CloudTax: A CloudSim-Extension for Simulating Tax Systems on Cloud Markets

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***Abstract*—Today service markets are becoming business reality as for example Amazon's EC2 spot market. However, current research focusses on simplified consumer-provider service markets only. Taxes are an important market element which has not been considered yet for service markets. This paper introduces and evaluates the effects of tax systems for IaaS markets which trade virtual machines. As a digital good with well defined characteristics like storage or processing power a virtual machine can be taxed by the tax authority using different tax systems. Currently the value added tax is widely used for taxing virtual machines only.**

The main contribution of the paper is the so called *CloudTax* component, a framework to simulate and evaluate different tax systems on service markets. It allows to introduce economical principles and phenomenons like the Laffer Curve or tax incidences. The CloudTax component is based on the CloudSim simulation framework using the *Bazaar-Extension* for comprehensive economic simulations. We show that tax mechanisms strongly influence the efficiency of negotiation processes in the Cloud market.

***Index Terms*—Cloud Tax; SLA Negotiation; Bilateral Negotiation;**

I. Introduction

In 2000 the IT boom ended in a wave of insolvencies known as the dotcom bubble. One cause of the dotcom bubble was the ignorance of basic economical principles [1]. The dotcom bubble exhibits that traditional economical principles are necessary for the successful development of business models enabled through new technology.

Currently service markets are becoming business reality as for example Amazon's EC2 spot market [2]. The goal of our research endeavour is applying and developing economical principles for Bazaar-based markets for services. A specific characteristic of Bazaar-based markets are multi-round negotiation processes.

In order to simulate, test and analyse markets for services we needed an adaptable simulation framework. CloudSim [3] allows to model Clouds but does not consider Cloud markets. Therefore, we developed the Bazaar-Extension [4] for CloudSim enabling the simulation of Bazaar-based markets for Cloud resources.

The service oriented paradigm has gained importance during the development of Clouds and has emerged as a relevant challenge for existing tax systems as shown by the letter ruling of the Massachusetts Department of Revenue [5]: the boundaries between usual software applications and services disappear resulting into tax issues. Identifying and understanding tax issues that arise when using Clouds is important for market participants and tax authorities.

Taxes are an essential element of markets but have not been tackled in our Bazaar-Extension so far. Thus, we developed a **CloudTax component** for simulating tax systems on Cloud markets. Using the Bazaar-Extension with the CloudTax component scientists are able to create a market, add market participants to the market, assign negotiation strategies to them, define a tax system and analyse the resulting resource allocation.

Tax systems were neglected by Cloud research until now. Several papers such as [6], [7], [8], [9] mention that Cloud services may be taxed without introducing an advanced analysis or well-known economic principles (see section II). Further, consulting corporations have published marketing papers as for example [10] emphasizing the challenges of tax authorities by taxing digital goods like Cloud services. [11] describes the economical importance of tax systems which have the goal to (i) raise money for the tax authority, (ii) improve equality and (iii) create incentives for market participants (e.g. for internalizing externalities).

The widely used value added tax is a proportional tax calculated on basis of the price. It does not create incentives. For example by taxing only the processing power of virtual machines the tax authority may create an incentive for consumers to reduce processing power consumption and consequently the energy consumption.

On Cloud markets new types of market participants appear like trust managers described in [12] which are using new business models resulting into additional taxation opportunities. Our tax component is adaptive so that these new market participants can be taxed too.

Usually a Cloud provider runs datacenters in different countries [3]. Consequently the services offered by the datacenters may be subject of different taxes. Papers like [13], [14] describe mechanisms and algorithms for cost efficient Cloud bursting and VM placement. To the best of the authors knowledge no paper considers that different tax systems may be applied for different datacenters in different countries. However, the burden of tax may have a significant impact on

9781-5090-1445-3/16$31.00 © 2016 IEEE (CloudCom'16)

effective VM placement and Cloud bursting decisions. Even Cloud cost models like [15], [16] do not consider taxes.

In this paper we introduce a descriptive analysis of Cloud taxes. It is a first step for analysing the impact of taxes on markets for virtual machines (VMs) as an example of Cloud services. The CloudTax component was integrated with the Bazaar-Extension and is able to simulate arbitrary tax systems and analyse their impact on market participants and consequently on the resource allocation. A normative analysis of tax systems in IaaS-markets (What is the best tax system in a specific market situation?) is part of our further research.

The contributions of this paper are:

- Design of the **CloudTax component** so that basic tax concepts like price elasticity and Laffer Curve can be simulated for service markets (see section III).
- The implementation of the **CloudTax component** for the Bazaar-Extension (see section V).
- The **simulation of tax systems** on service markets using a so called Bazaar-Score key figure (see section VI). This key figure allows to compare the efficiency of resource allocations and is explained in [4]. We show that tax mechanisms strongly influence the efficiency of negotiation processes in the Cloud market.

The following section II contains a state of the art analysis and introduces the baseline research. Section III gives an overview of tax systems which can be simulated with the CloudTax systems. Basic economical principles described in well known literature are described in the section IV. In section V the simulation environment of the CloudTax component as well as the CloudTax component itself are introduced. Simulation scenarios using the CloudTax component are presented in section VI. The paper is closed with the conclusion in section VII.

II. Related Work and Baseline Research

Service markets are currently evolving. Papers coping with service markets are assuming a simplified consumer-provider market without further market elements such as taxes [6], [8], [9], [17], [3], [18], [19], [20]. In [21] taxation of datacenter infrastructure is described. To the best of the authors knowledge taxation of Cloud computing services has not been considered yet by the scientific community.

Even papers focusing on economical aspects of Cloud computing as e.g. [22], [23], [24] have not considered taxes. In [25] taxation of Cloud computing is mentioned however a deep analysis, concepts or simulation is missing.

Our research endeavour is the analysis of economical aspects of Cloud computing. We envision the development of a service market ecosystem including market elements like taxes. In [26] we developed the concept of a generic service negotiation framework which is categorized in [20] as a novel approach enabling SLA negotiation and re-negotiation. In [4] we introduced a negotiation mechanism using an offer-counteroffer approach based on the WS-Agreement negotiation standard [27], which we called Bazaar-approach. An initial negotiation strategy for Bazaar-negotiations as well as the Bazaar-Score was introduced in [4], [28]. The simulation framework was realized by extending CloudSim [29] with our so called **Bazaar-Extension** [4]. This extension allows to create a service market, add market participants to the market, assign negotiation strategies to the market participants and analyse the resource allocations. Novel negotiation strategies can be evaluated and fine-tuned using the Bazaar-Extension.

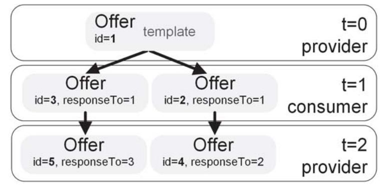


Fig. 1: Offer-Counteroffer example

In the Bazaar-Extension the subject of negotiation are virtual machines. In this paper we use the term resource for all resources of a provider which can be offered in form of virtual machines. Virtual machines are not commodities which are totally interchangeable. Virtual machines are goods which have several characteristics [30]. A virtual machine is characterised by: (i) processing power (ii) storage (iii) RAM and (iv) price.

The CloudTax component introduced in this paper extends the Bazaar-Extension. In the scenarios presented in section VI the consumers and providers are using the negotiation strategy introduced in [4]. Therefore we describe the most important concepts of this negotiation strategy in this section.

In a typical negotiation scenario, two negotiation partners such as provider and consumer exchange messages in an alternating way: each negotiation partner sends offers then it receives counteroffers to which it can respond again. As offers always contain virtual machines we use these terms synonymously. A simple example for the mechanism is provided in figure 1. A provider starts a negotiation by sending an offer to the consumer at time $t = 0$. The first message is usually called template. Templates are the initial offers published by the providers to promote negotiation [27]. Afterwards the consumer responds to the offer with two counteroffers ($t = 1$). The provider responds to the counteroffers with two new counteroffers ($t = 2$). This message sequence leads to a tree-based structure as figure 1 shows. Theoretically, a negotiation partner can create an arbitrary number of counteroffers in response to received offers. We use the term offer for both, a template as well as a counteroffer. An offer always contains a description of a virtual machine. So we use these terms synonymous.

In the Bazaar-Extension consumer and provider exchange four types of messages in addition to the CloudSim messages. (i) **Offer.** Consumer and provider exchange offers which are either templates or counteroffers. (ii) **Accept Request.** If a consumer or a provider considers the offer as suitable it sends an accept request to the negotiation partner. (iii) **Accept Acknowledge.** A negotiation partner can form a binding agreement by sending an acceptance acknowledge in response to a received acceptance request. It is also possible to respond with offers or with a reject message. (iv) **Reject.** If a poor offer is received its negotiation can be terminated. Usually, the negotiation between consumer and provider is continued for other offers. However, there is no obligation to form an agreement.

During negotiation consumers and provider receive several offers at the same time. These offers have to be ranked. Therefore utility functions are used. Utility is a measure of happiness [31]. Offers with high utility values are favoured by consumers and providers over offers with low utility values. Providers as well as consumers have different utility functions based on their needs, experiences and resources. For more information about the used utility functions see [4].

III. Cloud Tax Systems

Mankiw [32] distinguishes between consumption and income taxes. Income tax have to be paid independently from a buyers consumption decision. It is calculated based on a persons income and is not considered in this paper. A consumption tax is based on the items bought by a consumer. Contrary to income taxes, consumption taxes are only charged if an item is bought.

On Cloud markets consumers and providers trade virtual machines. We categorize taxes for Clouds along two characteristics: (i) taxable base and (ii) tax rate. The price, processing power, storage and RAM represent the taxable base in case of virtual machines. Currently, one of the most popular taxes is the value added tax which is charged based on the price of a good. In this paper taxes which are charged based on the price are called Price Taxes. Taxes which are charged based processing power, storage or RAM are distorting incentives of consumers. For example a tax on storage of a virtual machine makes storage more expensive usually reducing the required amount of storage. So they are called Incentive Taxes. For example a tax on storage may be realized by taxing each MB with a certain amount of money.

The tax rate represents the proportion of the taxes a consumer has to pay for an item:

$$\text{tax rate} = \frac{\text{tax}}{\text{price of virtual machine}} \tag{1}$$

[32] distinguishes between progressive, regressive and proportional tax rates. By using a proportional tax each virtual machine is taxed with the same proportion. The height of the taxable base does not influence the tax rate. An example of a proportional tax is the value added tax where each item is taxed with the same tax rate. The payroll tax is an example of a progressive tax rate. The higher the income the higher is the tax rate. For example a virtual machine with a net price of $100\$$ will be taxed with $10\$$ resulting into a tax rate of 10%. A virtual machine with a net price of 150 may be taxed with $50\$$ resulting into a tax rate of 33.33%. As the tax rate increases with increasing price the tax is progressive.

A regressive tax is inverse to a progressive tax. This is because the tax rate decreases with an increasing taxable base.

TABLE I: CloudTax Systems

	Lump Sum	Progressive	Regressive	Proportional
Price	Price Taxes			
Storage RAM Processing P.	Incentive Taxes			

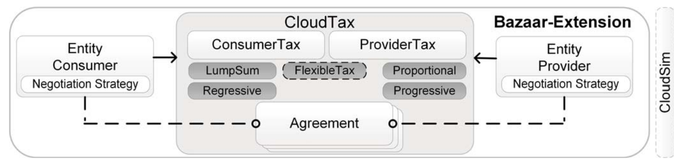


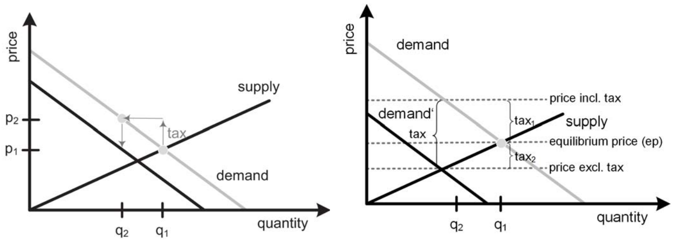
Fig. 2: CloudTax high level architecture

The lump sum tax is a special form of a regressive tax. A fixed amount of any market participant for any transaction independent of the taxable base is charged. So a lump sum tax can be considered as a fee.

Table I summarizes the tax systems along taxable base and tax rate for Cloud markets. Consumption of e.g. energy can not be taxed directly. This is because datacenters use heterogeneous infrastructures so that a direct mapping of the total datacenter energy consumption to virtual machines is not possible. In [15] we tackled this issue by considering idle times of datacenter hardware.

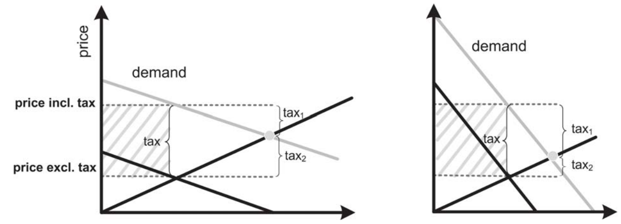
The CloudTax extension is able to simulate each of these tax systems. In our further work we envision a systematic comparison of the different tax systems. Especially flexible tax systems are an interesting research field. These taxes change over time making them appropriate for the highly dynamic Cloud service market. The tax authority may for example introduce tax exemptions at times when datacenter utilizations are usually low. This gives service users an incentive to reschedule their task in order to reduce cost and helps datacenter owners to reduce energy consumption.

Figure 2 shows the high level architecture of the CoudTax component which is integrated in the Bazaar-Extension. In the context of CloudSim consumer and provider represent entities which are able to send and receive offers. For evaluating received offers entities need to know how much taxes they would have to pay in case of buying or selling a VM. Thus they access the tax component during negotiation in order to calculate the cost/price of a taxed virtual machine. In a market scenario the tax component collects all taxes based on the formed agreements. Afterwards the resource allocation can be analysed. We implemented the CloudTax component as JAVA component. A market scenario uses exactly one tax system to which all entities have a reference. For the entities the CloudTax component is a blackbox: they send virtual machine to the tax component which returns the taxes which have to be paid in case of a transaction. Such a tax component may be useful for autonomous agents used in other domains too.



(a) Shift of demand curve (b) Tax incidence

Fig. 3: Impact of taxes on demand and supply



(a) Elastic demand (b) Inelastic demand

Fig. 4: Tax incidence examples

IV. Tax Incidence for Digital Service Markets

Digital marketplaces are virtual markets where e.g. virtual machines are traded. Virtual machines can be seen as virtual goods which are supplied by providers and demanded by consumers. So the fundamental market mechanisms for consumer goods can be applied to services too. Basically, the market controls price and quantity based on demand and supply [11]. A lot of effects of taxes can be explained using this simple market model.

Tax entities like consumers or providers have to transfer the tax determined by a tax authority. The so called flypaper theory [32] implies that the entity which transfers the tax has to pay the tax. So if the provider has to transfer the tax the provider losses profit because it has to pay the burden of the taxes. Conversely if the consumer transfers the tax then the provider does not lose profit because the consumer has to pay the tax according to the flypaper theory. The flypaper theory does not reflect reality as described in [32].

The tax incidence theory determines who finally pays the tax. The general impact of taxes on the market is shown in figure 3a. The demand before the tax is introduced is represented by a gray line. A tax which has to be transferred by consumer shifts the demand curve to the left. Consider a situation where the price is p_1 and the quantity is q_1. If the consumer has to transfer a tax the real price of the product is p_2. At this price the consumer demands a quantity of q_2. This is shown by the new demand line represented by a black line.

If the provider has to transfer the tax then the demand curve remains the same but the supply curve shifts upward.

The tax incidence theory introduced by [32] describes that the entity transferring the tax does not necessarily pay it. The price where the demand curve crosses the supply curve is called equilibrium price ep. A shift of the demand curve and the supply curve leads to a modification of the equilibrium. Figure 3b shows the equilibrium price before the tax is introduced. In the example depicted in figure 3b the tax is transferred by the consumer so that the demand curve shifts to demand as explained in figure 3a, which leads to a new equilibrium at price excl. tax and consequently to a new quantity $q2$. Although the consumer has to transfer the tax, both, the consumer as well as the provider, have to pay, as explained in the following.

- Before the tax was introduced the provider was paying the equilibrium price ep. After the tax was introduced the consumer has to pay price incl. tax. The difference between the two prices is marked with tax_1.
- The provider was receiving the equilibrium price ep before the consumer was transferring the tax. The introduction of the tax results into a shift of the curve and consequently to a new equilibrium price excl. tax. So the provider receives less money before the tax was introduced marked with tax_2.

As shown by this example the entity transferring the tax may not pay the burden of tax. The size of taxes a consumer has to pay is determined by the price elasticity of demand and supply. The elasticity is represented by the amount of the slope. It is calculated as shown in the following equation.

$$elasticity_{price} = |\frac{dQ/Q}{dP/P}| \quad (2)$$

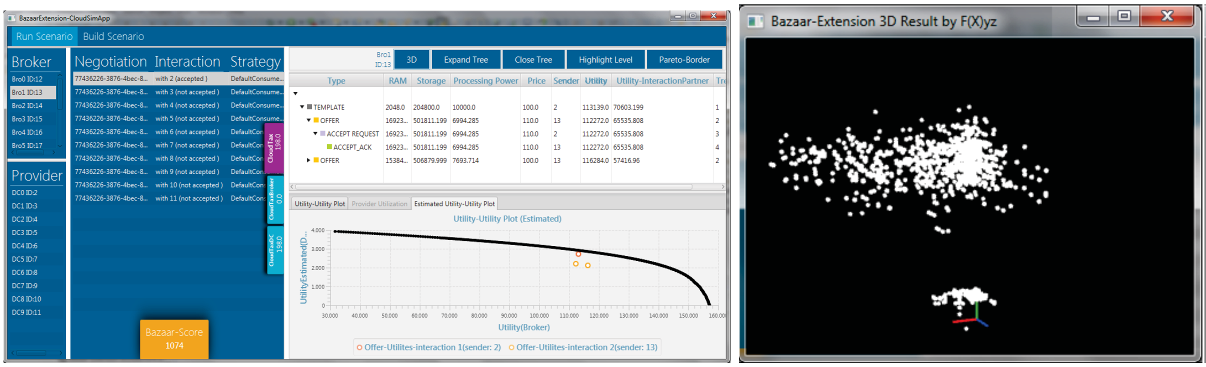
The higher the elasticity of the demand or supply the smaller is the size of the tax the consumer and the provider have to pay. This is because the elasticity can be interpreted as the flexibility of consumer and provider. For example a consumer with a high elasticity is price sensible because it has alternatives making it easy for it to leave the market. A consumer with a low elasticity is not very price sensible. This is because the consumer needs the product and has no alternatives so that the consumers has to accept a higher price.

Two examples are shown in figure 4. In both examples the size of the tax is transferred by the consumer and its size is identical. In figure 4a the demand is elastic so that the provider has to pay a larger part of the tax than the consumer. In figure 4b the demand is inelastic so that the consumer pays most of the tax. If the consumer's demand or the provider's supply curve is perfectly inelastic then the consumer or provider has to pay the full taxes.

In both examples the quantity sold is lower than in the situation without taxes. The tax revenue is highlighted by the gray areas in the figures. The total tax revenue is calculated by multiplying the quantity with the tax size as shown in the following equation.

$$\text{tax revenue} = \text{quantity} \cdot \text{tax size} \quad (3)$$

Generally, the higher the tax the lower is the traded quantity. So by increasing the size of the tax two effects have to be considered.



(a) Screenshot of Result-View of the Bazaar-Extension

(b) Screenshot of the 3D-plot

Fig. 5: Bazaar-Extension with Tax component

- **Effect 1**
  By increasing the size of the tax the tax revenue earned by each sold item increases.
- **Effect 2**
  By increasing the size of the tax the sold quantity decreases. This is because products become more expensive. Consumers having a lower value than the price are not buying the product any more. So some products will not be sold any more and consequently no tax revenue is earned for them.

These two effects are shown in figure 6a visualizing the so called Laffer Curve. In the left part of the curve effect 1 is stronger than effect 2. Due to the higher tax size the total tax revenue is increased even if the quantity is decreasing. In the right part of the Laffer Curve effect 2 is stronger than effect 1. The higher tax revenue earned by each sold item is unable to compensate tax revenue lost by the reduced quantity.

In the CloudTax-component the elasticity depends on the used negotiation strategy. The Bazaar-Extension is able to simulate arbitrary negotiation strategies. As already described utility functions are used for evaluating received offers containing virtual machines. The consideration of the price in the utility functions represents the price sensitivity of the consumer or provider. Negotiation strategies for the Bazaar-Extension are published in [4].

V. CloudTax Simulation Environment

The Bazaar-Extension allows to create an IaaS-market, add market participants to the market, assign negotiation strategies to them and analyse the resulting resource allocation using the Bazaar-Score. The integrated CloudTax component introduced in this paper allows to define the used tax system. In CloudSim brokers represent consumers and providers represent datacenters. A screenshot of the Result-View of the Bazaar-Extension including the CloudTax component is depicted in figure 5a. The left side of the window shows the consumers and providers attending the market scenario. By selecting a participant (consumer or provider) its negotiations including the used negotiation strategies are shown. In the Result-View the offers exchanged during a negotiation are represented as tree list and visualized in a so called utility-utility plot (see right side of the window). The axis of the utility-utility plot represent the utility value of an offer for consumer and provider. In [4] we developed utility functions considering economical principles from consumer theory as e.g. described in [32]. These utility functions are used in the Bazaar-Extension.

By using utility functions a Pareto-boarder can be calculated which is shown in the utility-utility plot in figure 5a. The orange box in figure 5a contains the Bazaar-Score of the executed scenario.

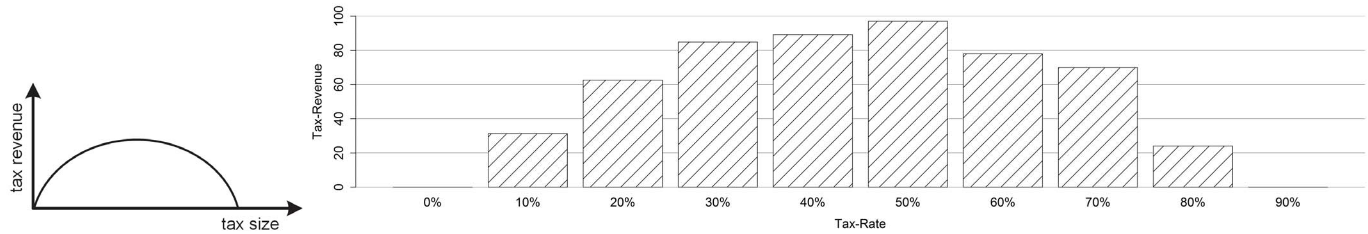
The violet and blue boxes in figure 5a contain the tax revenue generated in this market scenario. The violet box contains the total tax revenue and the blue boxes contain the taxes which have to be paid by consumer and provider. Negotiation results can be visualized in a 3D-plot as shown in figure 5b. The red, green and blue axis represent the processing power, RAM and storage.

The CloudTax component is able to assign a tax system to a market scenario. It is adaptive so that arbitrary tax systems can be developed and injected to the market scenario. The most important setup parameters which can be customized using the CloudTax component are (i) taxation of consumer and/or provider (ii) proportional, progressive, regressive or fixed tax (iii) taxation based on price or on the characteristics of the virtual machine.

The CloudTax component was designed to simulate taxation concepts as described in basic economical literature like in [11]. Using the CloudTax component phenomena like the Laffer Curve can be simulated. Further the price elasticity can be modified and so the tax incidence can be determined using a simulation based approach. It is also possible to design flexible tax systems which change tax behaviour over time. Thus it is possible to e.g. create tax exemptions for the first 100 sold virtual machines followed by a proportional tax for the remaining virtual machines.

VI. Tax systems Simulation

In this section we present simulation scenarios executed with the CloudTax component. The scenarios demonstrate that



(a) Laffer Curve

(b) Tax revenue depending on the tax rate

Fig. 6: Impact of tax rates

the component considers basic economical effects as described in [11]. The simulation setup parameters for the Bazaar-Extension are summarized in table II. During the negotiation counteroffers are created using a genetic algorithm which we have introduced in [4]. Fitness functions are stated in table II and are based on utility functions described in [4]: The utility function used by the provider represents the profit contribution. As shown in the table the provider has for example cost of 0.0001$ per MB. The consumers utility function is based on consumer theory [32]. A more detailed description of the simulation parameters is described [4]. We created 10 datacenters and 10 brokers. All datacenters were using the same utility function and all consumers were using the same utility function. The datacenters are also selling resources if they do not make profit to increase utilization. In all scenarios the tax was transfered by the provider. The consumer has not to transfer any tax.

A. Laffer Curve

The Laffer Curve shows that the tax revenue decreases if the tax rate is too high. This was shown in this simulation scenario.

The scenario simulates a usual value-added tax. This means a virtual machine was taxed on the basis of the price. During the simulation the tax system was not modified.

Figure 7 summarizes the results of the simulation scenario. It shows that the simulation was executed with 10 different tax rates. The total Bazaar-Scores of the consumer and the provider are decreasing with an increasing tax rate. This is because the higher the tax rate, the less consumers and providers are able to find a virtual machine at a price so that the traded VMs have utility for them. In other words, the tax leads to prices at which consumers will not buy and/or providers will not sell VMs. At a tax rate of about 50% the datacenters are unable to generate Bazaar-Scores due to the used negotiation strategies of consumers and providers. The negotiation strategies refelect the price sensitivity and consequently the price elasticity. Hence it decides who (consumer or provider) has to pay the tax. Nevertheless the negotiation strategy can not inverse the trend of decreasing Bazaar-Scores by increasing tax rates.

The simulation scenario shows, that the flypaper theory does not apply: even if the consumer has not to transfer the tax they have to pay the tax as the decreasing Bazaar-Score shows. The datacenters require higher prices which should compensate the tax which has to be transferred by them. Figure 6b shows the total tax revenue generated within the simulation scenario. Up to a tax rate of 50% the tax revenue increases. However, higher tax rates lead to a lower tax revenue. This is, as already explained a result of decreasing sales transactions.

B. Incentive-Tax

In the next scenario we created an incentive tax system where the tax is calculated based on the processing power (measured in MIPS) of the virtual machines which are sold/bought. The scenario result is shown in figure 8. The abscissa shows the tax per MIPS, the left y-axis shows the sold MIPS while the right y-axis shows the total tax revenue. It shows that the higher the tax per MIPS the lower is the total amount of sold processing power. Two effects are responsible for this trend.

- **Incentive Effect**
  As shown in [4] the characteristics of a virtual machine like storage or RAM are interchangeable at a certain degree. The more expensive processing power gets the more other resources of a virtual machine are attractive for consumer and provider. So the provider may offer the consumer additional storage or RAM instead of processing power to avoid the tax. Alternatively, datacenters may be willing to offer a discount to the consumers instead of providing expensive processing power.
- **Reduction of sold VMs**
  Consumers can not buy virtual machines without processing power in order to fulfil their tasks. They also have to buy processing power and consequently pay the charged tax. Thus the prices of virtual machines are increased by the incentive tax. This leads to less sales transactions as some consumers are not willing to pay higher prices for VMs. Thus the effect described by the Laffer Curve also occurs in markets using incentive tax system as shown in figure 8. Here the total tax revenue increases up to a price of 0.003. Then the total tax revenue decreases.

VII. Conclusion and Further Research

This paper was intended as a first step to analyse and design tax systems on service markets. The component CloudTax was introduced allowing to simulate taxes on service markets which are currently evolving. The component is integrated

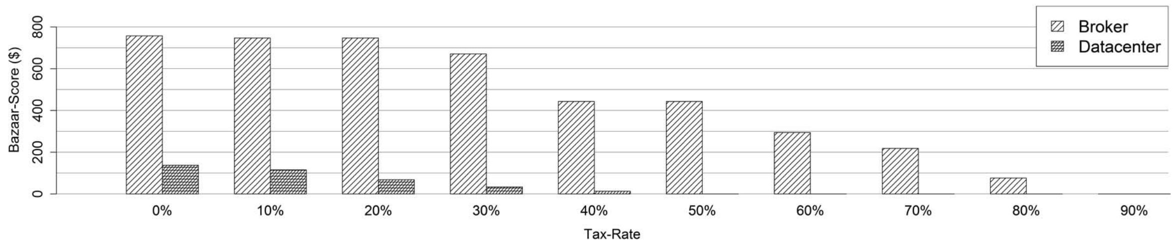


Fig. 7: Bazaar-Scores of consumer and provider

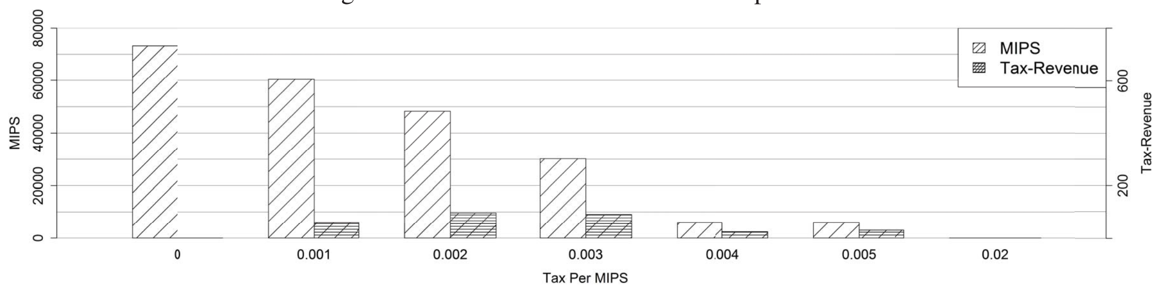


Fig. 8: MIPS and tax revenue depending on tax rate

with the simulation framework CloudSim and the Bazaar-Extension, which allows comprehensive market simulations. The presented simulations justify that taxes are a signification market element which are necessary for a realistic simulation of service markets and influence strongly the efficiency of negotiation processes. The negotiations results were analysed using the Bazaar-Score which was developed for comparing different resource allocations. In our further research we will implement different negotiation strategies in the Bazaar-Extension so that we can compare them including tax systems. Further we will investigate the equality of Cloud markets. For example we plan to analyse how tax systems can help small consumers and small providers to compete with huge consumers and provider usually dominating service markets. This requires implementations of further tax systems.

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TABLE II: Simulation setup parameters

Parameters	Values
Number of providers	10
Number of consumers	10
Genetic Algorithm for counteroffers generation	
Population Size	96
Received VM	(200,10000,7,30)
Mutation Probability	5%
Elitism	best 5%
Used parameters for utility functions	
consumer $U^{threshold}_{\text{accept request}}$	utility of the best template+1000
consumer $U^{threshold}_{agreement}$	$0.9 \cdot U^{threshold}_{\text{accept request}}$
consumer U^{reject}	30000
provider $U^{threshold}_{\text{accept request}}$	30000
provider $U^{threshold}_{agreement}$	$0.9 \cdot U^{threshold}_{\text{accept request}}$
provider U^{reject}	20000
Consumer Fitness Function	
$U_x = \begin{cases} log(x) & x \geq Min_x \\ -\infty & x < Min_x \end{cases}$	x $\in \{RAM, Storage, Proc.Power\}$
$U_{Price} = \begin{cases} log(Max_{Price} - Price + 1) & Price \leq Max_{Price} \\ -\infty & Price > Max_{Price} \end{cases}$	
U=$w_1 \cdot U_{Price} + w_2 \cdot U_{RAM} + w_3 \cdot U_{Storage} + w_4 \cdot U_{Proc.Power} + 100000$	
weights: $w_1 = 1$, $w_2 = 1.7$, $w_3 = 2$, $w_4 = 0.3$	
$\bar{U} = (Price - RAM \cdot 0.0001 - Storage \cdot 0.0001 - Proc.Power \cdot 0.00001)$ w=0.4029	
Provider Fitness Function	
$U= \begin{cases} (Price - RAM \cdot Price_{RAM} \\ -Storage \cdot Price_{Storage} \\ -Proc.Power \cdot Price_{Proc.Power} \\ \cdot 1000) \\ -\infty & \text{if } Storage > Max_{Storage} \vee RAM > Max_{RAM} \\ & \vee Proc.Power > Max_{Proc.Power} \end{cases}$	
no resource constraints, prices: $Price_{RAM} = 0.0001$, $Price_{Storage} = 0.0001$, $Price_{\text{Proc.Power}} = 0.00004$	
$\bar{U} = (log(Storage) \cdot 1 + log(Proc.Power) \cdot 0.8$ $+ log(Ram) \cdot 0.2 + \log(Price_{max} - Price + 1) \cdot 4$ w=0.38	

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