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Evaluating Investments in Portability and Interoperability between Software Service Platforms

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Abstract: Within a closed ecosystem, end-users cannot interoperate with other platforms or port their software and data easily without a cost for interface integration or data re-formatting. The customers of these closed software service platforms are locked-in. Potential customers, who are aware of this lock-in issue, are hesitant to adopt a closed software service platform, slowing down the wide deployment of the software service platform. This paper applies an economic perspective to investigate the value creation for providers and users at different levels of interoperability. For the analysis, a value creation model for software service platforms within a software service ecosystem has been developed. Simulations of the value creation model show that, even if investments in interoperability and portability are aimed at addressing user requirements, their impact also drives the providers' profitability. Furthermore, emerging providers require investing more than market leading providers, as they have less power to set de facto standards. The simulation results also show that there is an optimal level of investments, with respect to profit and return on investments. Overall, from these results, platform providers cannot only obtain an understanding on how investments in interoperability and portability impact cost, enable cost-effective service integration, and create value, but also design new strategies for optimizing investments.

Keywords: Cloud Computing, Software Service Platform, Interoperability, Portability, Value Creation Model, Computational Economics, Simulation, Value Analysis, Net Present Value, Return On Investments, Investment Assessment.

JEL Classification Numbers: C15, D24, D46, D85, E22, L86, M15, O31.

1. Introduction

Software service platforms provide services as alternatives to on premise (traditional) software [6]. The crucial difference between on premise software and software service platforms is that these platforms can potentially support multiple user groups and not only consumer-scale or enterprise-scale applications worldwide [7]. In addition to this, software service platforms provide on demand a set of cloud services, which can be close to the hardware or very high-level application services (e.g., software services, application management services, or infrastructure services) [1].

These platforms provide technologies, which enable consumers to conveniently access computing resources as pay-per-use services. As the cloud service market offers a large number of alternatives to users and competition gets stronger, gaining additional users and retaining existing users becomes more and more important [2] [3]. As a result, providers strive to support emerging service models and new requirements. Provision of similar or complimentary services over multiple cloud platforms is one of these requirements [4] [5].

Although the benefits of software service platforms to users are significant, the adoption of software services comes with the risk of being locked into a platform [8] [9]. For example, end-users (firms) that consider adopting cloud computing technology are concerned about owning a cloud implementation that cannot interoperate with other systems [10] [11] [12]. The lack of interoperability can be caused through the technological diversity of cloud service platform offerings (e.g., different virtualization technologies, different service interfaces, and development environments) [13] [14]. Evidence for this situation was found by a 2011 IEEE report and a 2009 IDC survey [15] [16], which state that organizations could not consolidate their IT systems within the cloud due to the lack of interoperability between cloud service platforms.

Therefore, in order to fully make cloud computing a widely accepted IT infrastructure, low data portability, low application portability, and low interoperability between cloud platforms should be overcome [13] [14] [8] [50]. That means, moving data, applications, and virtual machine images from one cloud service platform to another need to be possible for basic (frequently used) services. Programmers need to be able to work with the programming language of their choice. Basic services of different service platforms also need to be able to access each other's services. These capabilities would create a cloud service ecosystem with different levels of cloud service platform maturity. It would enable end-users to choose among different service providers according to their needs (e.g., their performance requirements, geographic location, and cost). It would also enable end-users, who are dissatisfied with a service or lost their service due to the bankruptcy of a provider, find alternatives. Consequently, the high lock-in risk would have been lowered significantly [18].

This article addresses this problem by focusing on cloud service platforms, which provide software as a service and platform as a service. The lack of interoperability and portability of these types of software services cause a significant barrier to wider adoption and value creation [39] [40]. This viewpoint of the problem is different from existing research, as this article considers economic aspects instead of technical aspects (e.g., standards building [1] [8] [13] [14] [15], architecture frameworks of interoperable clouds [9] [18] [22], and requirements of interoperability [24] [38] [49]).

The objective of this article is to validate the impact of high-level interoperability and portability on the value creation of software service platforms. This objective translates into the following four research questions: (1) What is the model that comprehensively describes the impact of interoperability and service portability on value propositions? (2) How does an increase in the level of interoperability and portability relate to the change in the value of platform providers and their users? (3) Does the maturity of a software service platform (i.e., emerging or market leading platform) make a difference in the impact of interoperability on the pace of adoption? (4) How do investments in interoperability and portability affect profit, net present value, return on investment, and discounted return on investment?

In order to tackle these research questions, we develop a value creation model for software service platforms, which shows the stakeholders and the value exchange between the stakeholders, based on the work by Gebregiorgis and Altmann [2]. Using this value creation model and system dynamics methodology, first, we analyze the relationship between the level of interoperability and portability and the value obtained by providers and users. Second, we use the model to investigate the role that interoperability plays in the adoption of software service platforms at different levels of platform maturity in the market. Third, we analyze the impact of investments in interoperability and portability, considering two platform maturity levels, two amortization periods, and different amounts of investments by providers. For the analysis, we calculate profit, return on investment, net present value, and discounted return on investment.

This article makes three contributions. First, the article presents a quantitative model of the impact of interoperability and service portability on value propositions of software service platforms, providing an economic perspective of interoperability and portability. Second, using this model, the paper determines the role of interoperability and portability in the creation of provider value and user value. The simulation results confirm that providers benefit from offering interoperability due to an enhanced attractiveness of their service platform. Interoperability and portability enable cost-effective service accessibility, flexibility, integration, and creation of a software service ecosystem. Providers and users can innovate by easily combining software services in the ecosystem. Third, although all platforms benefit from interoperability and portability, market-leading platforms require less investment for achieving the same amount of interoperability. Fourth, in spite of the positive impact of investments in interoperability on the creation of user and provider values, providers need to carefully evaluate their strategies for investments. It has to be considered that profit, net present value, return on investment, and discounted return on investment exhibit a maximum for certain amounts of investments. This investment analysis could become the basis for software service platform providers, in order to design new strategies for optimizing investments.

The remainder of this paper is organized as follows: The next section provides an overview of software service platforms, their adoption challenges, their requirements for interoperability and portability, and the value exchange between the stakeholders of the software service platform. Section 3 describes the interoperability and portability model for software service platforms. Section 4 explains the simulation results. Section 5 presents a discussion of the results and concludes the paper with a summary, limitations, and an outlook on further research.

2. Software service platforms

2.1. Concept of Portability and Interoperability of IT Service Platforms

Many IT service platforms have been built as closed systems (i.e., not providing the ability to interoperate with other service platforms). Unique to these closed (proprietary) IT service platforms is that all platform components are provided by a single vendor. Although it guarantees that all the components can work together, it creates a high dependency of end-users on the vendor. This lock-in is the cause for a low adoption of IT service platforms [14] [15]. A study by the IDC enterprise panel in 2011 identified that the issue of interoperable clouds is as important for their adoption as the issue of security [15]. Furthermore, a survey, which has been conducted by the World Economic Forum in 2009, indicated vendor lock-in to be the second most important concern about public clouds (with a value of 80%) in the European public sector [8] [9] [19].

The portability of services and the interoperability of platforms would ensure that end-users can port and combine services regardless of the platform, on which the services were deployed first. With respect to service developers, an interoperable, service-oriented IT service platform would be cost-effective, as, for example, they could keep their development environment [15] [16]. If customers of IT service platforms are dissatisfied with the services offered or location, they have an easy way out from an IT service platform due to portability and interoperability. In detail, the definition of interoperability and portability are given in the following two subsections.

2.1.1. Portability

Portability is defined as the characteristic of a service and service component to be executed on a platform different from its first design and deployment environment [53] [50]. In the context of cloud service platforms, service components comprise data, software, and hardware (both physical and virtual). The portability characteristic guarantees a component to have a common method of interaction to the underlying platform services. Therefore, the component always works in the same way, regardless of the cloud that could be public or private [22] [23]. An IT service platform, which supports portability, allows customer data, application services, and application service components to be moved easily from one provider to another. This is illustrated in Figure 1, where platform provider A and platform provider B can be accessed by the platform customer. A platform customer can be an end-user that wants to get its data processed, an application service vendor that runs its service on different platforms, and a software vendor that provides support services to third-party services. Portability can be achieved through the use of common semantics in data formats or conversion tools.

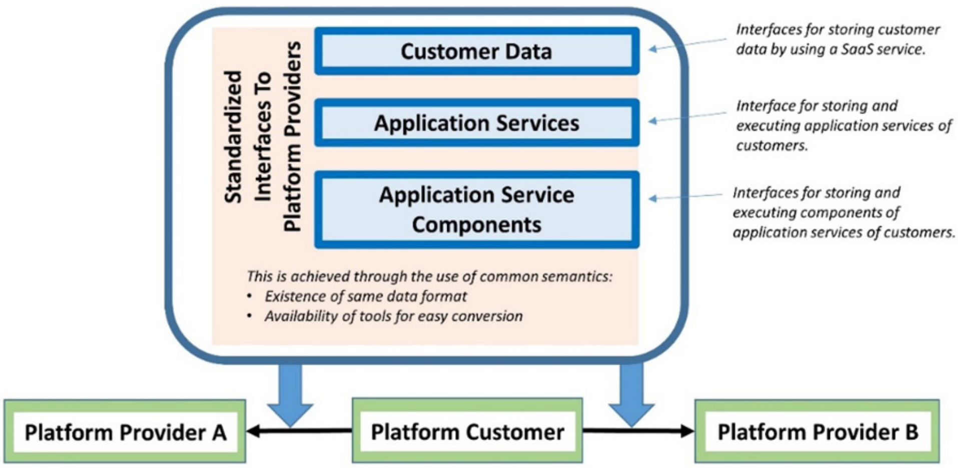

Figure 1. Concept of Portability.

Furthermore, as more IT service platforms and platform providers emerge, portability becomes more important. Any lack of portability of services hampers the provision of new services, as customers have to spend more time on the adaptation of the service to a new IT service platform than on adding new functionality to the service (i.e., being innovative). If end-users are able to select service providers depending on their performance needs, geographic location, and budgets, the utility of customers is increased and the costs are reduced.

2.1.2. Interoperability

Interoperability is defined as the ability of a component to work simultaneously with one or more components of other platforms, regardless of the differences between the platforms [53] [18]. Interoperability also means that all components (i.e., hypervisor, orchestration, automation systems, and metering tools) can come from different service developers. That means, interoperability allows service components, which are simultaneously active on more than one platform, to interact, in order to serve a common purpose. In order to enable this, the interaction between different IT service platforms needs to be based on standardized interfaces between the platform providers (Figure 2). The standardized interfaces can comprise those for business tasks, authentication, authorization, administration task, execution tasks, and specific data formats.

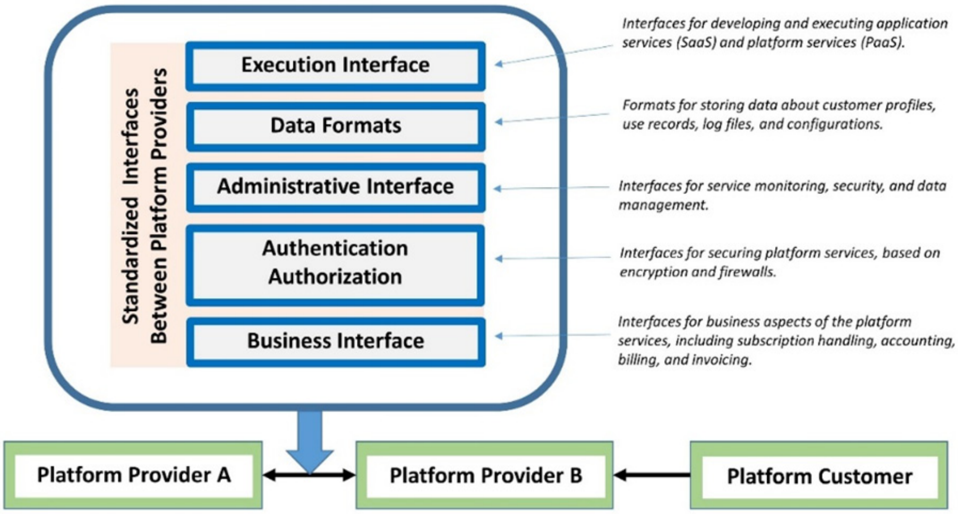

Figure 2. Concept of Interoperability.

An interoperable IT service platform allows for the creation of a system of compatible suppliers. This allows users to compose the best cloud services and to meet their specific needs on a pay-as-you-go basis [18] [24]. It helps users to compose solutions that are highly optimized towards their needs.

2.2. Economics of Portability and Interoperability of IT Service Platforms

Existing economics-based research studies have analyzed portability and interoperability of platforms in different ways. Matutes and Regibeau investigated product compatibility without network externalities [25]. Incompatibility of closed platforms obligates users to buy components from the same platform. Complementing research by Schiff analyzes the compatibility between platforms, considering closed systems of two-sided networks [26].

Arora and Bokhari compared closed systems with open systems [27]. Their finding is that, while firms running open systems can specialize in producing a single component, firms running closed systems cannot specialize and must produce all components. IT service platforms, which improve portability and interoperability, increase the possibility of software services integration [28]. Research on value creation through the federation of IT service platforms has been considered by Haile and Altmann [10].

Besides technology, the economics of interoperability is impacted by many factors such as the type of service used, the service ownership [29] [30], the policy maker's decision [58], the type of the cloud delivery model (i.e., private, public, hybrid, or federated clouds [31]), and the service level agreement between providers and customers [32].

2.3. Types of Issues of Interoperability and Portability

There are many examples that show a lack of interoperability and portability of IT service platforms. For example, Microsoft .NET application containers and Microsoft Azure database services cannot be integrated with Google App Engine [33] [34]. Another example is the data format used by different social media websites (e.g., Facebook), making it difficult to move user profile data from one platform to another. The technology types with potential issues of interoperability and portability can be classified into programming frameworks, application programming interfaces, and data formats [2]. Consequently, those technology types represent the means for achieving interoperability and portability (Figure 1 and Figure 2):

Programming Frameworks: As service developers are used to their software development tools, programming languages, and runtime environments, they avoid a change of their programming frameworks. Thus, IT service platforms need to support the programming frameworks that are in use today. Any change of a programming framework would come with the cost of learning a new technology for service developers [18] [28].

Application Programming Interface: Many IT service platform providers have their own application programming interface (API), preventing orchestration of applications across multiple service platforms of other providers. The incompatibilities of the APIs for uploading, downloading, inspecting, and configuring are a significant issue for interoperability. For example, the Amazon EC2 API is different from the GoGrid (Datapipe) API [35] [36], although both offer similar IaaS services. In addition to this, cloud providers have their own proprietary services. An example of valuable but proprietary services is Amazon Elastic Load Balancing [37]. This service only exists on a specific platform. Standardization of APIs would allow applications to be moved to different providers without any additional integration cost or switching cost. Another way would be the provisioning of programming toolsets, which enable their services to be deployable on multiple platforms [38] [39]. Although this kind of middleware could break the dependencies on specific APIs, it is only useful for new application developments [40]. Similarly, the format of virtual machines (VM) is one of the major challenges for creating seamless portability among IT service platforms. As platform customers have already different virtualization environments (e.g., VMware, Hyper-V, KVM, and Xen) in their in-house data centers, IT service platform providers should make sure that these customers can use their familiar one [40].

Data Format: Many application services provide their own semantic and format for storing data [18], making it costly to access the data with a different application. If no standard for the data format exists, conversion tools are needed to translate the data format of one application service into the data format of another application service [41].

Though interoperability and portability of these technology types provide a reduction in the cost for switching, learning new technology, and integration, it is to be noticed that incompatibility is a logical consequence of technological development and innovation. As major innovation and technological developments result in an increase in revenue, the challenge is to find a compromise between cost and revenue. If the innovation is too small, the change in technology might not be justifiable.

2.4. Stakeholders and Value Exchange within Software Service Platforms

Based on the definition of a value creation model, which comprises stakeholders and their exchange of value within a framework of collaboration principles and service level agreements (SLAs) [42], the value of each stakeholder can be identified. Related to cloud computing, a few studies have analyzed value creation models (i.e., value chains and value networks). For example, Haile and Altmann modeled the value creation for software service platforms [3] [11] [52]. Altmann et al. developed a taxonomy that describes stakeholders and their roles in grid computing [43]. Stanoevska-Slabeva et al. (2007) conducted another study, which is based on industrial case studies in the context of grid computing [4]. Lee and Leem investigated the value chain in ubiquitous computing [45]. Furthermore, a value chain reference model for cloud computing has been proposed by Bany et al. [46]. This model is based on Porter's value chain theory and an adaptation to the none-linearity value creation aspects in the cloud computing context. Böhm et al. also described different cloud stakeholders and the interactions between them but using e3 methodology [47]. Based on these models, we identified the stakeholders, which are relevant for our analysis, and the value exchange between these stakeholders. The resulting value model is shown in Figure 3.

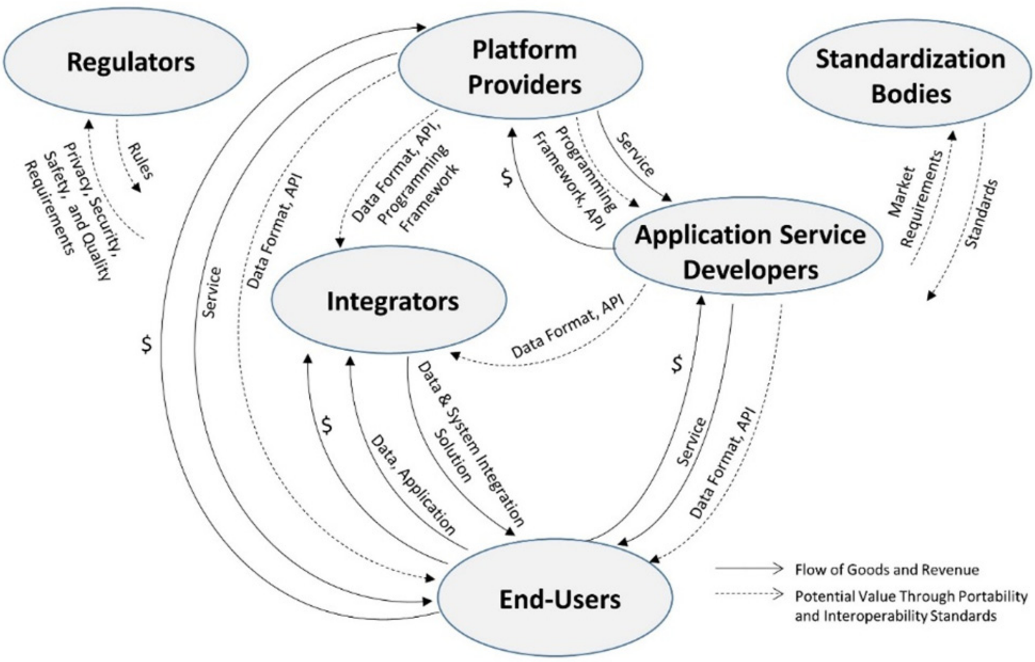

Figure 3. Stakeholders and value exchange within the value creation model for software service platforms (based on [2]).

Figure 3 shows six types of stakeholders, namely platform providers, application service developers, end-users (consumers), integrators, standardization bodies, and regulators. The roles of those stakeholders and their interactions with the other stakeholders are as follows:

Platform Providers: Platform providers deliver basic services to customers (i.e., end-users and application service developers). These services include an environment to develop, test, and run applications. In addition to this, they might include Web service integration, database services, VM management, and service versioning. These services depend on the operating system environment, the APIs available, and the programming languages used.

Application Service Developers: The application service developers build application services, which are value-added solutions for end-users, on top of the platform services. These application services became possible due to the service-oriented architecture of platforms. Three different types of application service developers can be distinguished: The first type combines services created by different providers into a new service. The second type represents value-added resellers, who add value to a service by addressing a specific need of an end-user. The third type of application service developers categorize, compare, and rank software services of different providers as well as provide marketplaces for those software services.

End-Users (Users): End-users, which consume software services, represent firms or individuals. They receive value from the consumption of the services within the software service platform and pay for the consumption of the services. End-users are the starting point (i.e., they request services) and the end point (i.e., services are delivery to them) of the value exchange.

Integrators: Integrators provide data and application service integration for end-users. Examples of these integration services are: (1) the conversion of pre-existing, on premise data into formats used in the cloud; (2) the integration of cloud computing solutions into the on premise IT environment; and (3) the development of interfaces between application services of different service developers and software service platform providers. Integrators also perform system integration testing, training of end-users, and customer support services.

Standardization Bodies: Standardization bodies coordinate the specification of interfaces of software services, increasing the portability and interoperability of these services. Any increase in portability and interoperability helps end-users, who need to move to a different application service or platform service without any additional costs [48]. However, the current operation of standardization bodies and the process of finding standards do not solve the problem of portability and interoperability, as they are rather driven by cost consideration and benefits of the parties involved in the standardization process.

Regulators: Regulators put laws into place that protect end-users from products and services that violate security, safety, and privacy requirements. Regulators determine the minimum quality requirements that need to be provided by platform providers and application service developers.

3. Value Model for Interoperability and Portability of IT Service Platforms

3.1. Modelling Technique

This study applies the causal loop diagram method (as used in system dynamics), in order to get a better understanding of the creation of provider value and end-user value depending on the level of portability and interoperability. A causal loop diagram is a model that shows the cause and effect relationship between key system variables. The system variable that is indicated by the start point of an arrow is called tail variable. The tail variable leads to changes in the head variable, which is indicated by the end point of the arrow. An arrow expresses true causality but not a statistical correlation [51]. To indicate the effect of a variable on another (i.e., the "polarity" of the link), a '+' sign or a '–' sign is placed next to the arrow. A '+' sign indicates an increase in the head variable through an increase in the tail variable. Conversely, a '–' sign indicates a decrease in the head variable through an increase in the tail variable [51].

3.2. Value Model

The value creation model designed here for describing the impact of interoperability and portability of services on the value of service platform customers and the revenue of service platform providers can show the dynamics between two stakeholders: the end-users and the platform provider. Application service developers are not explicitly modeled in this value creation model. It is implicitly assumed that the number of application service providers corresponds to the number of services offered on the platform. An end-user (user) can decide whether to join a software service platform, depending on the net benefit obtained from the platform. The user's decision is based on whether compatible services (functionalities) are available on the platform. The service compatibility helps using services easily, for example, for moving data to and from a public cloud. Furthermore, a user's decision also depends on whether it is possible to connect one platform service to another platform service, requiring interoperability between the providers. For example, a user might want to interconnect services running on its private cloud to services on a public cloud.

This value creation model, which has been built in response to research question 1 (What is the model that comprehensively describes the impact of interoperability and service portability on value propositions?), is shown in Figure 4. A detailed description of the different aspects of the value creation model is given in the following subsections. An overview about factors and coefficient used in the value creation model are presented in appendix A.

3.2.1. Quality of service

The quality of service (QoS) is one of the major factors impacted by the platforms ability to interact with other services (Figure 5). QoS depends on the amount of investments that a provider wants to allocate for improving the service quality [31]. Rust, Zohorik, and Keiningham in 1995 developed a framework for evaluating the return on investment on the quality of service (Return on Quality) for companies [17]. We follow their framework for modeling the quality of service and its impact on the value of software service platform stakeholders. The investment in QoS is beneficial in any market structure: In a monopolistic market or an oligopoly market, the strategy relies on non-price competition, differentiating products to attract more customers [17]. In a competitive market, high revenues motivate a provider to invest in QoS. Due to these economic principles, providers are assumed to improve the quality of service through investments and, therefore, attract more customers [17] [32].

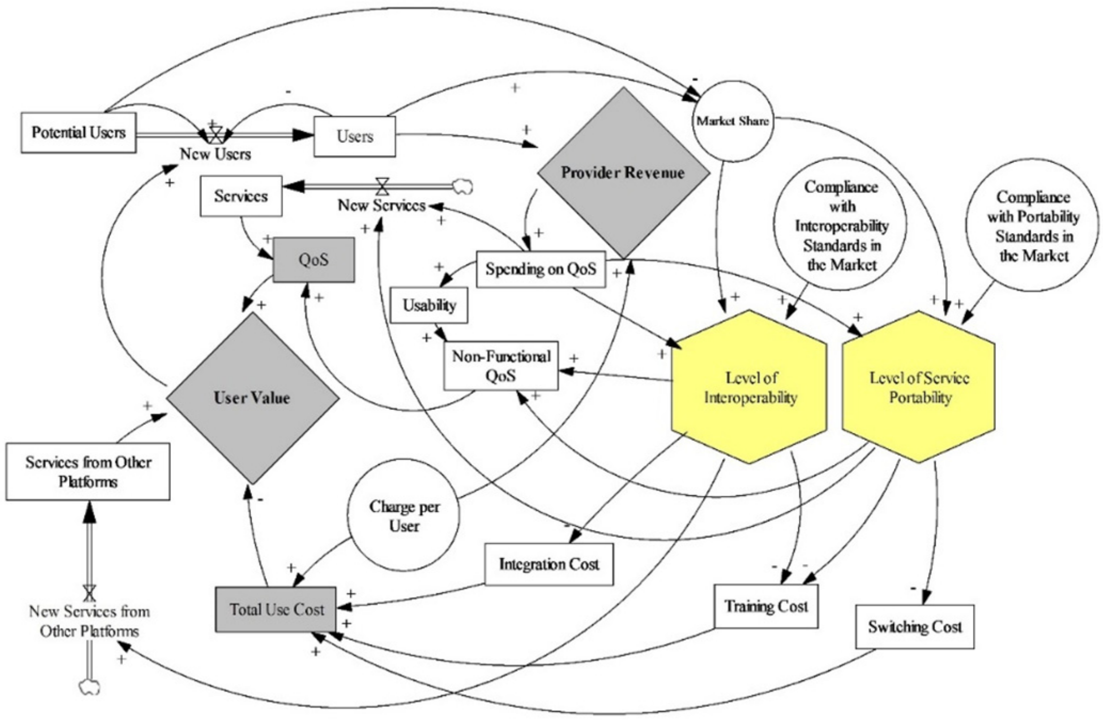

Figure 4. Value creation model considering the level of interoperability and the level of service portability.

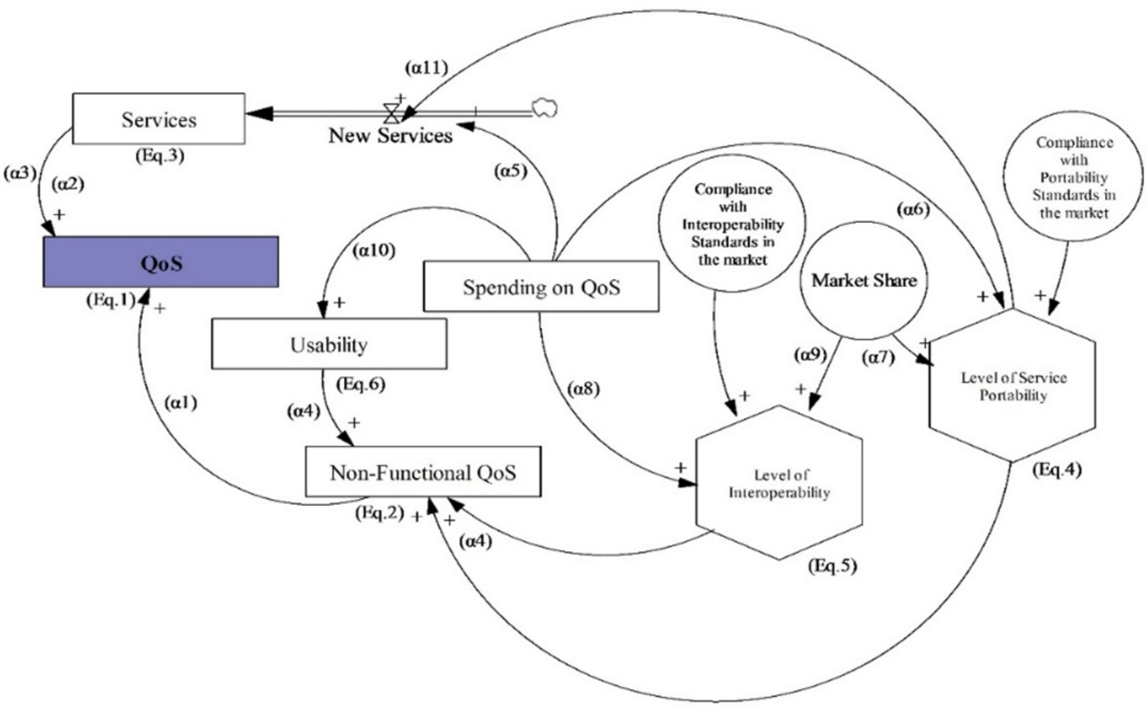

Figure 5. Factors determining QoS.

Based on these principles, QoS is considered to be a function of the fraction of revenue (SpendingOnQos) that platform providers allocate for improving the quality of service. As potential activities for increasing QoS, we follow the service management index (SMI) [33]. SMI identifies seven factors (including interoperability, portability, and usability) as objectives that need to be achieved for improving QoS. For example, QoS is determined by the ease of using a user interface (i.e., Usability). Besides increasing QoS through good usability [3] [52], QoS is also increased, if the interoperability and portability of services between platforms are improved. In detail, these improvements positively affect the non-functional QoS (NoneFunctionalQos) of the platform.

In addition to this, QoS represents the functionality of the platform services that are offered to the user. This is in line with Pitt, Watson and Kavan in 1995 and Grönroos in 1984, who included the actual services (functionalities) in their measurement of QoS [21] [56]. The number of services represents the functional QoS [56]. Accordingly, in our model, we assume that the value obtained from QoS increases as the number of services offered on the platform and the non-functional QoS are improved. This is expressed with the following formula:

$$Qos = \alpha 1 \cdot NonFunctionalQos + \alpha 2 \cdot (1 - 1 / (\alpha 3 \cdot Services(t))) \qquad (1)$$

In detail, the variable Qos is determined by the number of application services (Services) at time t deployed over the platform [21] and by the non-functional QoS of those services (NonFunctionalQos). The positive coefficients α1 and α2 are used for calculating the arithmetic average, while allowing weighting the variables Services and NonFunctionalQos. The coefficient α3 weights the number of services, in order to be able to reflect the amount of functionality. The value of the variable Services, which is larger or equal to 1 (i.e., at least, one service is present), is transformed to a value between 0 and 1 through (1 – 1 / Services(t)).

The variable *NonFunctionalQos* combines the variables *Usability*, *LevelOfInteroperability*, and *LevelOfServicePortability* [33]. These variables have a value between 0 and 1. For combining the variables, an additive function is used to capture the overall value of the three non-functional attributes. The value is scaled with the coefficient α_4, in order to calculate the arithmetic average.

$$NonFunctionalQos = \alpha 4 \cdot (LevelOfInteroperability + LevelOfServicePortability + Usability) \qquad (2)$$

Equation 3 also shows the growth in the number of services (*Services(t)*) that the platform exhibits over time. Showcasing the role of portability, a study by Gasser and Palfrey in 2007 demonstrated that a platform attracts more users, if it opens itself to outside applications [20]. It is assumed here that at each time interval new services are added, as developers continue to adopt the platform standard and provide compatible services (Equation 3).

$$Services(t) = Service(t-1) + \alpha 11 \cdot ((1 - 1 / \alpha 5 \cdot SpendingOnQos) + LevelOfServicePortability) \qquad (3)$$

The growth in the number of services (*Services*) is driven by the resources invested in improving the QoS (*SpendingOnQoS*) [17] and by the current level of service portability (*LevelOfServicePortability*) [22]. The number of services at time t is modeled to be the sum of the services at time $t-1$ and the new services that could be offered due to the level of portability with other platforms and due to the investments. The coefficient α_5 specifies the fraction of investment into QoS that is dedicated to increasing the number of services on the platform. The coefficient α_5 and the coefficients α_6, α_8, and α_{10} sum up to 1. They represent the split of investments into the four QoS aspects. The coefficient α_{11} translates the investment (after being transformed through *(1 – 1 / SpendingOnQos*) and the level of service portability into an additional number of services.

Portability is assumed to be at a level ranging between 0 (no portability) and 1 (full portability). It is assumed that the level of service portability progresses over time *t* towards 1. It also does not reduce (represented by the first term of Equation 4). Depending on the fraction of investment ($\alpha_6 \cdot$ *SpendingOnQos*), which the platform provider makes [17], and the market position of the provider (*MarketShare*), a fraction of the not portable services will become portable (represented by the second term of Equation 4). The consideration of the position in the market (*MarketShare*) is important, as it impacts the implementation of de facto standards by a platform provider. It also helps accounting for the emergence of new platforms in the market. The emergence of a new platform reduces the position of the platform provider in the market.

$$LevelOfServicePortability(t) = LevelOfServicePortability(t\text{-}1) + \\ ((1 - 1 / \alpha6 \cdot SpendingOnQos) + \alpha7 \cdot MarketShare) / 2 \cdot (1 - LevelOfServicePortability(t-1)) \quad (4)$$

The portability standards compliance that exists in the market and is followed by the provider is expressed with the constant ComplianceWithPortabilityStandardsInTheMarket. It is expressed as a value in the range between 0 and 1. This constant represents the minimum value that the variable LevelOfServicePortability can have.

Equivalent to the portability compliance constant, there is a constant for interoperability standards compliance, namely ComplianceWithInteroperabilityStandardsInTheMarket. It also represents the minimum value that the LevelOfInteroperability can have. Following Equation 4, a similar logic is applied to represent the level of interoperability in the model (Equation 5). The level of interoperability is also assumed to be at a level ranging between 0 (no interoperability) and 1 (full interoperability).

$$LevelOfInteroperability(t) = LevelOfInteroperability(t\text{-}1) + \\ ((1 - 1 / \alpha8 \cdot SpendingOnQos) + \alpha9 \cdot MarketShare) / 2 \cdot (1 - LevelOfInteroperability(t-1)) \quad (5)$$

Usability as a component of the non-functional QoS offered by a platform is also assumed to contribute to the value of the user in a similar way as interoperability and portability [33]. Therefore, for completing the explanation of equation (2), usability needs to be defined. Usability represents the extent to which a system, product or service can be used to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use [53]. It is related to the ease, with which users can achieve their goals while interacting with a service platform. This includes the minimum number of personnel requirements (i.e., skills, experience, education, and certification) that must be fulfilled by a user to effectively utilize a service [53]. Therefore, in this model, QoS eventually increases a platform user's value.

Providers continuously allocate resources to improve usability through the development of easier to use services [17]. Thus, the spending on QoS ($\alpha_{10} \cdot$ *SpendingOnQos*) drives up usability, if the factor representing spending is larger as the previous usability level (*Usability(t-1)*). This is expressed with Equation 6.

$$Usability(t) = ((1 - 1 / \alpha 10 \cdot SpendingOnQos) + Usability(t-1)) / 2 \tag{6}$$

It has to be noted that Equation 6 could be expressed alternatively in the same way as the equations for level of service portability (Equation 4) and for the level of interoperability (Equation 5). However, as usability is closely related with the environment, in which the user operates, and not with the service itself, usability can be considered an effort of a provider to integrate its service into its customer's changing environment, which is outside the model that we introduced.

3.2.2. Cost Structure

As a platform becomes interoperable with other platforms offering comparable and compatible services, users can easily switch between providers, adapt to new environments with less effort and integrate service components created on different platforms [9]. This impact of interoperability and portability on a platform is reflected in the resources (i.e., the cost for using the platform by the user) needed to use a platform. The composition of the cost that a user faces is depicted in the Figure 6.

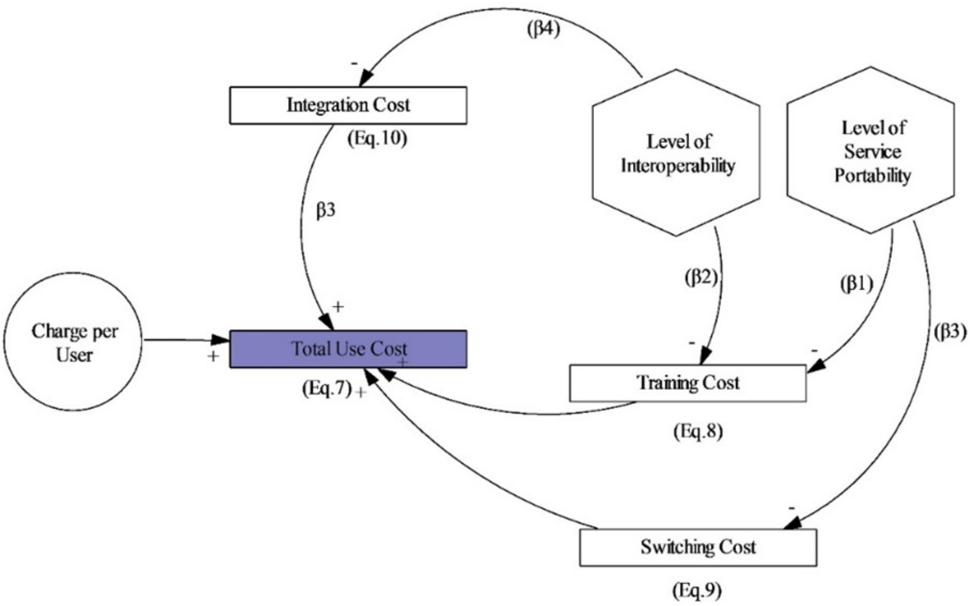

Figure 6. The cost of use of the software service platforms that a user faces.

Based on the efficiency benefits of interoperability and portability [20] and pricing schemes [5] [6], four cost items can be identified to be part of the total cost (TotalUseCost) for using a platform. The total use cost is the sum of these four cost items (Equation 7).

$$TotalUseCost = ChargePerUser + TrainingCost + SwitchingCost + IntegrationCost \tag{7}$$

The four cost items are the charge per user, the training cost, the switching cost, and the integration cost. In detail, first, the customer faces cost for the use of the services of the software service platform in form of a one-time fee, periodical service subscription fee, usage fee, or a cost for viewing advertisements [3] [5] [6]. The sum of these costs (*ChargePerUser*) represents the revenue per user generated by the application service provider. In this model, the charge per user is assumed to be a constant value per time period.

Second, investments in the determinants of quality of service (i.e., usability, interoperability, and portability) by providers decrease the cost of users for gaining additional skills and adapting services to work on a new platform. This cost, which is the training cost, is incurred, if a customer needs additional knowledge and skills to use a service in the cloud. Therefore, providing compatible programming languages to customers of the IT platform services reduces their training costs (*TrainingCost*) for learning a new programming language. As services become portable and platforms interoperate with each other, platform customers spend less on learning new skills. They can use existing knowledge of tools to use the target platform. Therefore, training cost is modeled to decrease as the level of portability and the level of interoperability improve. The coefficients β_1 and β_2 are used to calculate the arithmetic mean and scale the impact of the level of portability and interoperability to a value less or equal to 1.

$$TrainingCost = 1 - \beta 1 \cdot LevelOfPortability - \beta 2 \cdot LevelOfInteroperability \tag{8}$$

Third, the switching cost is incurred, if a customer needs to change the software service platform. As this cost is due to the lock-in effect caused by less portable services, the switching cost is modeled to be negatively related to the level of service portability. An increase in the level of portability decreases the switching cost (*SwitchingCost*) scaled by a factor β_3.

$$SwitchingCost = 1 - \beta 3 \cdot LevelOfPortability \tag{9}$$

Fourth, the integration cost incurs, if services need to be interconnected. That means, if interoperability is improved, the integration cost decreases. Therefore, if a user integrates two software services, which are deployed on different software service platforms, the process is less costly for services of two interoperable platforms than for services of two not interoperable platforms. The impact is scaled with a factor β_4.

$$IntegrationCost = 1 - \beta 4 \cdot LevelOfInteroperability \tag{10}$$

3.2.3. Value Obtained by Users

Due to the utility-maximizing behavior of users, an IT service platform user i decides to subscribe to a service or continue to use a service, if the perceived net user value (UserValue) is larger than zero. This value generation process is presented in Figure 7.

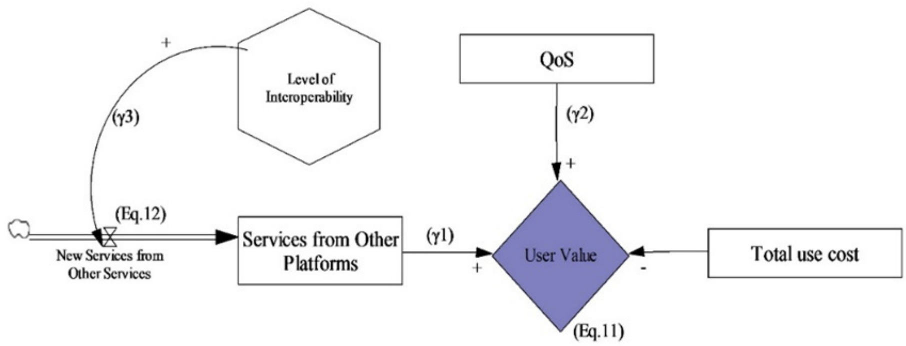

Figure 7. Factors of the value of cloud service platform users and their interaction.

In detail, the user value depends on the utility generated from the number of external services available to the user, as the result of interoperability with other platforms (*ServicesFromOtherPlatforms*) and the satisfaction from the quality of service (*Qos*) provided. Furthermore, from these benefits, the total cost of using the services (*TotalUseCost*) need to be subtracted (Equation 11).

$$\text{UserValue} = \gamma 1 \cdot (1 - 1 / \text{ServicesFromOtherPlatforms(t)}) + \gamma 2 \cdot \text{Qos} - \text{TotalUseCost} \quad (11)$$

This equation follows Lee, Kim, and Gupta in 2009, who used service quality in a model evaluating a user's net benefit [55]. Furthermore, research by Gasser and Palfrey in 2007 found a link between interoperable ICT systems and innovation, and its tendency to enhance user choice and reduce access barriers [20]. In interoperable software ecosystems, users are more likely to have access to various competitive applications [20]. In order to represent this phenomenon, we use the variable *ServiceFromOtherPlatforms(t)* as a function of the level of interoperability. *ServiceFromOtherPlatforms(t)* at time *t* is defined as the number of external services from other platforms at time *t-1* and the number of new services that become available due to the level of interoperability. The higher the level of interoperability, the more new services of other platforms can easily (i.e., at a lower cost) be accessed. The impact of the level of interoperability is scaled with the coefficient γ_3. This is shown in Equation 12.

$$\text{ServicesFromOtherPlatforms(t)} = \gamma 3 \cdot \text{LevelOfInteroperability} + \text{ServicesFromOtherPlatforms(t-1)} \quad (12)$$

3.2.4. Revenue of Providers

The revenue obtained by the platform provider is assumed to be equal to the revenue made from providing services to all users on the platform. The provider revenue is increased, if new users are attracted to the platform as a result of their positive valuation of the software service platform. A user's positive valuation corresponds to a net value larger than zero. The value creation process and the factors impacting the revenue are shown in the following figure.

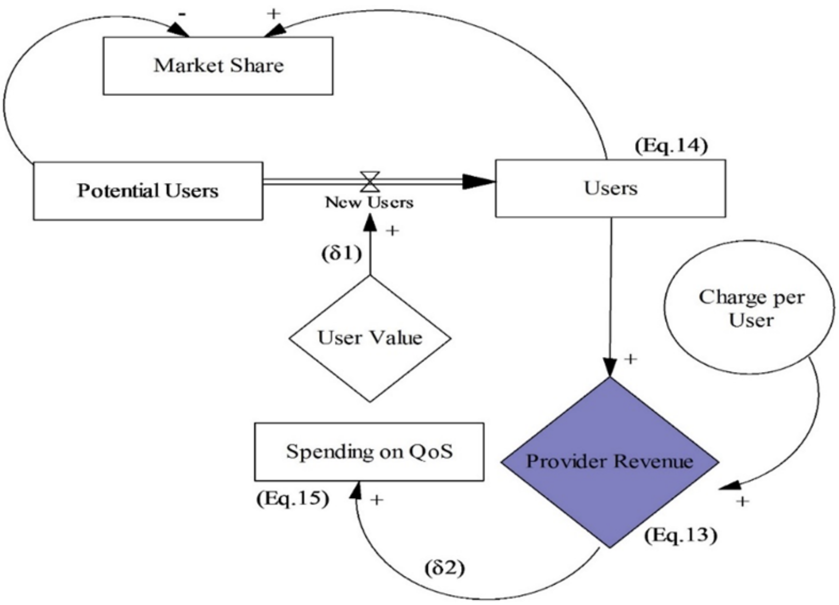

Figure 8. Factors impacting the revenue of providers.

In detail, the revenue of the provider can simply be calculated by multiplying the number of users (*Users(t)*) with the fee that each user has to pay in average (*ChargePerUser*). This is represented in Equation 13.

$$\text{ProviderRevenue} = \text{Users(t)} * \text{ChargePerUser} \qquad (13)$$

With respect to the provider revenue, it is interesting to understand how the number of users changes over time. The number of users at time *t* (*Users(t)*) is the sum of the number of users at time *t-1* (*Users(t-1))*) and the number of new users joining the platform (Equation 14).

$$\text{Users(t)} = \delta 1 \cdot \text{UserValue} \cdot \ln(\text{PotentialUsers/Users(t-1)}) \cdot \text{Users(t-1)} + \text{Users(t-1)} \qquad (14)$$

The number of new users depends on a logistic growth function according to the marginal utility theory of Gompertz [54]. The logistic growth function is determined by the product of ($\delta_1 \cdot$ *UserValue*), which describes the user's scaled valuation of the platform. As shown in section 3.2.3, a user's perception of the platform value is impacted by its level of interoperability and portability (e.g., level of customer lock-in, level of accessibility of compatible services).

Once a software service platform starts operating in the market and user requirements and market demand rise, platform providers need to plan for improvements. The value creation model allows for different investment strategies. Two of them have been implemented and used for the analysis in section 4. The first investment strategy simply specifies the fraction δ_2 of the revenue that is invested in the QoS of the platform. In detail, the fraction δ_2 of the revenue at time period *t-1* is allocated at time period *t* to functional QoS (i.e., development of new services) and non-functional QoS (i.e., improvement of interoperability, portability, usability) [17]. This is illustrated with Equation 15.

$$\text{SpendingOnQoS} = \delta 2 \cdot \text{ProviderRevenue} \qquad (15)$$

The second investment strategy, which has been implemented, fixes the amount of investment per month. The actual amount of money allocated for improving QoS could be based on an estimate of the total number of users that will have joined the platform at the end of the amortization period (*AmortizationPeriod*). Following this strategy, the fraction of revenue would be way higher in the first time period *t=1* compared to the time period at the end of the amortization period (e.g., *t=36*, after 3 years). This is caused by the different number of users at time period *t=1* and time period *t=36*. Consequently, Equation 15 would be redefined as *SpendingOnQoS=InvestPerMonth*. Consequently, the fraction of the provider revenue that is allocated to the investment could be calculated as $\delta_2 = \mathit{InvestPerMonth} \cdot \mathit{AmortizationPeriod} / \sum \mathit{ProviderRevenue(t)}$, where *t* goes from *1* to *AmortizationPeriod*.

The ability of obtaining more users through interoperability and maintaining existing users by improving the accessibility to services with less effort leads to an increased market share of the platform provider. This is based on Rust, Zohorik, and Keiningham, who modeled and tested a linear relationship between investments in QoS and market share [17]. As an increased market share can also translate into a nonlinear revenue increase due to external services becoming available, a re-enforcing feedback loop occurs. However, in order not to overcomplicate our existing value creation model, we did not consider the dynamic impact of market share in our model and leave it for further investigations in the future.

4. Simulation Analysis

Using the mathematical value creation model that has been proposed in section 3, we can set the simulation parameters to answer research question 2, research question 3, and research question 4. The model comprises 4 decision variables (indicated by circles in Figure 4), which are set based on the platform provider's market strategy or the market environment: The decision variable *ChargePerUser* is based on a pricing decision by the provider and is set to *$1.34* (which is close to the average of the value of a user to a platform provider, ranging between *$0.53* in the Asis-Pacific region and *$4.51* in the US and Canadian [57]) for all simulations. The two decision variables *ComplianceWithPortabilityStandardsInTheMarket* and *ComplianceWithInteroperabilityStandardsInTheMarket* represent the initial level of development requirements demanded by the market environment to be competitive. The values of these two variables range between 0 and 1. The last decision variable relates to the size of the platform provider (*MarketShare*), which is set to a value between [0,1], depending on whether the platform is an emerging provider (i.e., 0) or an established provider (i.e., 1). The simulation settings for the remaining variables and coefficients are presented in appendix A.

In order to address the three research questions, this chapter is split into three subsections: Section 4.1 focuses on evaluating how a change in the level of interoperability and portability relates to the value of platform users (research question 2). Section 4.2 addresses how an increase in the level of interoperability and portability relates to the revenue of platform providers (research question 2) and how the maturity of the platform provider (*MarketShare*) affects the impact of interoperability on the pace of adoption (research question 3). Section 4.3 is aimed at showing how investments impact profit and return on investment (research question 4).

4.1. User Cost and User Benefit due to Interoperability and Portability

4.1.1. Impact of Interoperability on User Value

As this analysis is conducted to address research question 2 (How does an increase in the level of interoperability and portability impact the value of platform users?), the analysis considers the user value (Equation 11). The decision variable values are set as follows: Without loss of generalization, an emerging software service platform (*MarketShare=0*) is assumed. To start operation in a market, the emerging software service platform requires low (medium and high) compliance with interoperability standards (i.e., *ComplianceWithInteroperabilityStandardsInTheMarket is set to 0, 0.5, and 1, respectively}*). The value of the variable *ComplianceWithPortabilityStandardsInTheMarket* is set to 0, in order to identify clearly the impact of different initial interoperability levels. Figure 9 shows how the user value changes depending on these three levels of initial interoperability at time *t=0*. The y-axis of the graph shows the user value (user utility), while the x-axis shows the time in units of months.

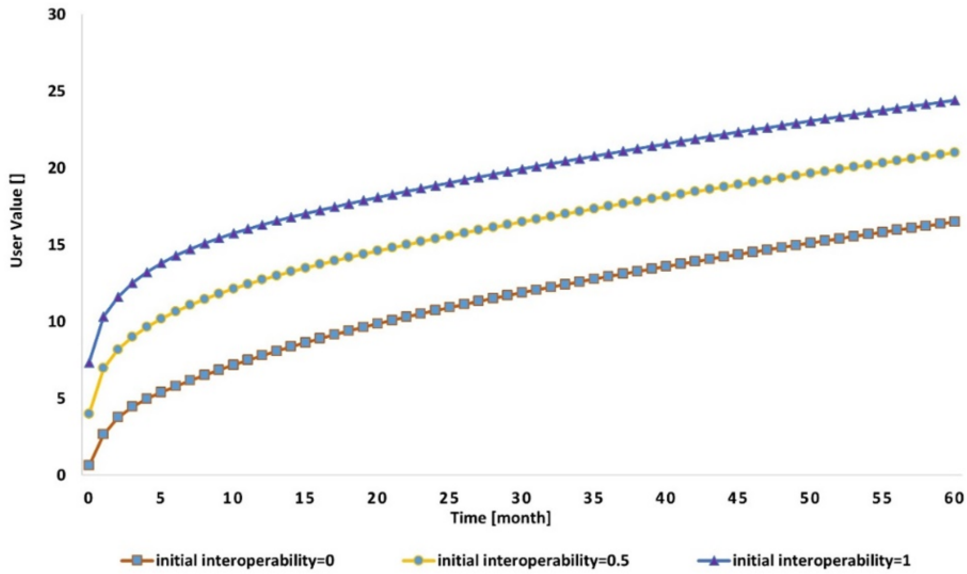

Figure 9. Impact of interoperability on user value.

As Figure 9 depicts, if a user choose to adopt a new service platform, the platform's level of compatibility with the existing services impacts its value to the user (user utility). If the platform satisfies all needs for interoperability (initial interoperability=1), the user gets the highest QoS and the user value shows the steepest value gain. A platform with no interoperability (initial interoperability=0) incurs extra cost for the user for accessing other services than its own and for integrating them with its existing IT environment. Thus, the user's utility is reduced and shows a slower growth in the beginning (Figure 9). In detail, a significant difference in the growth can only be seen at the beginning of the simulation (*t=0* to *t=5*). It is plausible, as the cost is mainly incurred for adoption of the new platform.

4.1.2. Impact of Interoperability/Portability on Service Availability and Service Flexibility

As interoperability and portability in this research are described as requirements for achieving service availability and service flexibility and for reducing switching cost and integration cost, it is useful to simulate with the value creation model the impact of interoperability and portability on the number of platform services and the number of external services.

As portability is essential for utilizing the different services on the same platform, portability drives the number of usable services on a single platform (Equation 3). If the provider supports portability, users can avoid the cost for adapting their data to another service. In order to evaluate the impact of portability, three different values for the decision variable *ComplianceWithPortabilityStandardsInTheMarket* are used in the model. The values are 0, 0.5, and 1, representing a portability level of low, medium, and high, respectively. The decision variable *ComplianceWithInteroperabilityStandardsInTheMarket* is set to 0, in order to be able to measure the impact of portability only. The other two decision variables are the same as before. The results of the simulation are in shown in Figure 10. The x-axis represents the time in units of months, and the y-axis the number of platform services available to the user without switching cost.

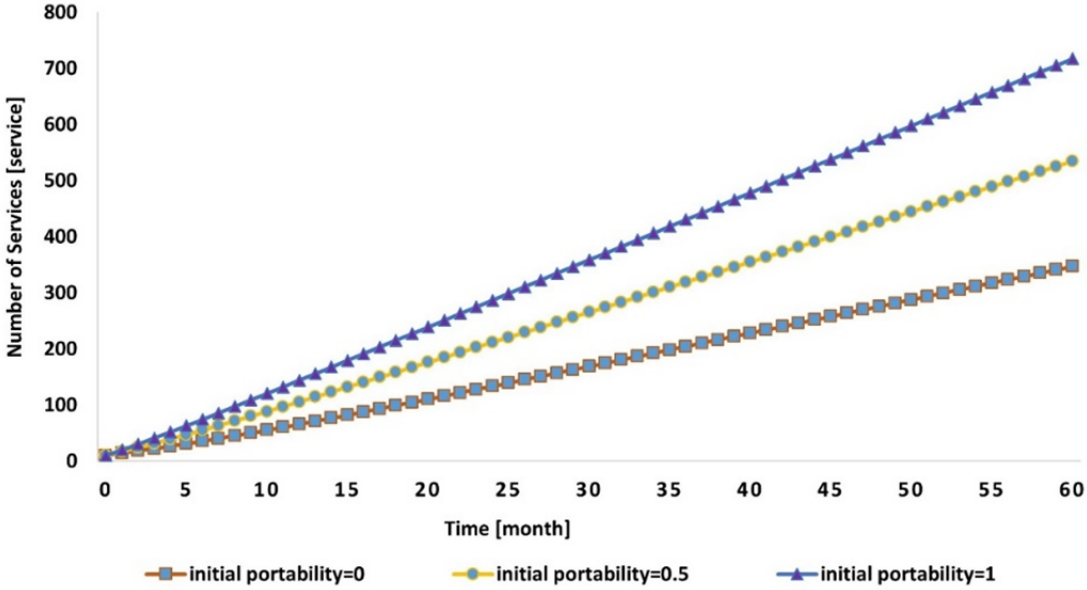

Figure 10. Impact of portability on the number of platform service availability.

As Figure 10 shows, even if the provider does not comply with any portability standards (initial portability=0), the user has access to a certain number of services, which are provided by the platform or have been developed on the platform at increased costs. However, an increase in the level of service portability allows users to utilize more services on the platform. For example, the number of services for an initial level of portability of 0.5 is higher than the number of services for an initial level of portability of 0 at all time periods. This characteristic is enhanced even further, if the initial level of portability is set to 1. Therefore, it can be stated that the level of portability has a strong impact on service availability on a platform.

In addition to this, users should be able to use services of other platforms with no or little integration cost. This means, through interoperability, platforms should provide services that are executed on another platform. Therefore, the value creation model is used to show how external (third-party) services increase as interoperability is improved (Equation 12). The results shown in Figure 11 are based on three values for *ComplianceWithInteroperabilityStandardsInTheMarket*, namely 0, 0.5, and1. The decision variable *ComplianceWithPortabilityStandardsInTheMarket* is set to 0. The other two decision variables are kept the same. The x-axis of the graph represents the time in units of months, and the y-axis the number of external services available to the user without integration cost.

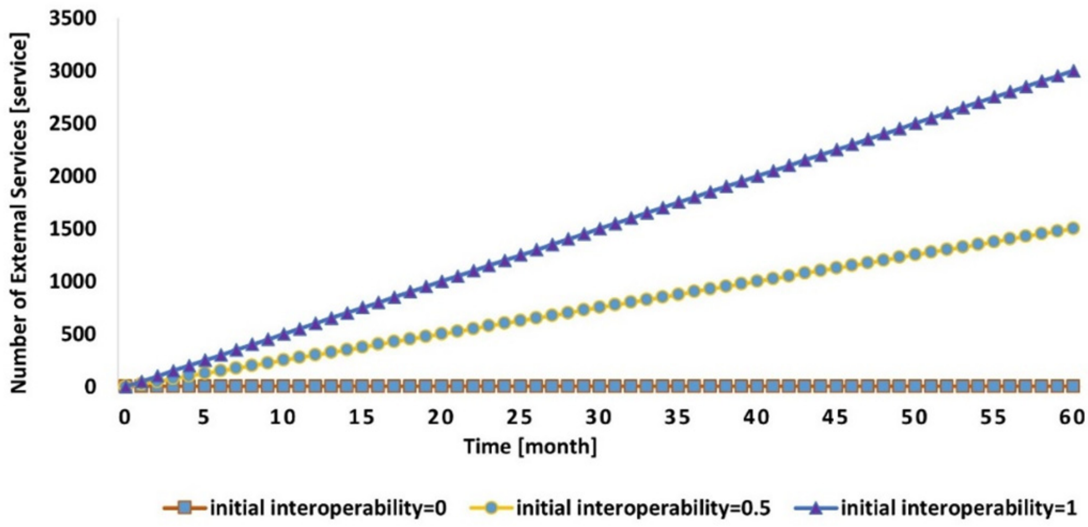

Figure 11. Impact of interoperability on the number of available external (third-party) services.

As Figure 11 illustrates, if the platform's initial interoperability is set to 0, there are no additional external (third-party) services available to users. The number of external services stays at the same level. However, as the compliance to interoperability is increased to 0.5 or to 1, the users' ability to utilize services of other IT service platforms is significantly increased. For a compliance with interoperability standards of 0.5 at time *t=60*, the number of external services is 1501. For a compliance with interoperability standards of 1 at time *t=60*, the number of external services is 3001.

4.1.3. Impact of Interoperability/Portability on Total Use Cost

The main objective of the effort to achieve interoperability and portability is a reduction in cost and an increase in QoS, which, in turn, lead to an increase in the attractiveness of the software service platform for potential users (i.e., new adopters). Therefore, the cost that the user faces is an important aspect to provider's decision making about interoperability and portability.

The analysis is based on Equation 7, which determines the *TotalUseCost*. The decision variables are set as follows: *ChargePerUser=$1.34, MarketShare=0*, and both variables for the compliance (*ComplianceWithPortabilityStandardsInTheMarket* and *ComplianceWithInteroperabilityStandardsInTheMarket*) are set to the same values, either 0, 0.2, 0.4, 0.6, 0.8, or 1, assuming similar investment in portability and interoperability. Figure 12 depicts the simulation results at time period *t=25* for five levels of interoperability and portability. The x-axis shows the initial levels of interoperability and portability while the y-axis depicts the total use cost in units of Dollars.

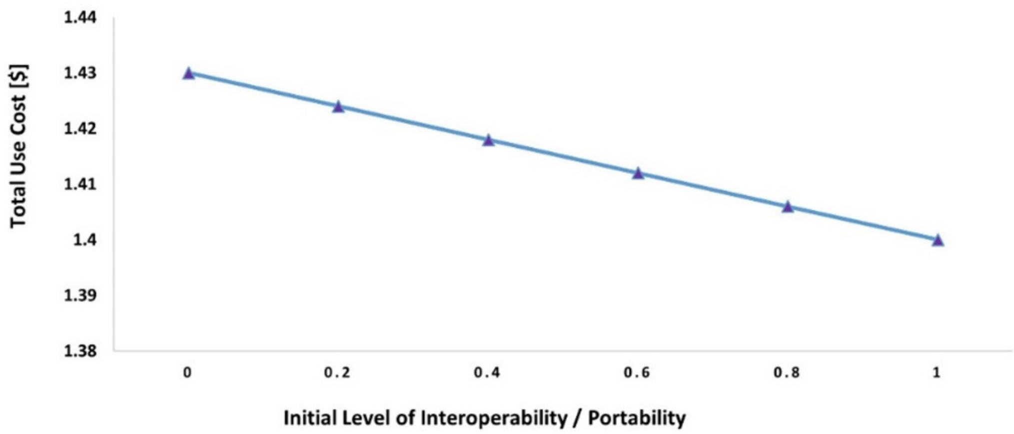

Figure 12. Total use cost at time period t=25, as the level of interoperability and the level of portability increase simultaneously with the same amount (0, 0.2, 0.4, 0.6, 0.8, 1).

Figure 12 illustrates that if the provider starts out by providing no interoperability and portability (i.e., both are set to 0), the user faces a cost of $1.43 per month to utilize services. This is due to the fact that a user needs to spend money on training, service switching, and service integration as well as on covering the service use charges of the platform provider (Equation 7). However, if the interoperability and portability are fully provided (i.e., both are set to 1), the total use cost incurred goes down to around $1.4. In this case, the user can avoid paying any *TrainingCost, IntegrationCost,* and *SwitchingCost* for using services on multiple platforms, as the platform provider complies with all standards.

4.2. Provider Benefit due to Interoperability and Portability

The analysis of this section is performed, in order to address research question 2 from the perspective of the platform provider and to address research question 3 (Does the maturity of a software service platform (i.e., emerging platform or market-leading platform) make a difference in the impact of interoperability on the pace of adoption?). The analysis is based on Equation 13, which defines the provider revenue. The provider revenue depends on the number of users of the platform at time *t* and the charge per user that the provider obtains in form of use fees or advertisement revenue.

4.2.1. Impact of Interoperability on the Revenue of Platform Providers

In order to justify any provider investment in interoperability and portability, the impact of interoperability and portability on the provider revenue needs to be understood (research question 2). For this, we use the same values for the decision variables in the simulation as in section 4.1.1: *MarketShare=0*, *ChargePerUser=$1.34/month*, *ComplianceWithPortabilityStandardsInTheMarket=0*, and *ComplianceWithInteroperabilityStandardsInTheMarket*=0 (or 0.5 or 1). The results of the simulation are shown in Figure 13. The x-axis represents time in units of months, while the y-axis indicates the provider revenue in units of Dollars.

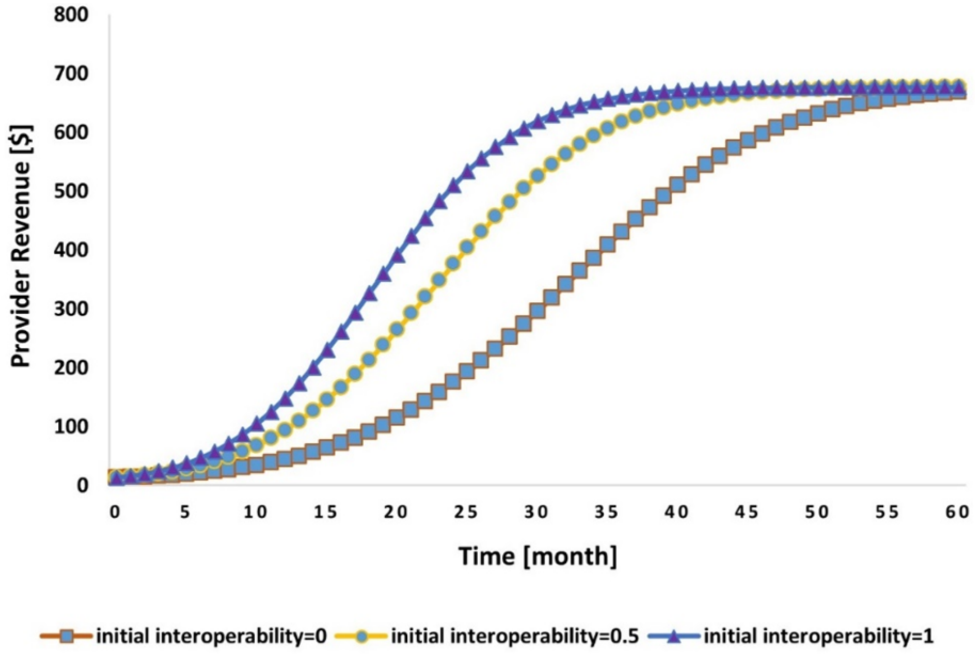

Figure 13. Impact of the level of interoperability on provider revenue.

Figure 13 depicts that the curves of the provider revenue show different increments over time. This is caused by the difference in the attractiveness of the platform to potential users. The higher the initial interoperability level of the platform is, the faster the platform gains users, which, in turn, drives the revenue. In detail, the curve for no initial interoperability (interoperability = 0) shows a slow revenue growth. The curve for full initial interoperability (interoperability = 1) increases faster and reaches the maximum earlier. Based on these results, it can be stated that there is a significant incentive for providers, to operate interoperable software service platforms.

4.2.2. Impact of Interoperability/Portability on the Pace of Adoption with Respect to Market-Leading and Emerging Platform Providers

In search of insight to answer research question 3, the effect of interoperability on the pace of adoption needs to be investigated with respect to market-leading and emerging software service platform providers. For this, the platform maturity, which is expressed through the market share, is considered in the simulations. The decision variable *MarketShare* is set to 0 (emerging platform) or 1 (established platform). The decision variable *ChargePerUser* is set to $1.34 again, while the two decision variables related to compliance are set to 0. The results of the simulation are illustrated in Figure 14. The x-axis represents time and the y-axis the number of users that utilize the platform.

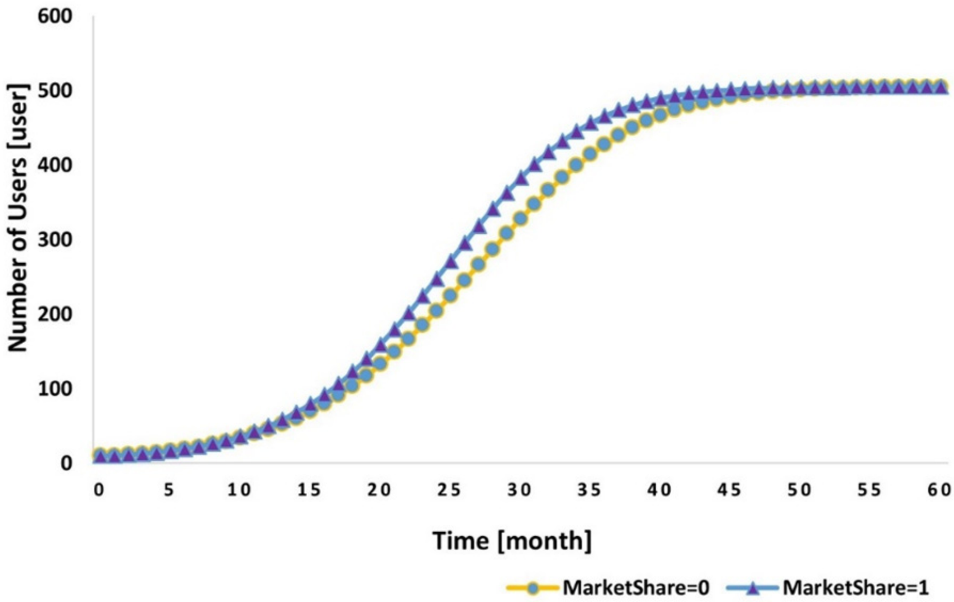

Figure 14. Impact of interoperability/portability on the adoption of services of emerging platforms and market-leading platforms.

As Figure 14 highlights, the market-leading platform is more attractive to potential users. The pace of adoption is higher. This is due to the fact that the market share impacts the interoperability and portability and, in turn, the QoS, which directly impacts the decision of potential users. This happens despite the fact that both platforms had equal interoperability and portability at time period $t=0$. From time period $t=15$ onwards, the market-leading platform clearly attracts new users faster.

In conclusion, the analysis shows that a market-leading platform gains users faster than an emerging platform. This is due to the fact that a market-leading platform sets a de facto standard with its platform. An emerging platform does not have this critical mass of interoperable and portable services.

4.3. Impact of Provider Investments in Interoperability and Portability

In order to run a sustainable business, platform providers need to know how much return on their investment they can expect from the resources they allocate to improving interoperability and portability. Thus, they need to compare cost and benefit and to aspire for the best outcome. Research question 4 (How do investments impact profit, net present value, return on investment, and discounted return on investment?) is aimed at addressing this aspect and at developing a method for assessing the impact of investments (section 4.3.3). For being able to provide the investment assessment method, two relationships need to be analyzed in more detail: (1) the direct impact of investments on the level of interoperability (section 4.3.1); (2) the impact on the revenue of providers (section 4.3.2).

4.3.1. Impact of Investments on Level of Interoperability

In order to see how investments in a platform impact the level of interoperability (*LevelOfInteroperability*), simulations are conducted for relating the monthly spending on interoperability with the resulting level of interoperability (Equation 5). Moreover, a comparison is also conducted between an emerging platform (*MarketShare=0*) and a market-leading platform (*MarketShare=1*). The decision variable *ChargePerUser* is set to \$1.34 [57]. The remaining two decision variables, *ComplianceWithPortabilityStandardsInTheMarket* and *ComplianceWithInteroperabilityStandardsInTheMarket*, are set to 0.

As the numbers of users of the two platforms are different at each time period, the investment strategy that considers the fraction of revenue (*Equation 15*) could not been considered for this simulation. In order to make the simulation results of those two platforms comparable, the monthly investment on interoperability has been fixed, making it independent to the actual number of users of the platform. In detail, the simulations are conducted for 9 different investment amounts per month, namely \$0.02, \$0.03, \$0.04, …, and \$0.1. Figure 15 illustrates the simulation results for both platforms (i.e., for an emerging platform and a market-leading platform) at time period *t=25*. The x-axis represents the amount of investment per month, and the y-axis the level of interoperability.

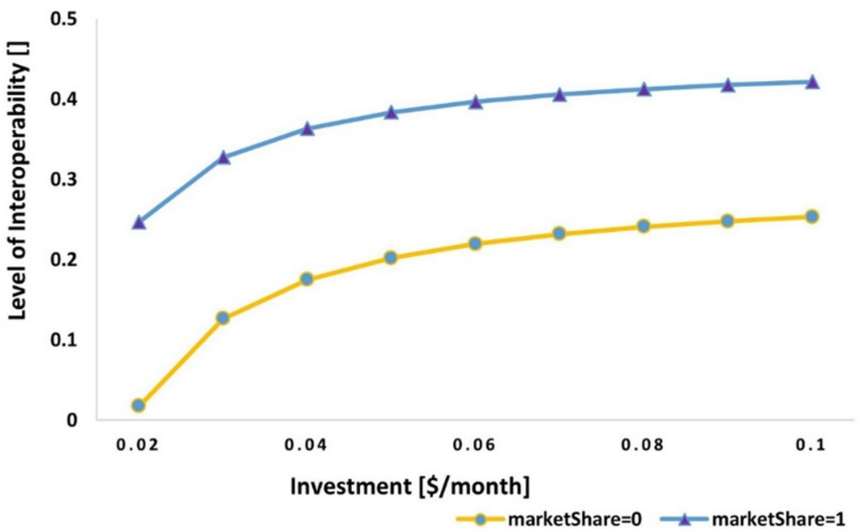

Figure 15. Impact of investment and market share on the level of interoperability.

Figure 15 depicts that the effect of investments on the level of interoperability of a platform is positive. A provider (i.e., an emerging platform provider or a market-leading platform provider) gain a competitive advantage through investments in interoperability. Moreover, the higher the amount of investment is, the higher the level of interoperability.

Figure 15 also shows that the effect is moderated by the market share of a platform provider. For an equal amount of investment, a market-leading provider (i.e., *MarketShare=1*) can achieve a higher level of interoperability than an emerging platform provider (i.e., *MarketShare=0*). The difference in the level of interoperability between the two providers is significant. For example, it is 0.17 at an investment of \$0.1 per month per user. However, for an emerging platform provider, the level of interoperability increases from 0.017 for an investment of \$0.02 per month (i.e., 0.01% of revenue) to 0.25 for an investment of \$0.1 per month (i.e., 0.05% of revenue). This increase is higher than the one for a market-leading platform provider, who experiences an increase from 0.25 to 0.42. An emerging platform provider sees a stronger increase in the level of interoperability for smaller amounts of investments than a market-leading platform provider.

Despite these differences in results for emerging platform providers and market-leading platform providers, it can be stated that the positive effect of investments in interoperability is independent of the market structure.

4.3.2. Impact of Investments on Revenue of Platform Providers

As a provider's decision on the amount of investment for building interoperable systems impacts the provider's revenue (research question 4), the provider revenue under different amounts of investments needs to be analyzed. For this analysis, a platform provider is assumed to allocate 1% ($0.0134), 2% ($0.0268), 3% ($0.0402), 10% ($0.134) and 20% ($0.268) of its revenue to investments in interoperability and portability equally. The investments in new services and usability (*Usability*) are set to 0. The values of the four decision variables are: *MarketShare=0*, *ChargePerUser=$1.34*, and the two compliance-related variables equal 0. Based on those variable settings, Figure 16 shows the simulation results, exhibiting the impact of investment on the provider revenue. The x-axis represents the time period, ranging from *t=0* to *t=60*. The y-axis represents the provider revenue at a certain time period.

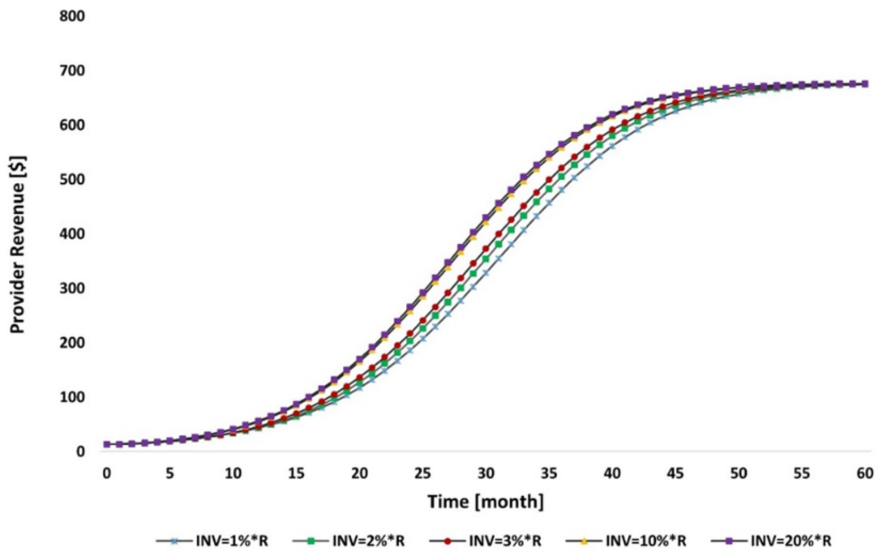

Figure 16. Provider revenue under five different amounts of investment.

Figure 16 shows that, the higher the investment on interoperability is, the faster the provider revenue increases. If the provider invests 1% of its revenue, the revenue grows slower than the revenue receiving from an investment of 20%. This fact can clearly be noticed between the time periods *t=20* and *t=50*. It indicates that the platform provider benefits directly from additional investments in the level of interoperability.

As the relationship between investment and revenue is not linear, the percentage change in revenue is different, depending on the amount of investment. Due to this fact, a platform provider needs support in making the optimal investment decision, which is investigated in the following section.

4.3.3. Investment Assessment

Although the previous section has shown that a platform provider can drive up its revenue through additional investments in interoperability, the effectiveness of these investments with respect to the net benefit is not clear. Furthermore, it needs to be investigated whether an optimal investment in interoperability and portability can be found, considering different costs and different length of operation of the platform.

For this, with the help of the value creation model, we compare the accumulated profit (i.e., revenue minus cost accumulated for the entire amortization period) and the return on investment (ROI) (i.e., profit/cost) of a software service platform provider for different monthly investments in interoperability and portability. The monthly investments in the platform range from \$0.5 to \$15 for all months within the amortization period. In order to account for the time value of money, the net present value (i.e., discounted profit) and discounted ROI are also calculated, assuming an interest rate of 0.07%. These four business measures are calculated at the end of year 3 (i.e., at time period *t=36*) and at the end of year 5 (i.e., at time period *t=60*), in order to understand the effect of different amortization strategies (i.e., strategy of having a platform amortized after 3 years or strategy of having a platform amortized after 5 years). Note, a 3-year amortization period might be preferable for IT technologies (especially, for software services) as the life span of IT technology is shorter than in other industries. Additionally, the effect of the amount of an initial investment (i.e., a pre-deployment investment in the platform) is also examined.

The decision variables settings, which are used for calculating profit, NPV, ROI, and discounted ROI, are: *ChargePerUser=\$1.34*, *ComplianceWithPortabilityStandardsInTheMarket=0*, *MarketShare=1*, and *ComplianceWithInteroperabilityStandardsInTheMarket=0*. Furthermore, the variables representing investments in new services (Equation 3) and usability (*Usability*) are set to 0.

Figure 17 shows the simulation results for different fixed monthly investments, while assuming no initial investment before the deployment of the software service platform and an amortization period of 3 years (time period *t=36*). These investments correspond to from 0.2% of revenue to 2.7% of revenue. The x-axis shows the investment in units of Dollars that is invested monthly in interoperability and portability. The first y-axis shows the accumulated platform provider profit and the accumulated NPV in units of \$1000. The second y-axis the ROI and discounted ROI in units of percent at the time period *t=36*.

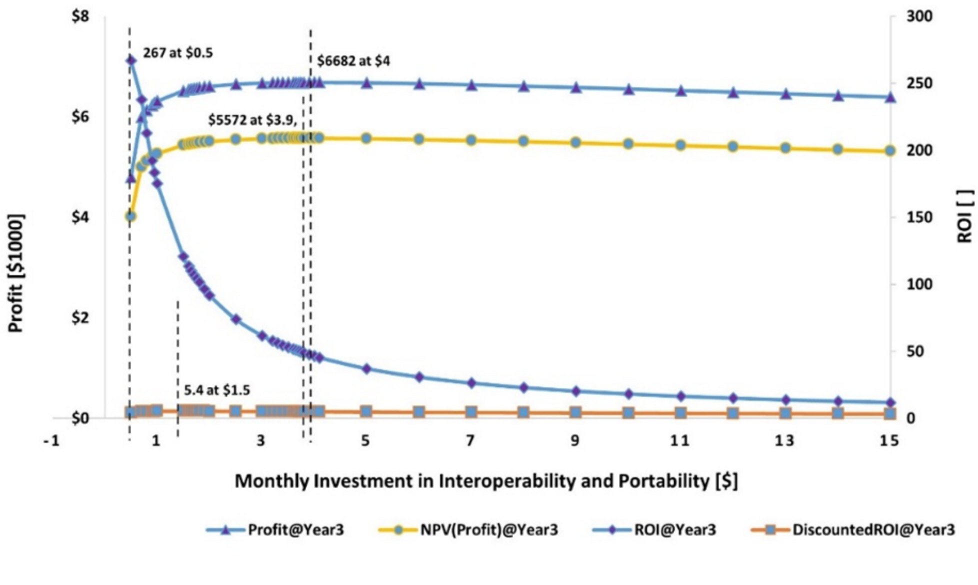

Figure 17. Accumulated profit, NPV, ROI, and discounted ROI from investments in interoperability and portability at the end of a 3 year amortization period with no platform pre-deployment investment.

Figure 17 illustrates that the accumulated profit ($6682) is maximized at a $4 investment per month for 36 months. Any further investment decreases the accumulated provider profit. The net present value (NPV) of the profit shows the highest value ($5572), if the provider invests $3.9 monthly. The highest ROI (267) is achieved at the lowest level of investment ($0.5 on each month for 36 months). The highest discounted ROI is 5.4 for an investment amount of $1.5 on each month for 36 months. The high ROI values indicate that an investment in interoperability and portability can achieve a high return.

Considering these results, it is remarkable that an amount of investment in interoperability and portability exists, for which the accumulated profit and NPV get maximized.

For an amortization period of 5 years (Figure 18), the results at the end of 5 years show the highest values for both ROI and accumulated profit at lower monthly investments than the monthly investments for an amortization period of 3 years. The ROI at a monthly investment of $0.5 is 630 and the accumulated profit is $22138 at a monthly investment of $3.75. The discounted ROI shows that the highest return (16.8) is obtained at an investment of $1. The platform provider obtains the highest discounted profit ($16963), if monthly investments of $3.7 are made.

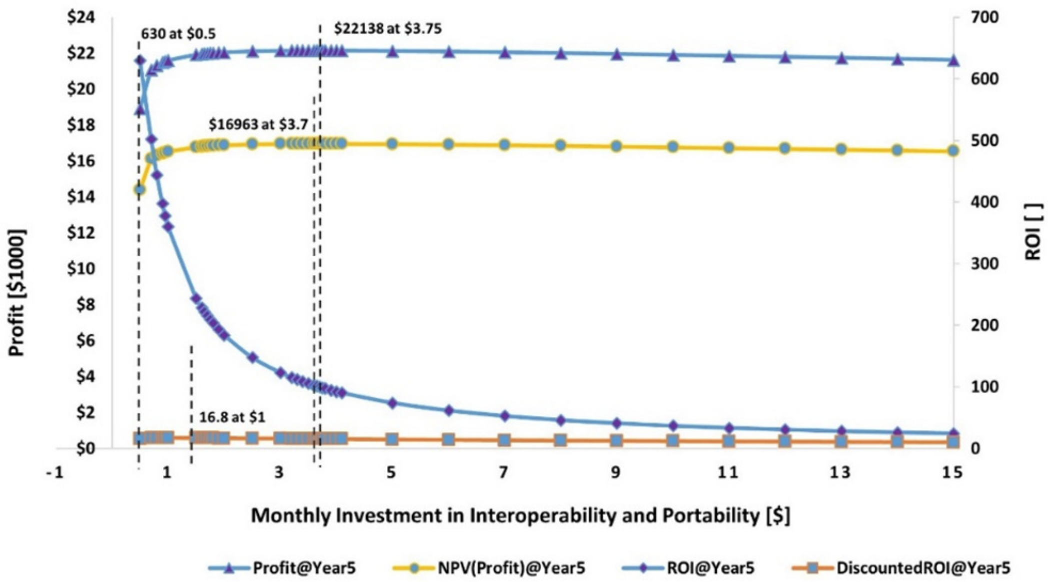

Figure 18. Accumulated profit, NPV, ROI, and discounted ROI from investments in interoperability and portability at the end of a 5 year amortization period with no platform pre-deployment investment.

Considering the simulation results presented in Figure 17 and Figure 18, the platform provider is better off implementing a 5-year amortization period (Figure 18). It shows a better profitability than the one for a 3-year amortization period (Figure 17). The discounted ROI is 16.8 at $1 for the 5-year amortization period instead of 5.4 at $1.5 for the 3-year amortization period. The NPV is $16963 at $3.7 monthly investment for the 5-year amortization period, compared to $5572 at $3.9 for the 3-year amortization period.

As for a 3-year amortization period (Figure 17), the results for a 5-year amortization period also show the remarkable existence of an amount of investment in interoperability and portability, for which the accumulated profit and NPV get maximized.

In order to understand the impact of an initial investment in setting up the software service platform (i.e., a platform pre-deployment investment), the same simulations are conducted as before but with an initial investment of $1000. This investment represents the cost that the platform provider faces for adopting a dominant market standard. Figure 19 shows the simulation results for an amortization term of three years.

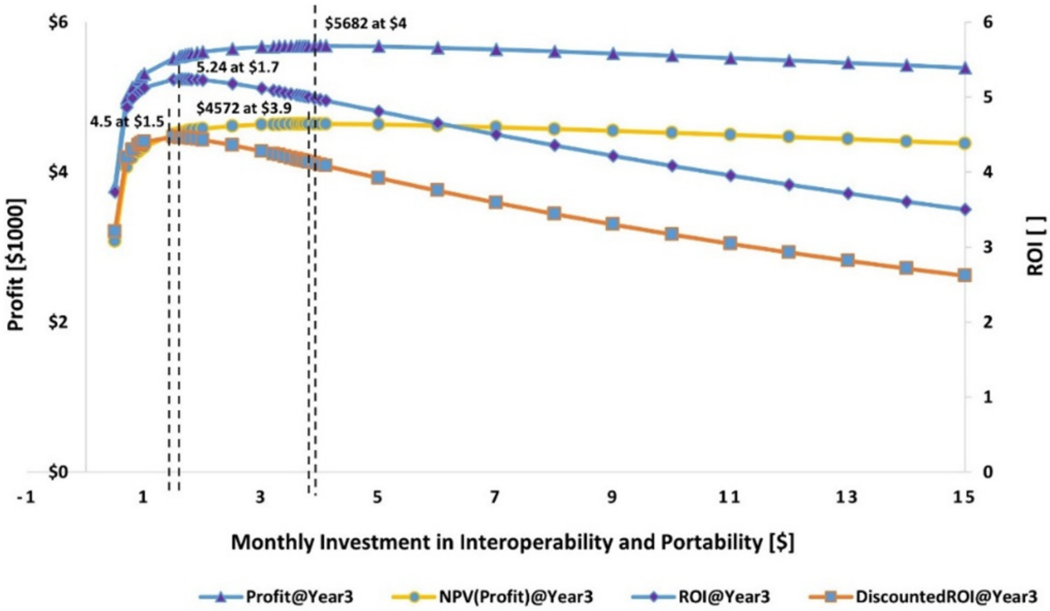

Figure 19. Accumulated profit, NPV, ROI, and discounted ROI from investments in interoperability and portability at the end of a 3-year amortization period with a platform pre-deployment investment of $1000.

Figure 19 depicts that, while the shape of the curve of the accumulated profit and NPV does not change (i.e., it just shows an absolute reduction by $1000), the ROI and the discounted ROI change significantly. The discounted ROI is the highest with 4.5, if $1.5 is invested monthly. The ROI reaches a maximum with 5.24 at $1.7. Although providers plan to achieve a certain target of ROI for a certain amortization period, choosing only the high-return strategy could result in a low profit. Therefore, providers are advised to pair the quest for the highest ROI with profit maximization. Consequently, we can indicate that the optimal monthly investment needs to be between $1.5 and $3.9 for an amortization period of three years.

Furthermore, these simulation results indicate that the return of investment is strongly impacted by the initial investment. If the initial investment gets larger, the maxima of ROI and discounted ROI move closer to the maximum of the accumulated profit. In addition to this, it can clearly be noticed that the minimum monthly investment (for achieving the maximum ROI) needs to get increased, in order to compensate for an increased initial investment. These results can help software service platform providers to find the optimal investment and amortization period for their platform.

Concluding, based on these cost benefit analysis results on investments into interoperability and portability, software service platform providers can find an indication on how the relationship between revenue and investment in interoperability/portability is for their platforms. It helps them to understand whether the targeted ROI is attainable within a certain amortization period. It also gives the provider an overview about the relation between the maximum ROI and the maximum accumulated profit. Based on those analysis results, an investment strategy can be identified and followed that could make interoperability and portability a differentiating factor for the success of a software service platform provider.

5. Discussion and Conclusion

5.1. Discussion

5.1.1. Impact of Interoperability on the Value of Platform Providers and their Users

The results of the simulations of the value creation model show a positive relationship between interoperability and both stakeholder values (i.e., provider revenue (section 4.2.1) and user utility (section 4.1)). The higher the interoperability and portability is, the higher the value creation, answering research question 2 (How does an increase in the level of interoperability and portability relate to the change in the value of platform providers and their users?). In detail, the results of the simulation show that the level of interoperability and the level of service portability enhance the quality of service (QoS) experienced by users. On the one hand, interoperability and portability enhance the ease and flexibility of use (i.e., non-functional QoS) provided to the user. On the other hand, they also increase the number of platform services (i.e., functional QoS) and the number of external services, which in turn lead to more functions available. If platform providers make it simple for services to be portable and interoperable, users can run services without difficulty on the current and other platforms. It illustrates that platform providers can make strategic decisions on improving the quality of service by increasing the interoperability and portability of their service platforms.

More and more users tend to employ multiple comparable services offered by different providers, making the flexibility to port and the integration to interoperate systems and components an attractive offering. Platform providers, who offer this and avoid the extra cost of development and service customization for users, are preferred. Our simulation results show that interoperable platforms help cutting these costs (i.e., integration cost, training cost, and switching cost). The higher the interoperability is, the lower the cost for integration platforms, training employees, and switching providers. Consequently, it can be stated, that the strategy to lock-in users through closed standards and incompatible data formats are no longer a viable direction for providers. It results in a lack of user trust and is perceived by users as a costly way for creating and using software services.

5.1.2. Impact of Interoperability on the Adoption of Emerging Platforms and Market-Leading Platforms

Our simulation results (section 4.2.2) show positive effects of the level of interoperability and the level of portability on the adoption of both emerging platforms and market-leading platforms, answering research question 3 (Does the maturity of a software service platform make a difference in the impact of interoperability on the pace of adoption?) positively. Therefore, it can be stated that enhancing the platform capabilities with respect to interoperability and portability offers a significant competitive advantage to an IT service platform provider. Both emerging and market-leading providers can benefit from the boost in attractiveness of their platforms.

However, due to today’s fast moving IT services market, offering value through easily integrateable and portable services is anyway a required move to build up the business of emerging platform providers. Market-leading platform providers also have an adequate incentive to invest in similar strategies. For them, it is a way to address the potential competition that they face from newly emerging platform providers.

5.1.3. Optimal Investments in Interoperability and Portability

The investigation of the impact of investments in interoperability showed, as expected, that investments have a positive impact (section 4.3.1 and section 4.3.2), answering research question 4 (How do investments in interoperability and portability affect profit, net present value, return on investment, and discounted return on investment?). The effect of investments in interoperability and portability is a driver for an improved perception of the platform among market participants and potential adopters. The perception of a valuable platform does not only help providers to retain customers for a long time but also attract new users who value service flexibility and service availability.

More importantly, it is remarkable that an optimal amount of investments in interoperability and portability can be found, depending on the amortization period, market share, and the initial platform pre-deployment investment (section 4.3.3). This is a surprising result as the idea exists that interoperability and portability should be as high as possible, in order to benefit the market the most. The existing of this optimal level of investment can help software service platform providers to set up investment strategies for achieving interoperability and portability. The investment strategies could aim at achieving competitive advantage or could become the basis for new sales strategies.

5.2. Summary

The role of interoperability of IT services platforms and the role of portability of services are significant for the development of a seamless software service ecosystem and an innovative marketplace. As the lock-in effect of closed platforms is counterproductive for providers as much as it is dissatisfying for users, there is a significant competitive advantage to be gained by providers striving for better interoperability and portability of software service platforms. Furthermore, as more and more daily functions of users rely on software services and as the advent of the internet of things (IoT) becomes a reality, interoperability and portability are no longer just optional functionalities for software services and software service platform providers.

This paper contributes towards comprehending the process of value creation in software service platforms through investments in interoperability and portability by operationalizing these investments. The basis is a value creation model for evaluating platform business decisions. It provides quantifiable results for assessing investments. This comprehensive value creation model, which considers different factors that impact the values of stakeholders, also helps understanding how stakeholders of a software service ecosystem can interact, in order to realize the potential of interoperability and portability in software service platforms (research question 1).

Our simulations of the model show that high levels of interoperability and portability impact positively the value obtained by both the platform providers and the users (research question 2). A moderating factor is the market share of platform providers (i.e., whether they are emerging platform providers or market-leading platform providers). A market-leading platform can expect a faster adoption of its platform than an emerging platform (research question 3). It confirms that all providers benefit from offering interoperability and service portability, as the attractiveness of their service platform gets enhanced. In addition to this, the simulation results also demonstrate that investments in interoperability and portability enhance the value creation for platform providers and users (research question 4). Common business measures (i.e., profit, net present value, return on investment, and discounted return on investment) have been used for this evaluation.

Considering these simulation results, a basis for new sales strategies of software service platform providers is given. Strategies could be designed that consider the interoperability and portability of platforms with respect to the amount of investments, the market share, and the amortization period.

5.3. Limitation

The limitation of this study is due to the research method applied. Simulations use relative values, in order to show the interdependence between the factors and to model the assumptions made during the modeling phase of the study. Therefore, this technique can only show the tendencies of results and the direction of impacts (i.e., the positive or negative impact), despite the fact that real values of variables (e.g., the charge per user, the fraction of revenue invested) have been used. However, a study is planned for validating the level of interoperability in the market through real data from service platform providers.

Acknowledgements

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Appendix: Simulation Settings

Table 1. Settings of scaling coefficients.

Coefficient	Coefficient Description	Assumed Fixed Value	Possible Value Range and Conditions
α_1	Factor together with factor α_2 is used for calculating the arithmetic mean of the variables *Service* and *NonFunctionalQos*.	0.5	$[0,1] \wedge \alpha_1+\alpha_2=1$
α_2	Factor together with factor α_1 is used for calculating the arithmetic mean of the variables *Service* and *NonFunctionalQos*.	0.5	$[0,1] \wedge \alpha_1+\alpha_2=1$
α_3	Factor weights the amount of functionality of services of a platform.	0.5	[service(0),∞)
α_4	Factor is used for calculating the arithmetic mean of the three non-functional variables.	0.33	(0,1]
α_5	Factor sets the portion of revenue that is spent on increasing the number of services.	0.25	$[0,1] \wedge \alpha_5+\alpha_6+\alpha_8+\alpha_{10}=1$
α_6	Factor sets the portion of revenue that is spent on portability.	0.25	$[0,1] \wedge \alpha_5+\alpha_6+\alpha_8+\alpha_{10}=1$
α_7	Factor sets the impact of market share on portability.	0.01	[0,1]
α_8	Factor sets the portion of revenue that is spent on interoperability.	0.25	$[0,1] \wedge \alpha_5+\alpha_6+\alpha_8+\alpha_{10}=1$
α_9	Factor sets the impact of market share on interoperability	0.01	[0,1]
α_{10}	Factor sets the portion of revenue that is spent on usability.	0.25	$[0,1] \wedge \alpha_5+\alpha_6+\alpha_8+\alpha_{10}=1$
α_{11}	Factor translates the investment and the level of service portability into an additional number of services.	0.001	(0,∞]
β_1	Factor is used for calculating the arithmetic mean of the level of portability and the level of interoperability, and it weights the impact of the level of portability.	0.5	$[0,1] \wedge \beta_1+\beta_2\leq 1$
β_2	Factor is used for calculating the arithmetic mean of the level of portability and the level of interoperability, and it weights the impact of the level of portability.	0.5	$[0,1] \wedge \beta_1+\beta_2\leq 1$
β_3	Factor scales the impact of the level of portability.	1	[0,1]
β_4	Factor scales the impact of the level of interoperability.	0.5	[0,1]
γ_1	Factor scales the benefit of services from other platforms with respect to the perceived user value.	0.5	[0,∞)
γ_2	Factor scales the benefit of QoS with respect to the perceived user value.	8	[0,∞)
γ_3	Factor scales the impact of the level of interoperability on the number of new external services.	50	[0,∞)
δ_1	Factor scales a user's valuation of the platform.	0.005	[0,∞)
δ_2	Factor sets the fraction of the provider's revenue that is invested in QoS improvements. It ranges from 3% (Apple) to 22% (Facebook) [59]	0.22	[0,1]

Table 2. Settings of model variables.

Model Variable	Description	Possible Value Range	Initial Value
Qos	Variable indicates the level of QoS.	[0,1]	-
NonFunctionalQos	Variable indicates the level of non-functional QoS.	[0,1]	-
Service(t)	Variable indicates the level of functional QoS (i.e., the number of services).	[1,∞)	2
t	Variable indicates time.	[0,∞)	0
LevelOfInteroperability	Variable indicates the level of interoperability.	[0,1]	*ComplianceWithPortabilityStandardsInTheMarket*
LevelOfServicePortability	Variable indicates the level of portability.	[0,1]	*ComplianceWithInteroperabilityStandardsInTheMarket*
Usability	Variable indicates the level of usability.	[0,1]	-
SpendingOnQos	Variable indicates the total investment in QoS.	[4,∞)	-
MarketShare	Constant describes the market share of the platform.	[0,1]	Depending on Simulation
ComplianceWithPortabilityStandardsInTheMarket	Constant describes the portability standards compliance that exists in the market.	[0,1]	Depending on Simulation
ComplianceWithInteroperabilityStandardsInTheMarket	Constant describes the interoperability standards compliance that exists in the market.	[0,1]	Depending on Simulation
TotalUseCost	Variable specifies the total cost that a user has to pay for using the platform.	[0,∞)	-
ChargePerUser	Constant sets the charge that a user of a platform faces. It also represents the revenue per user of service providers [57].	[0,∞)	1.34
TrainingCost	Variable describes the cost for gaining additional skills.	[0,1]	-
SwitchingCost	Variable describes the cost for changing the software service platform.	[0,1]	-
IntegrationCost	Variable describes the cost for integrating two software services.	[0,1]	-
UserValue	Variable describes the net benefit that the user gets from using the platform.	(-∞,∞)	0
ServicesFromOtherPlatforms(t)	Variable indicates the level of functional QoS (i.e., the number of services) of other software service platforms.	[0,∞)	0
ProviderRevenue	Variable describes the revenue that the platform provider gets from the users.	[0,∞)	0
Users(t)	Variable specifies the number of users at time *t*.	[1,PotentialUsers]	1
PotentialUsers	Constant sets the maximum number of users in the system.	[1,∞)	500
InvestPerMonth	Constant sets the amount of money invested.	[0,∞)	Depending on Simulation
AmortizationPeriod	Constant sets the number of time periods, in which investments have been amortized.	[1,∞)	36 (3 years) or 60 (5 years

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