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SUPPLY CHAIN REACTIONS TO THE RISE OF THE INTERNET OF THINGS: RESELLER ADOPTION OF SMART MICROGRID SOLUTIONS

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ABSTRACT

This study applies technology adoption and strategic orientation theories to investigate the reseller adoption of smart microgrids (SMGs). These intelligent power generation solutions, operating on the Internet of Things (IoT) technology, rely on sustainable energy sources to supply small-scale loads. Using data from 100 power system resellers in North America, the study reveals that resellers' performance expectancy and vendors' innovation orientation foster reseller adoption of SMG solutions, while adoption is not driven by resellers' effort expectancy. Furthermore, supply chain members play a crucial role in IoT technology diffusion, but the existing research lacks comprehensive models to help illuminate reseller adoption.

Keywords: Internet of Things, Smart microgrid, Reseller, Innovation orientation, Technology adoption

INTRODUCTION

There is an increasing interest in factors influencing the success of innovation diffusion and technology adoption [27]. In the field of clean energy, smart grids have surfaced as a prominent technology for distributed generation of energy [47]. They are distributed power generation systems that aggregate alternative and renewable energy sources, e.g. microturbines, fuel cells, wind systems, and photovoltaic systems, and employ bidirectional flows of electricity and communications to provide power and reduce peak load and energy losses [12]. Smart microgrids (SMGs) are solutions to small-scale local power generation based on smart grid technology. They have the capability to power by remote control and automate energy generation near demand [40]. SMGs can operate autonomously and disconnected from traditional grids, using local energy generation in times of power outages. They are important in the evolution of the Internet of Things (IoT) [12], as smart grids provide power utilities with digital intelligence and support millions of remote-intelligent devices, all connected through smart concentrators [48]. The intelligence from the data center to the edge means that these devices form intelligent networks that allow electric companies to manage the flow and consumption of energy [40]. The smart grid is a self-healing network that uses energy management system to restore itself [65].

The adoption of SMGs will have a great impact on the diffusion of IoT technologies in the power industry, as local and small-scale energy solutions are an important element of future energy systems [31]. These systems are based on intelligent control and monitoring capabilities, and can be connected with subsystems in local facilities. In spite of the benefits smart grids provide as a combination of power networks and communication networks, the market has not widely adopted SMGs [55]. They probably need more thorough consideration compared to conventional technologies [54]. Although recent studies have addressed the adoption of SMGs among stakeholders [28] and users [2], prior research lacks insight into the factors that affect the adoption of smart grid technology among supply chain members. This gap is notable, as the number of intermediaries within supply chains in the power industry is expected to grow, due to the opportunities provided by smart energy distribution systems [30]. While users and resellers evaluate the expected value of smart grids or other intelligent technology on different grounds, their underlying differences in adoption are not well understood. In particular, previous research has largely neglected the factors that affect reseller adoption of novel technology [58] and the role of vendor's intervention in the technology adoption process [60].

This study extends the existing research on technology adoption by focusing on the role of supply chains in the diffusion of IoT-based power systems technology. The lack of research on reseller adoption of technology is surprising given that resellers are essential supply chain intermediaries between vendors and end customers [7] and downstream channels help to diffuse innovations to markets [41]. There is a need for research on reseller intentions to become involved in a technology and the ways the technology vendor might advance these intentions. Hence, we address the role of vendor's intervention for reseller adoption through vendor's innovation orientation, which is a strategic orientation that explains why firms differ from each other in terms of how they compete in the market [16] and that aims at discovering and satisfying emerging customer needs with novel technology [33]. The study analyzes survey data from 100 North American power system resellers to examine these relationships.

SMART MICROGRIDS AND THE INTERNET OF THINGS

Smart microgrids integrate "green," smaller-capacity electricity sources (e.g. solar panels) in the grid, and apply IoT technologies to the operation and creation of intelligent services. As SMGs employ a two-way flow of electricity and information [6], the communication system is the key component of the smart grid technology infrastructure [59]. This bi-directional communication ability enables control of the local power system, reliability of operations, balancing of loads, and production of data for analytics, and enables users to effectively respond to energy shortages by lowering their energy consumption [51]. Smart microgrids require real-time information management, which is crucial for the reliable delivery of power from the generating units to the users [59].

In spite of the benefits smart grid technology provides, the adoption of SMGs remains limited [8]. SMG solutions can be adopted by diverse actors, including utility companies, universities, neighborhoods, companies, hospitals, and individuals. Excess energy produced by these actors can be stored during lower-demand times and used during peak demand periods or sold into the grid [15]. Changes in energy production and consumption require technical changes and social and cultural changes. Alvial-Palavicino and colleagues [6] argue that the adoption of SMGs depends on the characteristics of each adopting actor, but can be enhanced by the social intervention and understanding of the adopters' expectations associated to the complexity of the technology [6]. Feedback and trust enhance stakeholders' ability to communicate with each other, thereby reducing conflicts in regard to adopting novel technology [6]. Nonetheless, technology adoption is a highly complicated issue and needs more comprehensive research.

ADOPTION OF SMART MICROGRID TECHNOLOGY

Technology adoption models are among the most influential [22] [36] theoretical frameworks for studying information technology usage. The Technology Acceptance Model (TAM) [18] and the Unified Theory of Acceptance and Use of Technology (UTAUT) [63] explain the information technology usage decisions in a variety of contexts and in relation to different types of technology [36]. Such models underline that individual attitudes toward information technology use precede intentions to use the technology, which in turn precede the actual use of the technology [63]. However, technology adoption studies have largely neglected supply chain members as adopters. This is a significant gap, since the number of intermediaries within supply chains in the power industry is expected to grow due to the opportunities that smart energy distribution systems offer [30]. In particular, research has not focused sufficiently on the peculiarities of reseller adoption compared to user adoption [4].

We address two gaps in the technology adoption theory: i) supply chain members' adoption behavior, and ii) seller intervention in the adoption process. Thus, we investigate reseller adoption of SMG solutions that are IoT-based power systems, and focus on performance expectancy and effort expectancy because they define an input-output principle for the business. Any organization's business model can be defined as the system of transforming inputs, through its business activities, into outputs [34]. A reseller has to devote effort to understand and sell technology to the end customers (input) to achieve economic performance (output). We anticipate that the more a reseller expects to benefit from the adoption of a specific technology and the less effort it takes to learn to sell that technology, the higher the likelihood of reseller adoption. Also, we consider the likelihood of adoption through resellers' positive attitudes and behavioral intention to adopt SMG for reselling purposes.

Performance Expectancy, Effort Expectancy and Behavioral Intention

Performance expectancy is the degree to which using a technology will provide benefits in performing activities [62]. While TAM explains performance expectancy through perceived usefulness [5], innovation diffusion theories view it as an output expectancy [61] that pertains to the anticipated relative advantage associated with a technology [14] or as the outcome expectations [9]. Numerous studies have evidenced the impact of expected benefits on technology adoption [23] [56]. SMGs, as intelligent power systems, provide a number of benefits to resellers, including improved business performance as the demand for the technology upsurges [30]. However, resellers of such complex power systems technology are dependent on the vendors' knowledge of the projected user benefits and business opportunities that the technological development brings [44].

Effort expectancy is the degree of ease associated with the adoption of technology [62]. It predicts both outcome expectancy and adoption [61]. While TAM views effort expectancy as perceived ease of use [5] [63] diffusion theories stress the complexity of technology. Effort expectancy is traditionally studied in tandem with performance expectancy to grasp both the benefits and sacrifices associated with technology adoption. For SMG resellers, effort expectancy is linked with their need to learn these solutions and to engage in solving individual customer problems associated with the delivery and implementation of the solutions. Research on reseller adoption of cybersecurity solutions has suggested that the easier the solution is to adopt among the resellers, the less operational tasks are required in the supply chain and the smaller the expected effort is to sell the solution [44].

Previous research suggests that intention towards action is the best predictor of actual behavior [3] [38]. Behavioral intention measures the strength of an actor's attitude to perform the target behavior, such as the adoption of technology. According to Venkatesh and colleagues [63], the relationships between the intention to accept technology and performance expectancy and effort expectancy are essential parts of technology adoption. The UTAUT also emphasized the role of facilitating conditions and social influence [62] [63]. In the mainstream technology adoption research, facilitating conditions are considered as objective factors in the environment that observers agree make an act easy or difficult to accomplish. In the next section, we investigate vendors' intervention in terms of their innovation orientation as a facilitating factor for the reseller adoption of SMGs.

Innovation Orientation as Vendor Invention in Reseller's SMG Adoption

Previous research [17] [45] argues that innovation orientation can explain why companies differ from each other in terms of how they compete in the market. Differences in innovation orientation lead to different outcomes and performance [24] [50]. Yet, innovation orientation is poorly understood [53] because it has been conceptualized in many ways [17] [24]. Worren and colleagues [46] view innovation orientation as a commitment to more and faster innovations. New product introductions reflect the output that results from R&D inputs [17]. While businesses vary in terms of the input that goes into innovation activity [17], innovation orientation enhances the likelihood of developing radically new products [13]. Innovation orientation consists of an organization's learning philosophy, strategic direction, and transfunctional beliefs, which direct the strategy and actions toward innovation-enabling competencies and processes [24]. It means that change, creativity and risk-taking are encouraged in areas where one lacks prior experience [10] [66]. Ruvio and colleagues [1] associate innovation orientation, in terms of creativity, openness, future orientation, risk taking, and proactiveness, with the ability to generate ideas and innovate continually over time.

We draw on Simpson and colleagues [50], Talke and colleagues [32], and Dhewanto and Sohal [64], and define innovation orientation as "a strategic orientation that provides a business with the capability of identifying emerging customer needs and the capability of developing and implementing technology innovations to satisfy those needs". Innovation orientation supports the company in having more innovative ideas and in serving various market segments by producing more innovative products. It influences technology commercialization capability, which then influences technology commercialization performance [64]. In other words, innovation orientation influences marketing capabilities that affect new product performance [43]. However, we concede that innovation orientation may have both positive effects (advantages related to innovations, markets, employees, and operations) and negative effects on performance (too much change, market risk, employee attitudes, and increased costs) [50].

In sum, the hypotheses used to establish a conceptual research model and their theoretical bases are presented in Table 1.

Table 1. Hypotheses with their theoretical bases

Hypothesis	**Theoretical basis**
H1: Reseller's intention to adopt SMGs is positively influenced by the performance expectancy of the solution as perceived by the reseller.	TAM [18], The degree to which a person believes that using a particular system would enhance his or her job performance [18].
H2: Reseller's intention to adopt SMGs is positively influenced by the effort expectancy of the solution as perceived by the reseller.	TAM [18], The perceived ease or difficulty of performing a behavior and it is assumed to reflect past experience as well as anticipated impediments and obstacles [21].
H3: Reseller's intention to adopt SMGs is facilitated by the vendor's innovation orientation as perceived by the reseller.	UTAUT [60] suggests the role of interventions for adoption; Strategic orientation theory [16], innovation orientation enables firms to create business advantages through innovation [50].
H4: Reseller's actual sales of SMGs positively linked with their intention to adopt the solutions.	Theory of planned behavior [3] [20] [38] , Individual or organizational behavior is preceded by behavioral intention.

RESEARCH METHODS

We conducted semi-structured interviews with three industry experts in Canada to explore ideas for designing a survey. In early 2015, we administered an online survey to power technology resellers in North America on their adoption of SMG technology and attitudes on vendor intervention. We analyzed the survey data to test the hypotheses and validate the proposed research model. A total of 300 contacts were derived from the LinkedIn account of an author who works in the power systems industry. We excluded 7 incomplete questionnaires out of the 107 returned (36% response rate), thus resulting in a set of 100 completed questionnaires. The majority of surveyed resellers seem to target large customers (51%) located in all geographical market areas: local (36%), national (36%), and international (39%). The data confirms that reseller adoption of SMGs is low; 48% receive less than 5 percent of their sales from SMG solutions, and only 11% consider SMG solutions as a major source of revenue.

Measurement scales were derived from prior literature. As adoption of technology by supply chain intermediaries differs from that of individual users, we adapted measures for performance expectancy (PE) from Davis [18] and Venkatesh and colleagues [63]. Measures for effort expectancy (EE) were adapted from Davis [51], Venkatesh [90], and Venkatesh and colleagues [93]. We also used the list of new product launch failures by Schneider and Hall [35], because the easier the technology is to learn for resellers, the better motivated they are to sell the technology to end-customers. Measures for vendor's innovation orientation (IO) were derived from Dhewanto and Sohal [64]. Behavioral intention (BI) typically focuses on the direct intention to perform a task [37], but we measured the extent to which the resellers consider the SMG adoption to be a good business opportunity.

We used SmartPLS 3.0 software [29] to analyze data, test the research model, and validate the hypotheses. PLS suits for analyzing reseller adoption of SMGs because it is appropriate for predictive behavioral models such as user adoption [19] and it has been used in seminal research papers on user and technology adoption [60] [61] [62]. We used Harman's one-factor procedure because all data came from the same survey [25] as well as respondent's work experience (in years) as a marker variable [57]. The five factors explained 78 percent of the total variance, and the first factor explained 48 percent (KMO = 0.864, df = 210, $p<0.001$). No single factor explained most of the variance and there were no significant correlations between the marker variable and the latent variables, suggesting that common method bias is not a concern. As to reliability and validity tests, all item loadings were > 0.70 [60] and Composite Reliability and Cronbach's alpha for each construct was >0.70 [39]. Average Variance Extracted for each construct was >0.50 [26], suggesting convergent validity. To assess discriminant validity, we examined the correlation matrix of the constructs (cf. Fornell and Larcker [8]) and used the heterotrait-monotrait ratio of correlations (HTMT) (cf. Henseler and colleagues [26]). All HTMT values are <0.85, suggesting that there is sufficient discriminant validity.

RESULTS

The analysis shows that hypothesis H1 was confirmed (β=0.547, t=4.918, p<0.001), but performance expectancy also has an unexpected direct positive link (β=0.209, t=2.676, p<0.01) to reseller's sales of SMGs. H2 was not confirmed (β=-0.142, t=1.130, n.s.) although we anticipated that there will be a positive relationship. However, the analysis revealed that, if there was a correlation, it would be negative, which is in contrast to the theory of technology adoption. The analysis confirms H3 (β=0.233, t=1.961, p<0.05) and H4 (β=0.383, t=4.083, p<0.001). R^2 values are acceptable as performance expectancy and innovation orientation explain 38 percent of variance in behavioral intention which, in turn, explains 15 percent of variance in reseller's actual sales (cf. Legris and colleagues [49]). The final model and validated relationships are illustrated in Figure 1.

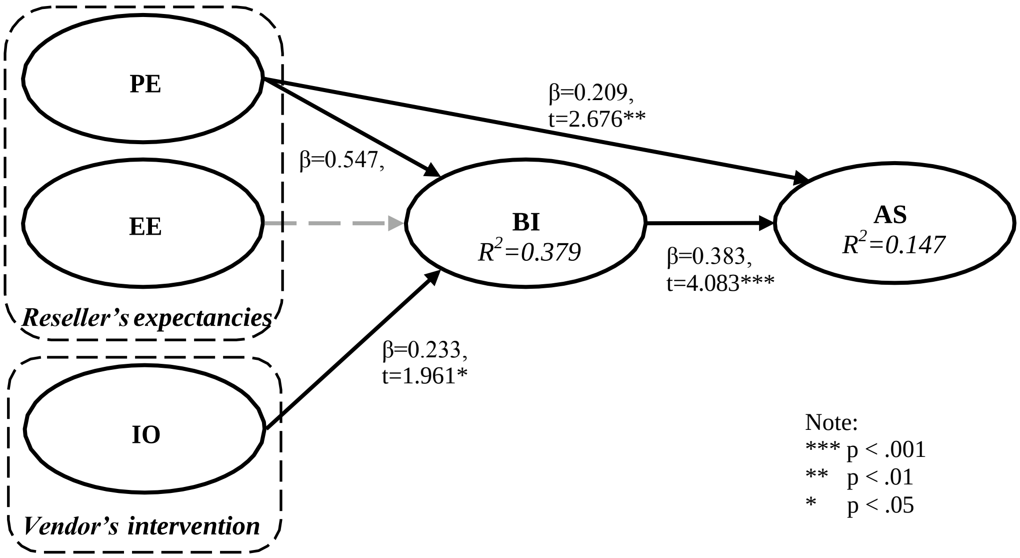

Figure 1. Final model and validated relationships

Finally, we examined the goodness of fit for overall model to validate the structural model. First, we calculated the global fit measure (GoF) (cf. Tenenhaus and colleagues [42]). Although this measure has been criticized in recent literature, the GoF of our model is 0.43, indicating a large effect and a good fit to the data. Second, we examined the standardized root mean square residual (SRMR) (cf. Henseler and colleagues [26]). A value of < 0.10 is considered a good fit, but a more conservative view recommends the 0.08 threshold [35]. SmartPLS reports the SRMR for both composite models and common factor models; usually, the composite model SRMR is relevant. The SRMR for our composite model was 0.074, thus suggesting a good fit of the model.

CONCLUSION

This study investigated the reseller adoption of SMGs that are intelligent power systems operating on the IoT technology. An analysis of survey data from 100 power system resellers in North America showed that resellers' performance expectancy promotes their SMG sales both directly and indirectly through the intention to adopt and resell such solutions. The unexpected direct relationship confirms that performance expectancy is the primary driver for resellers to sell novel IoT-based power system solutions. Conversely, effort expectancy does not drive resellers to adopt SMGs. This is interesting, because prior literature on technology adoption has consistently shown the positive relationship between effort expectancy and behavioral intention [52]. In fact, the negative yet statistically insignificant value fuels speculation; do some of the resellers even prefer selling novel, complex technology, because learning and mastering such technology would give them an advantage over their competitors?

We show that reseller adoption of IoT-based power systems technology is driven by resellers' performance expectancy instead of effort expectancy. Previous literature has stressed that effort expectancy has a dominant role in user adoption [18]. Our finding is in contrast with this notion and highlights that reseller motives to adopt new technology differ from those of users. The negative, yet statistically insignificant effort expectancy-behavioral intention relationship suggests that resellers value the effort required to learn the new technology, as easy-to-learn solutions are easy to sell, making them vulnerable to price competition. However, it remains for future research to investigate this relationship. The findings contribute to the literature of technology adoption by pinpointing the role of vendor intervention for reseller adoption. Our results extend the technology adoption theory by arguing that the vendor plays a key role in the adoption processes, while technology adoption studies commonly [18] [62] [63] address the value of technology itself, the effect of environment, previous experience, or the role of peer influence. Also, the results increase our understanding of the role of innovation orientation in organizational decision making within supply chains.

As to limitations, our strict focus on reseller adoption does not allow to investigate the adoption of the new intelligent technology across various stakeholder groups in the power systems market. Our study suggests that reseller motivations differ from those of end users, whereby user adoption theories may not work well for reseller adoption, and possibly to other stakeholders. Thus, we call for the development of more accurate models for reseller adoption, including different motivational factors, other indicators of vendor intervention, and the influence of other stakeholder groups on reseller adoption. Finally, our study took place among power systems resellers in North America serving end users in various market areas, but previous research has indicated some differences in technology acceptance across different countries and cultural areas [56], [11]. Hence, it would be interesting to investigate whether such differences between cultural and geographical areas exist among supply chains in different markets.

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