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Abstract

The adoption of Cloud Computing (CC) is growing rapidly. However, studies on the adoption of these new technologies by individual users are rare and almost exclusively focused on the business context. This paper presents first results of a research project addressing the adoption of CC by individual researchers and small research groups in Higher Education institutions. We surveyed users of the Frankfurt Cloud, an IaaS environment provided at the Goethe University of Frankfurt that serves affiliated researchers with on-demand computing and storage resources. On the one hand, the findings indicate that users benefit from fast and easy access to computing power for their research, on the other hand, user concerns related to cloud adoption are identified, which have to be taken into account during further development of CC services for academic research.

Keywords: Cloud computing, IaaS, cloud users, cloud adoption, academic research

1 INTRODUCTION

Cloud Computing (CC) describes the paradigm of shifting the location of computing infrastructure to the network – with the aim to reduce the costs associated with the management of hardware and software resources (Hayes 2008, Vaquero et al. 2009). A widely-cited definition of CC has been proposed by the NIST, where CC is seen as *'a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction'* (Mell and Grance 2011, p. 2). CC is usually categorized into three types of *service models*: Software as a Service (SaaS) provides specialized software applications that run on the cloud, Platform as a Service (PaaS) provides operating systems that support the development and deployment of applications, and Infrastructure as a Service (IaaS), whereby units of computation (virtual machines) and storage are provided to end-users, who access the resources via Wide Area Networks (e.g., Hay et al. 2011, Su 2011, Marston et al. 2011). Those services are provided via the following *deployment models*: public clouds (managed by a third-party service provider), private/community clouds (the cloud environment is managed within the organization or an organizational consortium), or hybrid clouds (a composition of a set of private and public clouds).

The *adoption of CC* is developing rapidly from both, the supply side as well as the demand side (Su 2011). On the supply side, many IT firms offer CC as key service in their portfolio, on the demand side, more and more organizations in developed countries as well as in emerging countries adopt cloud technologies. Compared to grid computing, CC offers two main features that drive this rapid adoption: First, CC offers virtualization – and thus immediate access – also for hardware resources; second, through hiding deployment details, CC offers an easier entry point for users than the rather complex and management-intensive grid computing environments (Vaquero et al. 2009, Marston et al. 2011). Since cloud adoption is a rather novel field of study, there are only few papers dealing with this topic – mostly focusing on cloud adoption in a business context. For instance, Low et al. (2011) identify factors that affect the adoption of cloud models by firms belonging to the high-tech industry, Saya et

al. (2010) analyze the effects of institutional influences on a firm's intention to adopt CC, and Chebrolu (2011) investigates the impact of cloud adoption on IT effectiveness.

In contrast, this study addresses the personal use of CC – with the focus on CC to support individual researchers and small research projects in Higher Education institutions. We present preliminary results regarding the Frankfurt Cloud, an IaaS environment located at the Goethe University of Frankfurt, Germany, that provides on-demand computing and storage resources. With the aim to identify factors that determine the adoption of these cloud services from an end-user perspective, we conducted a quantitative survey of affiliated scientists working with the Frankfurt Cloud.

The paper is structured as follows: In section 2 we give a short overview on CC in Higher Education institutions and describe the Frankfurt Cloud environment, which is the object of research in this study. In section 3 we develop our hypotheses based on the Technology Acceptance Model. Section 4 depicts empirical results with regard to the structural model and discusses some interesting descriptive results of the survey. The paper closes with an outlook on further research in section 5.

2   CLOUD COMPUTING FOR ACADEMIC RESEARCHERS

The majority of the yet few CC approaches for universities aim on supporting students' education, in particular e-Learning. CC as basis for modern e-Learning applications is for instance documented in articles by Dong et al. (2009), who describe a cloud framework developed by Xi'an Jiaotong University (China), or Doelitzscher et al. (2011), who depict the private cloud infrastructure of Hochschule Furtwangen University (Germany). Furthermore, Behrend et al. (2011) investigate predictors relating to the acceptance of a CC platform in community colleges, and Taylor and Hunsinger (2011) analyze factors influencing students' usage of the cloud application Google Docs.

Of special interest with regard to our research is a paper by Truong and Dustdar (2011), who conducted a study on the state of the art of *CC for small research groups* in computational science and engineering. They identify various issues raised with regard to adoption of CC services by small research groups. Benefits for scientists in those projects are: improved sharing of research results in form of applications, improved data sharing and collaboration with other research groups, support of creating reproducible research findings, and especially reduction of operation and management cost as well as resource cost. The authors draw the conclusion that the current landscape of cloud ecosystems neglects potential end-users from small (computational and engineering) research groups and urgently call for CC providers and researchers to address this issue (Truong and Dustdar 2011).

With the aim to provide on-demand infrastructure for researchers at the Goethe University of Frankfurt, the *Frankfurt Cloud initiative* (http://www.frankfurt-cloud.com/) was founded in October 2010. To guarantee free access to the technology for the researchers, Goethe University receives substantial support by industry partners, which allocate hardware, hosting and cloud management software. In October 2011, over 20 research projects with nearly 50 involved researchers use the provided IaaS for various applications (e.g., data or compute intensive applications, communication intensive applications, intrinsically parallel or sequential application structures). The number of participating scientists is growing steadily. For the provider(s) the Frankfurt Cloud functions as a testbed to evaluate cloud products and service offerings and to design and investigate novel cloud management concepts (e.g., load distribution, management of federated clouds).

3   HYPOTHESES DEVELOPMENT

The technology acceptance model (TAM) (Davis et al. 1989) is widely used by researchers and practitioners to predict and explain user acceptance of information technologies. Originally an adaptation of the theory of reasoned action (Fishbein and Ajzen 1975), TAM was designed to understand the causal chain linking external variables to its user acceptance and actual use (Davis and Venkatesh 1996). Starting with the salient beliefs preceding attitude in the theory of reasoned action,

Davis et al. 1989 proposed and operationalized two core beliefs, perceived usefulness and perceived ease of use, which they stated capture all relevant beliefs in information technology usage contexts (Benbasat and Barki 2007). Similar to the theory of reasoned action, TAM postulates that usage (behavior) is determined by behavioral intention, but differs in that behavioral intention is hypothesized as being jointly determined by an individual's attitude towards using the system and perceived usefulness (Davis et al. 1989). However, due to its low predictive validity compared to perceived usefulness, the attitude was excluded from later versions (Venkatesh and Davis 2000).

With reference to the Frankfurt Cloud, the TAM represents an effective model to explain the user's usage and acceptance of the project. Regarding the hypothesized effects of the two determinants perceived usefulness and perceived ease of use, the present case of the Frankfurt Cloud is interesting. An IaaS cloud environment slightly differs from information systems usually examined in IT adoption studies, because 'hired' infrastructure instead of software applications represents the IT artefact. Comparing perceived usefulness and perceived ease of use with regards to the Frankfurt Cloud, we hypothesize that both have a positive effect on behavioral intention *(H1, H2)*, although we expect the effect of perceived usefulness to be stronger for the reason that users of the Frankfurt Cloud hire computing capacities: The user interface thereby completely adapts to the user's desktop and only the increase of computational power or storage should be recognizable. Therefore, compared to perceived usefulness, ease of use should not be such a critical factor regarding the adoption of the cloud. In line with this argumentation, we also hypothesize that unlike the original TAM, perceived ease of use does not influence perceived usefulness significantly *(H3)*. Finally, we hypothesize a positive effect of behavioral intention on usage *(H4)*. Figure 1 depicts the TAM including the research hypotheses.
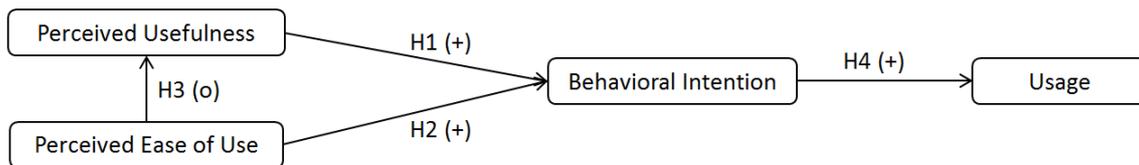

Figure 1.   Research hypotheses.

4   RESULTS

In order to test the hypotheses, an online questionnaire was prepared and invitations sent to the 40 researchers of the 21 projects actually working on the Frankfurt Cloud. At the end of the three-week period, 21 complete questionnaires made up the final sample, yielding a response rate of 55%. Beside the constructs questions, researchers were asked questions about other external factors (job relevance, subjective norm, etc.), which were later excluded from the structural analysis, because of the limited sample size: The minimum sample size should be ten times the number of maximum arrowheads pointing on a latent variable – in our case 20 observations (Barclay et al. 1995). However, since these data give very interesting insights into the users' opinions on academic CC, we present them in descriptive form in section 4.3.

We operationalized the proposed research model as a structural equation model (SEM) and used the partial least squares (PLS) method for the validation. PLS handles measurement errors in exogenous variables better than other methods, such as multiple regression analysis, and requires fewer distributional assumptions about the data (Chin 1998). Furthermore, PLS is the recommended SEM approach regarding small sample sizes (Chin and Newsted 1999). Since PLS is a SEM technique, the measurement model and the structural model are estimated simultaneously to combine the advantages of regression analysis and multivariate measurements approaches.

4.1   Measurement model

Since the content validity of the TAM has been tested extensively within IS literature (e.g. Davis et al. 1989, Venkatesh and Davis 2000), in the present section, the focus lies on construct reliability and

construct validity. *Construct reliability* refers to the internal consistency of the measurement model. It measures the degree to which items are free from random error and yield consistent results. The reliability of the reflective constructs was assessed by using the composite reliability and the Cronbach's alpha scores. According to Hair et al. (1998) and Nunnally (1978), both measures should exceed the threshold of 0.7. As Table 1 indicates, both criteria are met.

Table 1.   Construct reliability and construct validity.

	Composite reliability	**Cronbach's alpha**	**AVE**	**Intention**	**PEoU**	**PU**	**Usage**
Intention	0.99	0.98	0.9780	0.9890			
PEoU	0.90	0.83	0.7564	0.7026	0.8697		
PU	0.98	0.97	0.9299	0.8125	0.3514	0.9642	
Usage	0.90	0.79	0.8272	0.5847	0.1469	0.8150	0.9095

In contrast to construct reliability, *construct validity* refers to the wider validation of measures. Referring to the construct and its indicators, construct validity reveals whether the construct measures what it intends. Construct validity can be assessed in terms of *convergent* and *discriminant validity* (Campbell and Fiske 1959). Convergent validity determines whether the indicators that should theoretically be related are observed to be related in the dataset. According to Fornell and Larcker (1981), the average variance extracted should exceed the threshold of 0.5, so that at least 50% of measurement variance is captured by a construct. As depicted in the fourth column of Table 1, this holds true for all constructs. Tests for discriminant validity validate whether the inter-construct-correlations are low enough. In order to test for discriminant validity, the Fornell-Larcker criterion was used. As the results of Table 1 show, the square roots of the AVE scores (diagonal elements) are greater than the correlations between the construct and any other construct (off-diagonal elements). This indicates that the constructs share more variance with their assigned indicators than with any other construct (Fornell and Larcker 1981). Since all constructs satisfy the reliability and validity criteria, they were used to test the structural model. The results are presented within the next section.

4.2   Structural model

Figure 2 shows the results of the structural model. In order to test for significance, an ordinary bootstrapping procedure was applied. As expected, the impact of perceived usefulness on behavioral intention was slightly stronger than the impact of perceived ease of use; both reveal strong and positive coefficients (Chin 1998). Furthermore, the R^2 values of behavioral intention and usage indicate that a high and moderate amount of variance is explained by the model (Chin 1998).
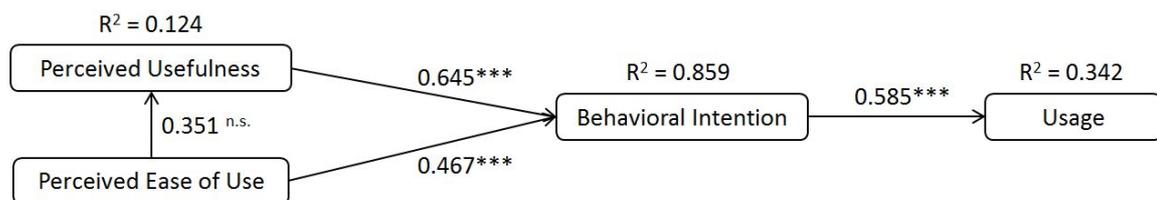

Figure 2.   Results of the structural model.

With respect to the hypotheses, the coefficients in the model support all four hypotheses formulated in the precedent section. Thus, we draw the conclusion that the perceived usefulness and perceived ease of use are the core drivers of the usage with respect to the Frankfurt Cloud. Although perceived usefulness turned out to be stronger (0.645) compared to ease of use (0.467), perceived ease of use still has a strong effect on behavioral intention. As to content, this can be interpreted as a hint that accelerated computational power is useful and thus utilized by users of the Frankfurt Cloud, but effortless handling also is an important issue. Interestingly, both drivers are not, in line with hypothesis 3, causally related. So the degree to which users perceive the usage of the Cloud to be free of effort does not influence their perception of the Cloud's usefulness. This is unusual with regard to the original TAM model, but referring to the Frankfurt Cloud it seems quite logical as explained within the precedent section.

4.3   Descriptive results

Finally, we want to present results concerning some important issues that had – in this early stage of research – not been included in the structural analysis. Figure 3 depicts the results on questions related to *job relevance* and *subjective norm* (for the sake of clarity, in the following we collapse the scales from 7-point or 5-point to 3-point scales). Nearly 80% of the Frankfurt Cloud users say that usage of the cloud is relevant for their job/research. Nevertheless, every fifth respondent disagrees to this statement. Furthermore, the majority of interviewed researchers content that colleagues, who are important to them, think that they should use the Frankfurt Cloud. In this context it is important to mention that 95% respondents assure that their use of the Frankfurt Cloud is/was *voluntary*.
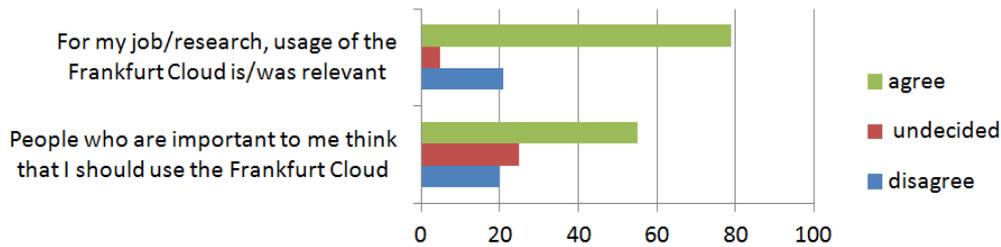

Figure 3.   Job relevance, subjective norm [in %].

Figure 4 highlights the answers regarding two main concerns of cloud users: *data security and privacy*. Cloud users must be protected against attacks malicious tenants (Vaquero et al. 2011) and the provider must assure that the data is accessible and usable at all times (Jansen 2011, Kaisler 2011). Since the Frankfurt Cloud is deployed as a private/community cloud, according to Subashini and Kavitha (2011) trust in secure data access and consumption should be high. This is reflected in the results of our survey, where only about 5% of the users disagree to the statement that their data is safe in the Frankfurt Cloud. However, to nearly 60% of the respondents, data security is only of little importance. Interestingly, with regard to anonymity, the picture is diametrically opposed: The majority of researchers are perturbed about a lack of anonymity in the cloud environment. Hay et al. (2011) point out that the problem in this context lies in determining an adequate degree of 'insiderness' of the service provider. The fear of being 'monitored' has to be addressed in the further development of the Frankfurt Cloud – and in the provisioning of cloud technology to academic researchers in general.
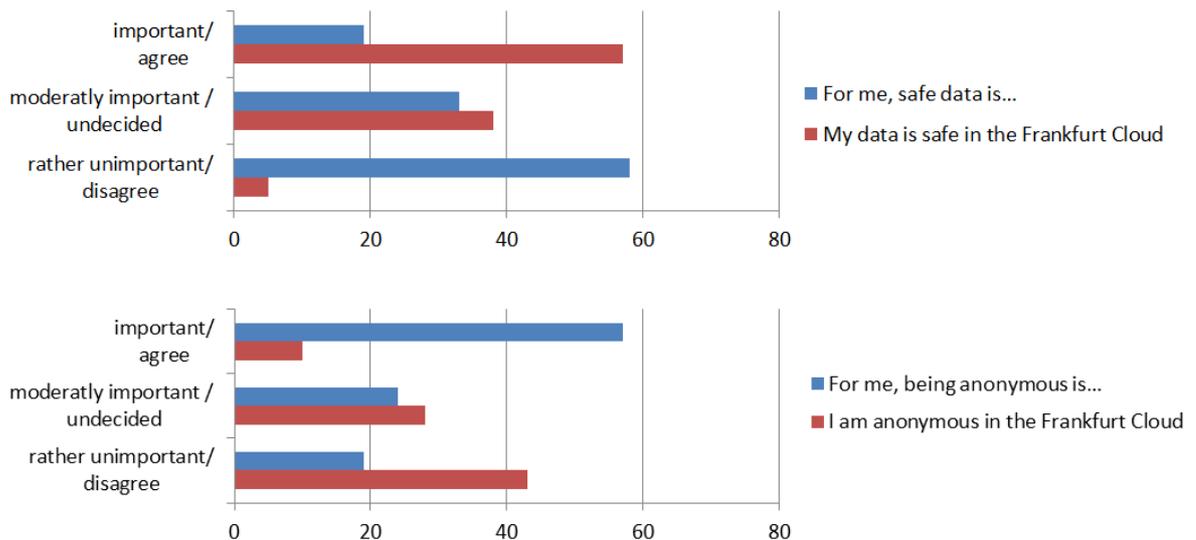

Figure 4.   Data security and privacy in the cloud environment [in %]

Finally, Figure 5 summarizes the answers to questions regarding a more general evaluation of the Frankfurt Cloud initiative. With regard to cloud *performance*, possible problems might come along with the handling of an increasing number of simultaneous users and the (in)ability to scale up the

computing infrastructure in the case of increasing customer demands (Kim et al. 2009). As Figure 5 shows, the vast majority of users are satisfied with the computational performance as well as the technical support provided. Four out of five persons say that the Frankfurt Cloud satisfied their expectations in general. However, with regard to the *willingness to pay*, less than 20% are sure that they would still use the Frankfurt Cloud, if the service is not longer for free. This topic clearly has to be analyzed in more detail in further research on business models of CC in Higher Education. Especially against the background that 90% of the interviewed scientists expect CC to be *important for academic research* in the future.
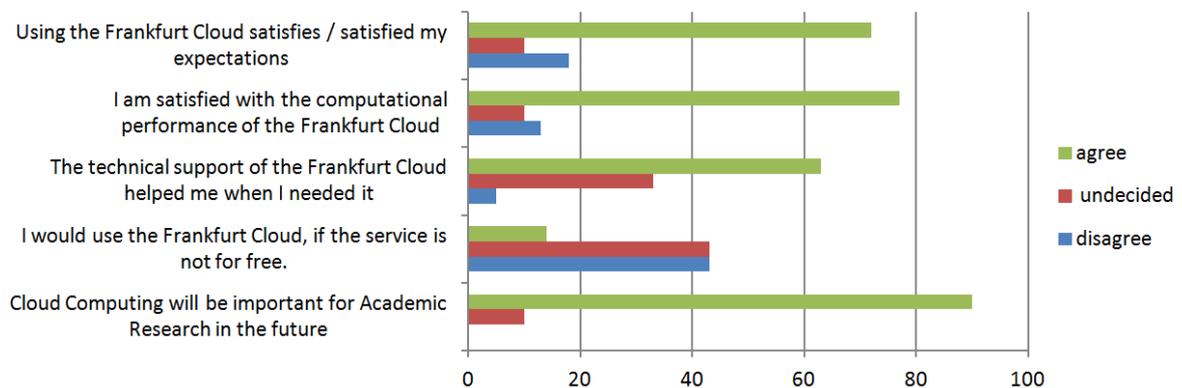

Figure 5.   *Performance, willingness to pay, and future importance [in %]*

5   CONCLUDING REMARKS

As stated above, this research on CC for Higher Education institutions is in an early stage. However, the first results presented in the previous sections implicate that IaaS deployed in form of a private/community cloud – as in the case of the investigated Frankfurt Cloud initiative – could be a suitable concept for supporting academic research in the future. Especially individual scientists or smaller research projects benefit from a fast and easy access to computing power. A typical use case is a researcher, who wants to conduct simulations and benefits from the provided infrastructure in such a way that he does not need to 'block' own hardware resources for days or even weeks, but has the option to outsource his research on virtual machines. Further evolution of the Frankfurt Cloud, accompanied by further research on this topic, will show in which direction concepts of CC for Higher Education will develop. In particular, questions regarding the type of provisioning cloud services to the end-users – e.g., institutional-based private/community clouds vs. commercial third-party service providers – may lead to interesting discussions. As Wheeler and Waggener (2009, p. 66) had put it, *'campus leaders can ignore the signs, or they can embrace the opportunities presented by the (…) rapid innovations in cloud computing models'*.

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