Cross-country review of smart grid adoption in residential buildings

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A R T I C L E   I N F O

A B S T R A C T

A smart meter is an energy metering device with advanced features that allow consumers to track their energy consumption. Smart meters are widely considered a solution for achieving energy efficiency and sustainable development. In addition to understanding consumer perceptions, expectations and intentions, a clear understanding of the influence of how national values and norms affect smart meter adoption behavior is needed by policy makers and investors in smart grid deployment. The aim of this study was to examine similarities and differences in consumer adoption of smart meters across Taiwan, Korean, Indonesia, and Vietnam. Data obtained from surveys in the four countries were analyzed by structural equation modeling to determine the interacting factors in consumer acceptance of smart meters. Consumer perceptions, expectations, and intentions regarding the potential use of smart meters across the four countries were analyzed and compared. The findings of this study improve understanding of regional differences in consumer adoption of smart grid systems. The findings can also help investors and policy makers involved in smart grid investment decision making. Finally, suggestions are given for maximizing the success of smart grid development in the researched countries.

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1. Introduction

In addition to the development of innovative renewable energies in recent years, efficient energy use and smart manageable energy systems have been pursued to cope with substitution of fossil fuel, problems related to climate change, and increasing demand for energy and resource resulting from rapid economic growth. The use of smart meters is widely viewed as effective for increasing energy efficiency and is consistent with the attempts of many countries in issues of energy efficiency and sustainable development [1–3].

Smart meter is an energy metering device with enhanced capacity to store and analyze information about energy consumption in real time. A smart meter also enables two-way communication function between energy utilities and each end user. Smart meter is a major component of next-generation smart grid because they can integrate information technology into the grid.

After collecting energy consumption data from customers using appropriate devices and communication infrastructure, utility companies can manage electricity demand more efficient and advise users to consume the power wisely [1,4]. Based on the long-term power usage pattern, the feedback information from smart meter data analytics offers consumers a better understanding of their energy consumption and help them increase end-use energy efficiency.

Because of their expected benefits, smart meters are being studied and deployed in many countries. In fact, some countries in Europe have already installed smart meter systems [5,6]. In other countries, such as the US, smart meter deployment is underway [7]. In some newly developed countries or regions such as Korea and Taiwan, smart meter systems are still under development. In Indonesia and Vietnam, smart meter systems are still in long term planning, and their status is mainly known through unofficial communication media.

Obviously, deployment of smart meters involves many policy, economic, technological, and management challenges, and no less important is consumer acceptance [1,8]. The first step in smart grid development is to ensure consumer acceptance of smart meters in their residences [9]. Smart grid deployment could be easily refused if consumers underestimate their benefits or overestimate their problems. Thus, studies of consumer adoption of smart meters are needed to guide policy makers in deploying smart grids.

Furthermore, prior studies indicate that national values and norms strongly determine motivation and behavior [10–12]. Thus, consumers in various countries differ in the perceptions, preferences, and values that affect the intention to adopt an innovation [13–16]. Therefore, comparative studies of the tendencies of consumers to adopt a new technology, e.g., smart meters, are essential. However, a literature review reveals few studies of the similarities and differences in the smart meter adoption tendencies of consumers across nations.

Therefore, the aim of this study was to examine the similarities and differences in consumer adoption of smart meters across Taiwan, Korea, Indonesia, and Vietnam. A research model was developed based on technology acceptance model, and data obtained by a survey performed in Taiwan, Korea, Indonesia, and Vietnam were analyzed by structural equation modeling (SEM).

To enhance understanding of corporate operational efficiency by utility companies in the service-oriented industry, consumer perceived expectations and perceptions of the importance of smart meters, changed term of Importance–Performance Analysis (IPA) was conducted. A consumer adoption propensity (CAP) index was developed for use as a comparative measure of residential smart meter adoption. Finally, based on the analysis results, a Strength–Weakness–Opportunity–Threat (SWOT) strategic matrix is proposed to increase consumer adoption of smart meter in the researched countries.

The findings of this study improve understanding of regional influences on smart meter adoption behavior, which would be useful for policy makers and investors when promoting smart grid development in the four researched countries. The analytical result of this study can help investors identify the countries with the greatest potential markets for smart meter systems. This study also indicates factors that policy makers should consider when promoting the adoption of consumers for smart meter and for maximizing the success of smart grid development in each country.

Moreover, this study provides models of interacting factors influencing smart meter consumer adoption in the four researched countries. The similarities in these models can be considered principals of smart meter adoption, and the differences resulting from socio-economic and cultural conditions of these countries can be considered by policy makers and investors in smart grid development in these countries. The results of this study contribute not only to the literature on smart meter adoption, but also to the general literature on cross country technology adoption. The research process is divided into four stages as shown in Fig. 1, including research objective and hypotheses; questionnaire design and survey analysis; structural model optimization; result discussion and conclusions.

The remainder of this paper is organized as follows. Section 2 reviews the literature on the status of smart meter technology deployment, global smart meter adoption, influence of country on technology adoption. Section 3 presents the proposed hypotheses and research model. Section 4 then details the research methods used. Next, Section 5 presents the analytical results, managerial implications and practical applications of the study. Finally, Section 6 concludes the study.

2. Literature review

2.1. Current status of smart meter technology

Because of their expected benefits and advantages, smart meters are being studied by policy makers and governments throughout the world. US, EU have been among the first-movers in the development of smart grid [17]. Currently, smart meter systems are being deployed at a growing scale worldwide. Global smart meter shipments reached 19.2 million in the 3rd quarter in 2011 [18]. This section briefly reviews smart meter deployment status over the world.