Cloud Computing Economics: Issues and Developments

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***Abstract*—Cloud computing is an IT paradigm that has progressed successfully in some organizations and enterprises across the world. Cloud users can leverage on the facilities available on the cloud to develop and deploy applications. Cloud providers also have software that can be utilized for routine services by users already deployed on the cloud. The services provided by the cloud are scalable and available at a cost. On the other hand, most organizations have continued to utilize on–premise infrastructure which some consider cheaper than migrating to the cloud. Migration to the cloud is believed to reduce or even eliminate the capital and operational expenses of an enterprise. This paper examines present trends in the area of cloud economics and provides a guide for future research. The study was executed by means of review of some literature available on cloud economics. In the present work, the objective is to answer the following question: what is the current trend and development in cloud economics? The finding is that a balance of the supply and demand side of economies of scale is critical to cloud economics. Different pricing methods being adopted by CSPs is appropriate for the user in terms of choice.**

***Index Terms*— Cloud Computing, Economics, Cost**

I. Introduction

"CLOUD computing is a model for enabling universal, on-demand and convenient network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" [1]. Vaquero [2] defines cloud computing as a large pool of easily usable and accessible virtualized resources such as hardware, platforms and services. These resources can be dynamically configured to a variable load scale, allowing for an optimum resource utilization. This pool of resources is usually exploited by a pay–per–use model, in which guarantees are offered by the infrastructure provider using service level agreements. Cloud computing provides elastic and scalable services exploiting on-premise infrastructure or off–premise facility from cloud service providers (CSP). Cloud utilizes the core concept of virtualization and operates using multi–tenancy. The services are provided remotely using a web browser or over the Internet. Cloud computing makes it possible for large enterprises to migrate some functions to the cloud, while small scale businesses can utilize the cloud without bothering about initial hardware and software cost. Cloud computing is a new evolution of IT services delivery from a remote location, either over the Internet or intranet involving multi-tenant environment enabled by virtualization.

Cloud computing has three primary types of service, Software–as-a-Service (SaaS), Platform-as-a-Service (PaaS) Infrastructure-as-a-Service (IaaS). In SaaS, the CSP provides an application over the Internet that is accessible to multiple users utilizing the application simultaneously. Users do not have to worry about installation cost and licensing fees. In PaaS, the CSP provides a platform to enable users develop and deploy an application. The user does not have control over the underlying infrastructure, but has control over the application and the hosting environment [2]. In IaaS, the CSP provides infrastructure for storage, computing and network. The core concept utilized is virtualization. The user has no control over the hardware, but controls the operating systems, storage and the deployed application at a cost. IaaS and PaaS consumers are mostly enterprises, using the cloud to outsource their IT functions [2]. SaaS consumers are individuals moving their email, social networking and backup, word processing to the cloud [2]. That is migrating data, compute, content and entertainment needs to the cloud. There are four cloud deployment models. Private, public, community and hybrid clouds. A private cloud is utilized by an organization using in–house infrastructure. It can be managed on-premise or off–premise. A public cloud provides infrastructure and services to the public. The infrastructure is owned by the organization and services provided at a cost. A community cloud is owned by several organizations with shared common interest. The infrastructure may be managed by the organizations or a third party. Hybrid cloud is a combination of two or more cloud types bound together by technology that enables data and application portability [2].

As in the past and recent times, a lot of investment has been going into the cloud, both on the consumer and provider's side. According to Margaret Reuse in TechTarget, cloud economics is a branch of knowledge concerned with principle, cost and benefits of cloud computing. Although the cloud can facilitate resource

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provisioning and flexible pricing, there are several cloud computing costs beyond instant price list to consider. Pricing usually involve storage, networking, load balancing, security, redundancy, backup, software services and operating system. Salaries and bandwidth are also issues associated with cost.

According to the IDG 2016, Cloud Computing Survey, the average company was expected to devote 28% of its IT budget to cloud computing in 2017 [3]. Enterprises plan to invest an average of $30.4 million, while small scale businesses (SMBs) will spend $286,000. According to the 2017 Cloud Migration Survey report by Amazon Web Services, two thirds of the companies surveyed estimate the cost of migration to be more than $100 per machine [4]. The report also indicates that in 2017, the three top drivers for migrations are cost (23%), security and compliance (20%) and high available (18%). Countries are also investing heavily in cloud computing. According to [5] China invested $240m into SaaS in 2009, and India SaaS investment in 2007 was $27m. The purpose of this paper therefore is to examine the economics of cloud computing.

The focus will be on the economic benefits and economic of scales of cloud computing. The paper will contribute to further understanding of the economics involved in cloud. The remaining part of the paper is organized as follows: Section 2 discusses related work; Section 3 examines economies of scale related to cloud computing; Section 4 focus on current industry trend in the economics of cloud computing; and Section 5 concludes the paper and recommends future works.

II. Related Works

The Economics of the Cloud in [6] discussed the economy of the cloud with a view to utilizing the cloud and providing a good understanding of the future of the cloud. Various aspects of cloud computing in terms of cost, benefits and projections on the cloud was carried out. The Truth about Cloud Economics in [7] briefly discusses the basis for the growth of cloud computing. It concludes with ways enterprises can adopt the cloud. To move or not to move: the economics of cloud computing in [8] examines the cost of cloud adoption. Important aspects relating to cloud adoption was discussed with applicable cost by some cloud providers. Suggestions were also offered in terms of options. Cloud Computing in Developing Economies: Drivers, Effects and Policy Measures in [5] examines the nature of cloud computing in the developing countries. Various indices were used to analyze economic impact in some developing nations. Based on infrastructure issues the growth in cloud computing utilization is not expected to be rapid. The economics of cloud computing in [9] examines the impact of cloud computing on industries. Adoption of the cloud would positively affect investment and growth in various economic sectors. There were suggestions from the European perspective on how to best encourage cloud adoption. The economics of cloud computing in [2] view the cloud in terms of wholesale and retail cloud applications, hence such should be the terminologies used to refer to cloud services. The term wholesale would be for large businesses, while the retail will be for consumers.

Cloud accounting: a new business model in a challenging context in [10] discusses a new business model known as business accounting. This is in view of the fact that the rapid growth of cloud computing is impacting on the economic environment. This has led to lowered cost and increased productivity. Economic models for cloud service markets: pricing and capacity planning in [11] examines the economic activities of the public cloud providers in terms of nature of application and QoS. Economic models were proposed in terms of pricing and QoS, and also in terms of resource provisioning. SMEs' perception on cloud computing solutions in [12] examines SMEs in terms of cloud computing solutions and the attendant benefits. Certain observations were made and solutions were also proffered to enhance SMEs utilization of the cloud. Cloud Computing for Higher Education Institutes: Architecture, Strategy and Recommendations for Effective Adaptation in [13] focused on cloud computing utilization in tertiary education. The paper proposes five steps for seamless adoption of cloud computing. It concludes that there will be reduction in IT efforts if cloud adoption is carried out. Equilibrium in cloud computing market in [14] examines the economic benefits of cloud utilization both in terms of the providers and the consumers. The more the resources public cloud providers are able to make available the better it is for the consumers. The economics of cloud computing on educational services in [15] discusses the economic impact of using the cloud to provide educational services. Various services being provided were examined and the benefits enumerated.

III. Economics of The Cloud

After the review of cloud computing economics and current issues in literature, this sections discusses costs, pricing of cloud services, benefits and risks of clouds, and cost or benefits models.

A. Cost, benefits and risks of Clouds

In [19] the authors described several types of Cloud Computing benefits such as economic benefits, staffing benefits and operational benefits. Some economic benefits to consider are fewer staff members needed, Cloud suppliers can provide hardware in a much cheaper and faster time for the cloud providers and users. Operational benefits are related to the way the organization operate and some of the benefits include: reduced cost, increased storage, automation, flexibility, better mobility, better use of IT staff. Staffing benefits in SaaS include benefits for the consumer and benefits for the provider [19]. The consumer benefits include:

- No software installation or maintenance.
- Shorter deployment time.
- Worldwide availability.
- The vendor ensures that application is constantly improved.

The provider's benefits include:

- Operating environment owning.
- Predictable revenue stream.
- Small and regular upgrades.

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- Customer relationship management.

Rosenthal et al. [20] examined how the biomedical informatics sectors can leverage on cloud computing. They concluded that for applications that are not I/O sensitive and do not demand a fully mature environment cloud computing can sometimes provide major improvements. The goal of their paper is to help decision makers at biomedical laboratories to understand how to access adequate cloud services. Three major cost drivers of biomedical informatics systems are system administration, idle capacity, and power usage and facilities [20]. The authors also identified some Cloud Computing qualitative benefits such as scalability, management, superior resiliency, homogeneity, and fewer issues to negotiate with institutional authorities. Some risks are also shown which include: risks due to hackers, multi-tenancy risks, and protections at virtual machine boundaries.

In [21] the authors discussed the concepts, benefits and risk of SaaS and PaaS for mobile operators. Benefits for platform owner in SaaS are economies of scale, predictable revenues, shorter sales cycle, expanded customer base and shorter development lifecycle. Benefit for the same stakeholders in PaaS is that revenues are based on hosted applications' usage. End-users in SaaS models have little initial investment, they can eliminate software management activities, have lower total cost of ownership of IT resources, and stable, reliable and flexible experience. In PaaS there is also access to innovative software. From the developer's perspectives, PaaS model has many benefits such as single environment, faster time-to-market, reduced IT infrastructure provisioning, and interoperability with other applications. In [21][5], the risks in SaaS and PaaS models were enumerated. In SaaS, there are risks for platform owners such as up-front infrastructure investment, diverse new skills, and managing network of suppliers. For end-users, risks such as exposing and losing business-critical data, lock-in, high switching costs, less tailored software are involved. PaaS model also has many risks for different stakeholders such as platform adoption, unavailable applications, long learning curve, lock-in, restriction to available APIs, closed platform, lack of interoperability etc. In SaaS and PaaS there are performance, security and scalability risks [21].

B. Cloud Service Prices

In [22] a dynamic pricing mechanism for the allocation of shared resources is proposed and its performance is evaluated. The economic properties of this pricing scheme are formally proved using the mechanism design framework. [23] proposes a resource pricing and allocation policy in cloud computing, in which users can predict future resource prices. In [23], a game theory to solve the multi-user equilibrium allocation problem was employed. They integrated budget and deadline conditions and solved the cloud service price prediction problem with incomplete knowledge. The paper used simulation framework CloudSim to conduct experiments.

In [24], an autonomic metered pricing for a utility computing service was examined. Today, cloud providers charge users using a simple pricing scheme, and fix prices based on resource types. [24] advocated charging variable prices and providing guaranteed quality of service through the use of advanced reservations, that guarantees access to a computing resource at a particular time in the future for a particular duration. The paper concludes that charging fixed prices is not fair to both the provider and the users in the cloud computing environment. Providers could maximize revenue by differentiating the value of computing services provided to different types of users. In [25] a proposal of an economic model for a cloud cache suitable for the querying service of large scientific datasets was discussed. It is based on a cost model that takes into account network bandwidth, disk space and CPU time. Metrics and formulas for the calculation of cloud computing Total Cost of Ownership (TCO), that is, the cost of building and operating a cloud are presented in [26]. [26] defined a calculation model which contains server, software, network, support and maintenance, power, cooling, facilities and real-estate cost. Another cost is Cloud Utilization Cost which embodies the cost caused by the cloud utility and reflects the dynamic nature of utility. The paper also developed a web calculation tool which provides a way to analyze the effect of different metrics on the final cost.

C. Cost Benefits models

In [27], many dimensions of cloud computing value such as ongoing operational cost reduction, capital preservation, value of upsizing and downsizing on-demand, shifting the risk, agility and reuse were discussed. In [27], the cost/benefit methodology that is composed of eight steps: understand the existing issues, assigning costs, model "as is", model "to be", defining value points, defining hard benefits, defining soft benefits, and creating final business case was also considered.

D. Economic Benefits of Cloud Computing

According to [16], cloud computing has the following benefits economically:

- For individual enterprises, cloud services provide benefits that broadly fall into the category of lowering overall costs for equivalent services because they only pay for what they use.
- Increased strategic flexibility to meets market opportunities without having to forecast and maintain on–site capacity.
- Access to the advantages of CSP's massive capacity, instant scalability and parallel processing capabilities which reduces task processing time and response latency. There is also system redundancy which improves reliability and better capability to repel botnet attacks.
- Public cloud vendors can achieve unparalleled efficiency compared to data centers because they are able to scale their capacity to address the aggregated demands of many enterprises.
- Cloud computing allows for much higher server utilization rates, lower unit cost, and easier capacity planning leading to a much higher return on assets than is possible for individual enterprises.

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In view of the fact that locations of the public cloud vendor facilities are not tied to the interest of the individual clients, they are able to locate, scale, and manage their operations to take optimum advantage of reduced energy costs, skilled labor pools, bandwidth and inexpensive real estate. Matzke also suggested that the level of required skills or specialized expertise along with the required economies of scale, drive the optimum choice for outsourcing IT initiatives. The availability of scalable skills combined with other economies of scale are among the compelling benefits of cloud computing.

E. Economic Cost of Cloud Computing

Just as there are economic benefits of the cloud, so also are the economic costs.

- Potential cost of service disruptions in an enterprises.
- Data security concerns.
- Potential regulatory compliance issues arising from sensitive data being transferred, processed or stored beyond defined borders.
- Limitations in the variety and capabilities of the development and deployment platforms currently available.
- Difficulty in moving proprietary data and software from one cloud service provider to another.
- Integration of cloud services with legacy systems.
- Cost and availability of programming skills needed to modify legacy applications to function in cloud environment.
- Legacy software CPU–based licensing cost increasing when moved to cloud platform.

The economic costs and benefits of implementing cloud services vary depending on the size of the enterprise, and it's existing IT resources / overhead including legacy data infrastructure. Other factors include computer hardware, legacy software, maturity of internal processes, IT staff, and technical base. These issues determine the strategic cost and benefits that accrue to individuals and enterprises depending on their size.

1) Economies of Scale in Cloud Computing

The emergence of cloud services is again shifting the economics of IT. Cloud architecture facilitates elastic computing, self–service and pay–as-you–go pricing. Cloud also allows core IT infrastructure to be brought into large data centers that take advantage of significant economies of scale in three areas [6].

- Supply–side savings. Large scale data center lower cost per service.
- Demand–side Aggregation. Aggregating demand for computing smooths the overall variability allowing server utilization rates to increase.
- Multi–tenancy efficiency. When changing to a multi–tenant application model, increasing the number of tenants lowers the application management and server cost per tenant.

2) Supply – Side Economics of Scale.

The economics of scale result from the following area [6]

a. Cost of Power. Electricity cost is rapidly rising to become the largest element of the total cost of ownership currently representing 15% - 20%. Power tend to be significantly lower in large facilities and for operation of multiple data centers than in smaller ones.
b. Infrastructure Labor Cost. Cloud computing lower labor cost by automating many repetitive management tasks. While a single administrator can service around 140 servers in a traditional data center, the same administrator can service thousands of servers in a cloud data center.
c. Security and Reliability. Large CSPs are often able to bring deep expertise to bear in the problem of security than a typical corporate IT department, thus making cloud systems more secure.
d. Buying power. Operators of large data center can get discounts on hardware purchase of up to 30% over smaller buyers. The infrastructure homogeneity in cloud computing also enables scale economic**s.**

3) Demand – Side Economics of Scale

The overall cost of IT is determined not just by the cost of capacity, but also by the degree to which capacity is efficiently utilized. The impact that demand aggregation will have on cost could be as a result of randomness, time–of-day patterns, industry–specific variability, multi–resource variability, and uncertain growth patterns.

4) Relationship between demand and supply patterns [7]

For cloud service providers, the pay–as–you–go model's flexibility allows users scale their services up or down based on their needs. If a user can easily add or subtract resources and pay for cloud service in small increments, the provider has no guarantee of future business. Therefore, to reduce the risk, the provider must dictate the terms of service and condition in its favor. However, if the customer assumes most of the risk, critical applications will not be hosted with a CSP. That would limit cloud computing market growth to a set of non–critical applications or to small-to-midsize businesses that would not use cloud services, making it unprofitable for a CSP to build a $500 million data center. On the other hand, if the CSP, assumes all the risk, then in most cloud environment with multiple consumers, the amount of liability within a provider's service could be greater than the value of the company. To ensure a win-win economic situation, cloud providers must enter into what is called "enterprise agreement", where the two parties can define the parameters of the relationship based on mutual risk sharing. Eventually, CSPs will deliver better services and better guarantees, hence ask for and get more money, while users will get the flexibility of pay–as–you–go.

F. Optimizing Cloud Cost

The cloud is the result of enormous IT needs within an enterprise and individual business units utilizing cloud resources as required by the organization. Also, when IT professionals formally plan for cloud, it is done without full consideration of cost and risks. There are however, many ways an enterprise can optimize cloud in terms of performance and cost [17].

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1) Strike a Cost-Performance Balance

Nearly every cloud provider offers a baseline service prices. This is the cloud service that the provider displays in its advertised cloud pricing. Although, it is likely to be the least expensive, most users may not use the service. They may pay for premium hosting, elasticity, geographic diversity, high availability and other special factors. These additions can be valuable in the long run, but they are just waste of funds. For users these features double the cost cloud resources being used. The best approach is to validate a cloud choice by performing a pilot test of an application using the provider's standard cloud service. To determine needed features, run the application one to three months, measuring the quality of experience, downtime and application cost in both test and production environment.

2) Know Which Applications Are Right for Cloud.

It is important to examine a running application for optimization purposes. Public cloud services are often less expensive than on–premises IT, when applications do not fully use data center resources. However, an application that generates a lot of traffic requires a lot of storage and demands regular in–cloud maintenance, which is probably not saving money in the cloud. It is important to determine the cost and IT effort associated with each application. Also, identify the applications that are most expensive to run and requires most work to maintain. It may be helpful to adopt PaaS or SaaS if internal support cost for IaaS are too high.

3) Consider User Location

Understanding the cloud–to–user connecting is critical for cloud optimization. Organizations with the most successful cloud applications ensure that users could access those applications across a large geographical location. If cloud users reside in one particular location, it will be less costly to host applications internally. However, if users span multiple zones, it is better to establish hosting points that are local to users, which improves performance and helps manage costs.

4) Cloud Negotiation.

Negotiation helps cloud optimization. It is desirable to get a good price offer from a CSP, but an organization must also understand their cloud application needs and get the best services to meet those needs. Carrying out a pilot test of the most demanding and expensive applications establishes the balance for cloud usage and QoS, that will fit into the SLA. There are three primary points to be considered when negotiating cloud prices. They are the providers' guarantees in the SLA, the base price of cloud service during the service period and the price of extra service on top of the basic service model. There are three important areas of negotiation.

- The CSP will adjust prices pro-rata based on prevailing current price of cloud services used by the enterprise even within the contract period.
- An enterprise can renegotiate a contract if a named competitor offers a price that is more than 10% below the currents provider's price.
- A contract can be renegotiated if the SLA is not met more than twice in any given month.

G. Optimizing Cost of Virtual Machine.

The most expensive way to buy virtual machines is to pay for them on demand. It is possible to compare cost of virtual machines (VMs) among the major IaaS providers, but checking the cost against another is not the only issue that will affect price. Factors such as size of virtual machine, type of VM and contract length will influence price as discussed in Right Scale [18]. One advantage of IaaS is that users can spin resources up and down as needed, and will save money if they commit to a long-term contract [18].

1) Amazon Web Services

The primary way to optimize cost is by using reserved instances (RIs). The user gets a discount for making one to three years commitments. If payment is made for some or all committed usage upfront the percentage is higher. The percentage of RI to on-demand VMs ranges from 24% to 75%.

2) Google Services

Google utilizes the sustained usage discount (SUD) which happens automatically and require no upfront. Discount is on each monthly bill, based on the percentage of time that instances in some certain categories were running during the month. Basically, the more the enterprise uses the VM, the less expensive it became. For example, if an instance of the VM runs for 25% of the month, there is a 20% discount on future use.

3) Microsoft Cloud

Microsoft clouds utilize the enterprise agreement (EA) that is negotiated with individual customers, so discount methods are not publicly available. However, it is believed to be less expensive with long term commitment. Generally, Google has the lowest on–demand pricing for VMs, followed by Microsoft Azure. Domestic operations are generally less expressive than international ones for most providers. Google and Microsoft offer per minute pricing of workloads, while AWS offers varying pricing.

IV. CONCLUSION

Cloud computing provides elastic, scalable and on–demand services to user over the Internet. SaaS provides applications to users, while PaaS basically provide platform for deploying users' application while IaaS provide computing and storage infrastructure. Cloud economics deals with the economic costs and benefits of utilizing the cloud. There is a demand side and supply side economics of scale in terms of utilizing the cloud. A balance in the demand and supply sides of the economies of scale is critical in cloud economics. The CSPs could harmonize pricing in the interest of the user. The cost and benefits of utilizing the cloud also affect the users and providers alike.

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