 1978; Schultze 2003). For example, in case of the housing market, the price of a property is determined by the characteristics of the house (e.g., size, appearance, features, and condition) and the characteristics of the surrounding neighbourhood (e.g., accessibility to schools and shopping, levels of water and air pollution, and the values of other homes). The hedonic pricing method is used to estimate the extent to which each characteristic affects the price.

In information systems, the hedonic pricing method has been widely applied to the personal computer market and the operating systems market (Nelson, Tanguay and Patterson 1994; Pakes 2003; White et al. 2005). Brynjolfson and Kemerer (1996) used the hedonic pricing method to determine network externalities and intrinsic microcomputer spread sheet software prices. To our knowledge, the hedonic pricing method has never been used as a tool to make complex pricing plans more transparent. In the next section, we describe the basic framework of the hedonic pricing method.

3 Two Pricing Plan Comparison Methods

3.1 The Hedonic Pricing Method

Rosen (1974) model for the hedonic pricing method assumes a relationship between the market prices of products and their objective characteristics, which can be expressed by a function. According to this relationship, we can describe a product *X* entirely by a vector of its characteristics:

$$X = (x_1, x_2, .., x_i, .., x_l) \tag{1}$$

Where x_i is the level of the i^{th} characteristic of the considered product, i.e., the amount of the i^{th} characteristic in each product and l is the number of relevant characteristics of the product.

The function defined in Equation (2) thus gives the relationship between the billing amount for using the service (BA_p) and the vector of a product´s characteristics when choosing provider *p*. Rosen (1974) states that this relationship can be specified as either a linear or a nonlinear function and may also include interactions between the variables. The choice of a functional model depends on the product researched, on the economic value of each characteristic, and its potential correlation with other characteristics.

$$BA_p(X) = BA_p(x_1, x_2, .., x_i, .., x_I) \qquad (p \in P) \qquad (2)$$

The hedonic pricing method builds upon several assumptions: First, the product under study is treated as a vector of objectively measured utility-bearing characteristics. Second, markets are perfectly transparent and customers and producers value the products based on these characteristics. Third, there is no preference for certain products or producers on the demand side, and when choosing between two objectively identical products, the customer picks the less expensive one.

Tomkovick and Dobie (1995) define three principal steps to determine hedonic prices: In the first step, we limit the target market, including products and competitors. In the second step, we identify all the product characteristics that are relevant for both customers and providers and that can be objectively measured. The third step consists of estimating the hedonic price of each of the product's characteristics. Thereby, we use a linear regression model, in which the hedonic prices β_{ip} of the characteristics i are expressed as follows:

$$BA_p(X) = \beta_{0p} + \sum_{i \in I} \beta_{ip} \cdot x_i + \varepsilon_p \qquad (p \in P) \qquad (3)$$

This estimation is performed separately for each provider p.[2] The error term ε_p represents the residuals of the assumed functional form of the characteristics. The parameters β_{0p} and β_{ip} increase the transparency by decomposing the billing amount of each provider into monetary values of IaaS characteristics. For IaaS, these "hedonic prices" help customers to better assess the price of characteristics for which they have high computing requirements and which would drive the billing amount. Providers can use the results to investigate whether and how they differentiate their pricing from competitors.

3.2 PriCo – A Pricing Plan Comparison Method

One shortcoming of the hedonic pricing method is that the pricing plans of each provider are analysed separately and independently of the competitive situation of the studied market. However, neglecting competing offers may result in biased estimates and typically does not properly reflect the IaaS market. To overcome this limitation, we introduce a new method, the Pricing Plan Comparison Method (PriCo), to complement our understanding of IaaS pricing plans.

The main goal of PriCo is to identify the "most favourable profile for each provider", a term that describes a set of computing requirements for which a customer benefits the most when choosing that provider instead of a competitor. The objective function in Equation (4) maximises the monetary advantage MA_p, which is the difference between the billing amount of provider p's next-cheapest competitor BA'_p and p's pricing plan BA_p.

$$\max MA_p = BA'_p - BA_p \qquad (p \in P) \qquad (4)$$

$$BA_p = \left[\sum\nolimits_{i \in I} (p_{xip} \cdot x_i)\right] \cdot (1 - DB) + \left(Pb_p \cdot DB\right) \qquad (p \in P) \qquad (5)$$

$$BA'_p \le BA''_p \qquad (p \in P) \qquad (6)$$

[2] If we include the provider as a characteristic, we would observe the general price level of each characteristic, but we would no longer be able to identify differences in the hedonic prices of the characteristics between providers.

$$x_i \leq UB_{ijp} \qquad (if\ DB = 1; i \in I; j \in J; p \in P) \qquad (7)$$

$$Pb_p \leq Pb_{jp} \qquad (p \in P; j \in J) \qquad (8)$$

The decision variables in the model (4)–(8) are the x_i, which together form the most favourable profiles for each provider. PriCo distinguishes price bundling and unbundling using a dummy variable, *DB*, that takes the value 1 in the case of bundling and 0 otherwise. Equation (5) specifies the billing amount either as the price charged by provider *p* for the bundled price Pb_b, which fulfils all computing requirements (see also Equation(7)) or, in the case of unbundling, as the sum of the prices for the infrastructure characteristics p_{xip} times the required number of units of each characteristic x_i. If more than one price bundle fulfils all computing requirements, we assume that the provider picks the cheapest one. Equation (6) ensures that the cheapest competitor is always picked. For this purpose, we use BA'_p as an auxiliary variable to compare the billing amounts among the competitors to the considered provider *p*. Equation (7) ensures that the computing requirements x_i for each characteristic *i* are fulfilled in the case of price bundling, meaning that x_i is lower than or equal to the characteristics of bundle *j*, UB_{ijp}, from provider *p*. Furthermore, Equation (8) ensures that the customer picks provider *p*'s cheapest pricing plan *j*.

The results of PriCo identify the most favourable profile for each considered provider and determine the extent of the monetary advantage of the most favourable profile compared with all competitors. Negative MA_p values reveal that compared with other competitors, the considered pricing plan does not provide a monetary advantage to the customer, i.e., that all the provider's plans are dominated by the competition. To make the monetary advantage comparable among different providers, we transform the absolute value of MA_p into the relative value RMA_p:

$$RMA_p = \frac{MA_p}{MA_p + BA'_p} \qquad (p \in P) \qquad (9)$$

In summary, the PriCo model (4)–(8) enables the identification of the most favourable profile for each provider in the market. The model also allows both groups to quantify the extent to which these profiles are superior to those of the competitors. Moreover, the PriCo results enable providers to test whether their pricing plans are completely dominated by those of the competition. The PriCo method results in a characterisation of each pricing plan by its most favourable profile, and customers can then reduce their set of pricing plan choices and so have a significantly less complicated decision to make. To provide a better understanding of the two price comparison methods, we employ both methods in an illustrative study in an IaaS context.

4 Empirical Study

The aim of the empirical study is to demonstrate the use of the two price comparison methods in the context of IaaS. We outline the types of results from these methods and also analyse the current pricing strategies of IaaS providers in the market. We first explain the study design and then present the insights gained from the application of the two price comparison methods.

4.1 Study Design

To select IaaS providers for our study, we concentrated on those that are frequently listed in the top 10 in various rankings (e.g., BTC Logic 2011). The five providers that we chose to compare are Amazon Elastic Compute Cloud (subsequently referred to as *Amazon*), IBM Cloud (*IBM*), Microsoft Windows Azure (*Microsoft*), Terremark IaaS Platform (*Terremark*), and Google App Engine (*Google*). We collected information about the pricing of the five providers in March, 2011.

Amazon offers 8 price bundles specified by the amount of storage and memory capacity and the number of CPUs. For example, the available number of CPUs per instance ranges between 1 and 26. Prices range between $68 and $1,785 per month for unreserved instances. All bundles are offered using either Linux or Windows as the operating system, and price discounts are available for long-term contracts when using reserved instances. Like Amazon, IBM offers a similar pricing plan structure with 7 price bundles. The available number of CPUs per instance ranges between 1 and 20 for IBM, and the prices for unreserved instances range between $86 and $1,433 per month. Microsoft offers 5 different price bundles specified by the amount of storage, memory, and the number of CPUs. The prices of these bundles vary between $36 and $691. Terremark differs from Amazon, IBM, and Microsoft because storage is not included in the bundle and must be specified separately. Terremark offers 32 bundles, with CPUs ranging between 1 and 8 per instance. Finally, Google uses price unbundling and only charges for each CPU and each GB of storage and memory capacity. The five providers are summarised in *Table 1*. Further service characteristics are listed in *Table* 5 in the Appendix.

	Amazon	IBM	Microsoft	Terremark	Google
Type of Pricing	Price bundling	Price bundling	Price bundling	Price bundling for memory and CPU, price unbundling for storage	Price unbundling
Number of Price Bundles	8	7	5	32	-
Price Range per Month	$68–$1,785	$86–$1,433	$36– $691	$25–$671	Depends on the size of the characteristics

Table 1. Pricing plan overview for the five IaaS providers.

For ease of illustration, we restrict the price comparison to three characteristics: the number of CPUs (assuming each operates at 1 GHz), storage capacity (measured per 100 GB), and memory capacity (measured per GB). Thus, the IaaS characteristics are described by the vector X=(memory, CPU, storage). Based on our analysis of the IaaS market, these characteristics have a major impact on the pricing of the product and are relevant for both IaaS providers and customers. With no loss of generality, we herein use only the prices of unreserved instances and Windows as the operating system. Furthermore, we also assume a linear additive relationship for all characteristics and that an increase in the value of any characteristic results in an increase in the product price.[3]

To determine the most favourable profile of each provider and the hedonic prices, we use Grid search on a full factorial design, which varies the number of CPUs from 1 to 11 in steps of 1 and the memory from 1 to 11 GB with the same step length. Storage is varied from 100 GB to 1.1 TB in steps of 100 GB. This range was chosen to satisfy most customers' typical needs, as reflected by the fact that these configurations are supported by all five providers. For all 1,331 configurations and all 5 providers, we determine the monthly billing amount, which results in 6,655 billing amounts in total. These billing amounts serve as the dependent variable for the subsequent price comparisons.

4.2 Results of the Hedonic Pricing Method

Table 2 summarises the results of the hedonic pricing method. The adjusted R^2, as a measure of the goodness of fit of all five models, is summarised in the last column (Kvalseth 1985). The adjusted R^2 values range between 0.43 and 0.69 (when neglecting Google), which indicates that the linear assumption is violated for some providers.

[3] Expanding the study with other factors such as data transfer rates, operating systems, or a nonlinear specification of the characteristics is straightforward. Nevertheless, we refrain from doing so here to better outline the two comparison methods.

With the exception of the constants for IBM, Terremark, and Google, all parameter values are significantly different from zero. The results of the hedonic pricing methods reveal that IaaS providers indeed differentiate their offerings through price bundling. The constant, which represents a monthly fixed fee, is approximately zero for IBM, Terremark, and Google, and it is approximately 220 € for Amazon and Microsoft.[4] In addition, the billing amount also depends on the number of CPUs, for which Amazon and Microsoft charge a lower price than IBM and Google. These differences indicate that Amazon and Microsoft are more suitable for high computing requirements, whereas Google, IBM, and Terremark better address the market for lower requirements.

	Const. ($)	Memory ($ per GB)	CPU ($ per CPU)	Storage ($ per 100 GB)	Adjusted R^2
Amazon	224.58*** (9.35)	4.30*** (0.86)	44.47*** (0.86)	16.08*** (0.86)	0.69
IBM	-17.86 (n.s.) (25.55)	18.42*** (2.35)	62.40*** (2.35)	36.99*** (2.35)	0.43
Microsoft	210.77*** (10.93)	23.08*** (1.00)	28.38*** (1.00)	6.94** (1.00)	0.50
Terremark	10.96 (n.s.) (10.24)	42.21*** (0.78)	37.97*** (0.78)	25*** (0.94)	0.76
Google	0.00 (-)	0.45 (-)	70.00 (-)	15 (-)	1.00
Average	85.69	17.68	48.64	20.00	0.68

*** $p < .01$, ** $p < .05$, * $p < .1$; n.s., not significant. Standard errors are in parentheses

Table 2. Results of the hedonic pricing method.

This approach makes pricing plans comparable because the unpublished prices of each characteristic are now revealed through the hedonic prices. Although the providers are using different types of pricing plans, customers can now better understand all pricing plans and make well-grounded decisions based on their specific computing requirements.

4.3 Results of the Pricing Plan Comparison Method

The application of PriCo can complement these results and identify profiles under which the pricing plan is superior to all other providers in the market (see *Table* 3). The highest value of MA_p is realised by Terremark, at $466.45, and Amazon is the lowest, at $50.95. Both Terremark and Google provide very high relative monetary advantage RMA_p values for their most favourable profiles (here, 81% and 69%). Google´s most favourable profile only satisfies very low-CPU and high-memory requirements, Terremark´s most favourable profile is suitable for high-CPU and low-memory requirements. All MA_p values in *Table* 3 are positive, which indicates that all providers have a certain profile in mind, which they address with their pricing plan. The last column of *Table* 3 shows that Google´s pricing plans seem to be a real threat to the other competitors. In all five most favourable profiles, the comparatively best pricing plan is always the one offered by Google.

Provider	Billing Amount BA_p	Monetary Advantage MA_p	Relative Monetary Advantage RMA_p	BA'_p (in $)	Memory (in GB)	CPU (in units)	Storage (GB)	Best Comparative Pricing Plan
Amazon	$434	$50.95	11%	$484.95	11	6	400	Google
IBM	$350	$153.60	31%	$503.60	8	5	1,000	Google
Microsoft	$336	$237.15	41%	$573.15	7	6	1,000	Google
Terremark	$109	$466.45	81%	$575.45	1	8	100	Google
Google	$209.05	$462.95	69%	$672.00	9	1	900	Microsoft IBM

Table 3. Most favourable profiles for each provider using the PriCo method.

[4] In fact, we obtain a negative constant for IBM. However, because a server requires at least 1 GB of memory, 1 CPU, and some storage, also IBM's monthly price is always greater than zero.

The above results are restricted to the most favourable profiles for each provider, but which provider should a customer choose when his computing requirements differ from these five profiles? To answer this question, *Figure* 1 illustrates which provider generates the lowest billing amount for specific computing requirements. Therefore, we calculate the average over all MA_p values for the remaining dimensions (either storage or memory) and shrink the characteristics into a two-dimensional space.

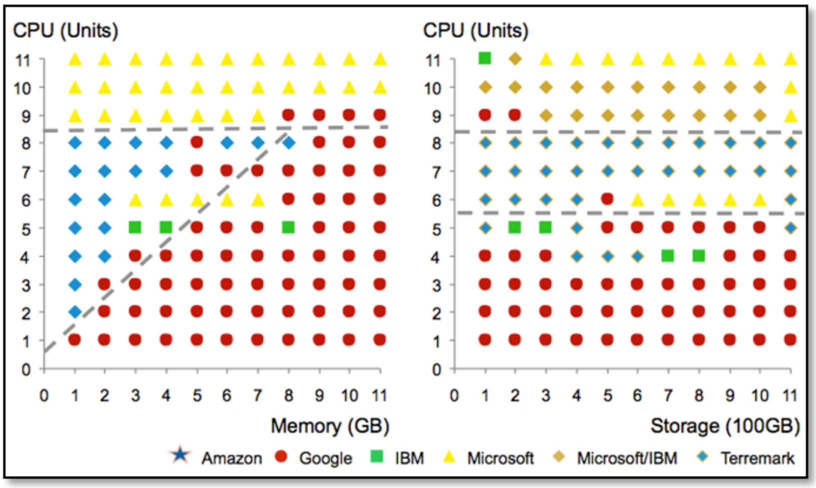

Figure 1. *Most favourable provider at a specific combination of CPU and memory or CPU and storage.*

Figure 1 shows that Terremark and Google are the cheapest providers when 8 or less CPUs are required: Terremark leads in low-memory regions, and Google leads in high-memory regions. For CPU requirements above 9 CPUs, Microsoft is the overall leader. Terremark leads in the region between 6 and 8 CPUs, and IBM and Microsoft share leadership for CPU requirements above 9 CPUs. No combination of characteristics exists in which Amazon has the lowest prices.

4.4 Difference Between the Two Methods

The major difference between the hedonic pricing method and PriCo is that the results from the hedonic pricing method require accounting for an error term, ε_p, which is not required in PriCo. In this section, we aim to demonstrate that the results and recommendations of the two price comparison methods can differ substantially. Therefore, we apply PriCo to the results of the hedonic pricing method and calculate the most favourable profiles. We also compare the most and least expensive providers and the relative monetary advantages according to both methods.

Figure 2 shows that the optimal profiles can differ substantially between the price comparison methods. Although the two methods deliver similar results for Terremark and Google, PriCo suggests that the most favourable profiles for IBM, Amazon, and Microsoft are those with an approximately average number of CPUs, whereas the hedonic pricing method instead suggests extreme values for the number of CPUs (either 1 or 11). We deduce that using the hedonic pricing method to estimate the most favourable profiles for each provider would lead to a deviation from the true favourable profiles for some providers.

Table 4 summarises a comparison of the most and least expensive providers using both methods. Here, again, the error term causes substantial differences. For example, IBM is never the least expensive provider but is rather, at 52.3%, the most expensive provider according to the results of the hedonic pricing method. In contrast, PriCo shows that IBM should be preferred in 22.1% of all possible profiles and is the most expensive provider in 22.5% of all the profiles. Comparing the relative monetary advantages between both methods also shows that the hedonic pricing method diverges from the results of PriCo due to estimation errors.

In summary, the hedonic pricing method is a simple method that helps customers and providers to identify which characteristics are less or more expensive in comparison with those of the competitors. Hedonic pricing can be used as a first step in the price analysis; however, the results are subject to an error term in the estimation and, furthermore, do not reflect competition. PriCo complements the insights of the hedonic pricing method by identifying the most favourable profile under which each provider offers the largest monetary advantage compared with the competitors. Thus, PriCo reflects competition in the market and its results are not biased by estimation errors. PriCo also enables providers to evaluate pricing decisions and to test whether their pricing plans really attract the intended customer segments.

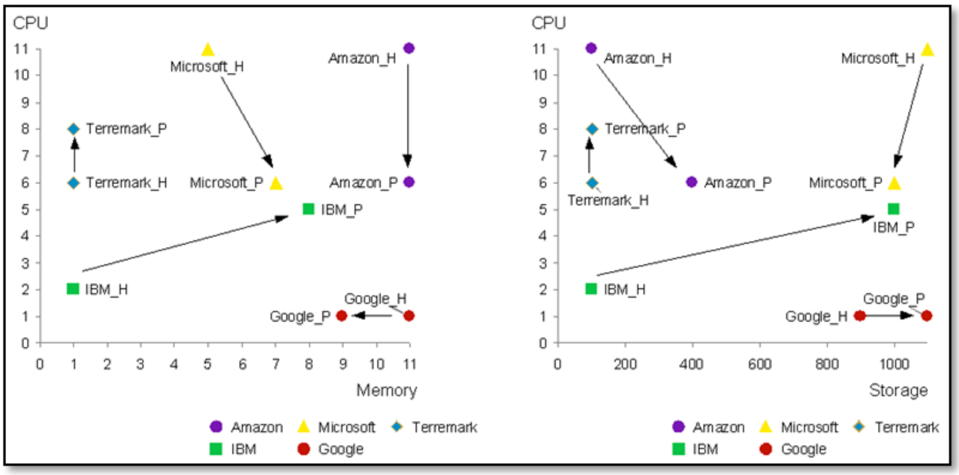

Figure 2. Comparison of most favourable profiles for combinations of CPU and Memory or CPU and Storage (H for Hedonic pricing and P for PriCo).

Provider	Method	Amazon	Microsoft	IBM	Terremark	Google
Least Expensive Provider	Hedonic Pricing	0.1%	33.1%	0.0%	8.4%	58.4%
	PriCo	2.3%	38.3%	22.1%	13.2%	42.0%
Most Expensive Provider	Hedonic Pricing	14.1%	3.7%	52.3%	28.8%	1.1%
	PriCo	31.3%	9.2%	22.5%	41.5%	2.0%
Relative Monetary Advantage	Hedonic Pricing	1%	22%	-5%	26%	51%
	PriCo	11%	41%	31%	81%	69%

Table 4. Comparison of most and least expensive providers obtained with the two methods.

5 Conclusions and Implications

The use of price bundling for IaaS contradicts cloud computing's principle of scalability and restricts customers' flexibility in using and changing plans. Low price transparency in the market is one of the major consequences. Therefore, we propose two price comparison methods to study IaaS pricing plans: the hedonic pricing method and the new PriCo method. The difference between the two methods is that the hedonic pricing method determines implicit prices for the major characteristics of an IaaS offering, whereas PriCo also considers the competitive situation in the IaaS market and delivers a map of favourable customer profiles for each provider.

We show how to employ the two methods in the context of IaaS pricing. Particularly, we reveal that providers indeed use the low transparency of price bundling to differentiate their service from competitors. We also show that Google, as the only provider using price unbundling, offers the most attractive prices for most computing requirements.

Our study is limited in that it assumes rational customers who only take price into account when choosing an IaaS offering. Future research could investigate this issue from the customer perspective, e.g., their indifference to price bundling or unbundling or whether they prefer one plan over another. Furthermore, we neglect other characteristics such as the operating system, data transfer rates, and guaranteed uptime rates (see *Table* 5), which may also be important in customers' IaaS provider choices. Including the operating system or data transfer rates is straightforward and similar to the studied service characteristics. Including the guaranteed uptime rate is more challenging because it requires making assumptions about the importance of this rate to customers. Nevertheless, we find both price comparison methods promising and also transferrable to other types of pricing plans and other contexts than price bundling or cloud computing services.

6 Appendix

Provider	Amazon	IBM	Microsoft	Terremark	Google
Reserved Computing	Yes (1 & 3 years)	Yes (6 & 12 months)	Yes (6 month terms)	No	No
Shortest Contract Length	1 hour	1 hour	1 hour	1 hour	1 hour
Data Transfer Rates	Varies from $0.08 to $0.19 (also depending on the region)	Varies from $0.08 to $0.15 (also depending on the region)	$0.01 in/ $0.15 out/ GB	$0.17 per transferred GB	$0.12 out /GB
Service Credit if Below Guaranteed Uptime Rate	10% (of the bill) if <99.95%	1 week or 1 month of the monthly monitoring charge	10% of the bill if <99.95% 25% if <99%	Unspecified service credit for downtimes	10% if <99.95% 25% if <99.00% 50% if <95.00%
IP-Address	$0.01/h/IP	$0.01/h/IP	Not listed	$0.01/h/IP	Not listed
Operating System	Linux & Windows	Linux 5.4 & 5.5, Linux 11.0 and Windows	Windows	Windows	Not listed
Differentiation between 32- and 64-bit	Yes	Yes	No	No	No
Premium Support	From $49 to max. 10% of monthly billing amount	Percentage of services charges from 10% to 20% of billing amount	Not listed	Greater than $500 or 20% of usage fees	Free for developers

Table 5. Additional IaaS characteristics.

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