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The role of educational trainings in the diffusion of smart metering platforms: An agent-based modeling approach

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HIGHLIGHTS

- Impact of educational trainings on the diffusion of smart metering platforms (SMPs) is evaluated.
- Motivated by Bamberg's model of self-regulated behavioral change.
- Mass-media advertising and educational trainings lead to similar adoption rates.
- Spatially concentrated (group) trainings are never worse than randomly scattered ones.
- For a certain range of parameters group trainings are significantly better.

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ABSTRACT

Using an agent-based modeling approach we examine the impact of educational programs and trainings on the diffusion of smart metering platforms (SMPs). We also investigate how social responses, like conformity or independence, mass-media advertising as well as opinion stability impact the transition from predecisional and preactional behavioral stages (opinion formation) to actional and postactional stages (decision-making) of individual electricity consumers. We find that mass-media advertising (i.e., a global external field) and educational trainings (i.e., a local external field) lead to similar, though not identical adoption rates. Secondly, that spatially concentrated 'group' trainings are never worse than randomly scattered ones, and for a certain range of parameters are significantly better. Finally, that by manipulating the time required by an agent to make a decision, e.g., through promotions, we can speed up or slow down the diffusion of SMPs.

1. Introduction

Nowadays, the energy system faces a lot of challenges. On one hand, energy demand is increasing rapidly and – according to experts – further growth will be observed due to increased 'electrification' of our lives and population growth. On the other hand, due to the constantly decreasing natural resources, the generation may face problems of scarcity of fossil fuels. The increasing presence of *renewable energy sources* (RES), like wind and solar, may help to provide the demanded power, but its non-dispatchable (non-controllable) character negatively influences power system stability. These challenges, as well as the ambitious goals set by the European Commission and other international organizations, e.g. CO_2 reduction and a

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significant increase of energy efficiency, will have a great impact not only on electricity generation but also on consumption. The consumers will need to decrease their consumption and shift loads to off-peak hours, which may involve changes in everyday behavior and routines [1,2].

As a remedy, the *smart grid* (SG) concept has been proposed recently. SGs use modern communication technologies to exchange information between market agents (generators, market operators and end-users) in order to improve power system efficiency [3–5]. However, the basic requirement for the success of this approach is the roll-out of *smart meters* (SMs) among electricity end-users [6,7].

The diffusion of smart meters is usually combined with offering an access to so-called smart metering information systems or platforms (SMPs) [2,8,9]. For instance, the local *distribution system operator* (DSO) in Wrocław (Poland) is planning to install SMs at all households by the end of 2017. The households will get access to the information about their energy consumption via a web-based SMP called *e-licznik*, which runs on smartphones and tablets, and will receive alerts when the targeted energy consumption level is exceeded. However, as the literature suggests, the potential success of the smart meters' roll-out is combined with consumer awareness of the potential technologies and their engagement [4,5,7]. Particularly, the regular use of SMPs is found to be related with consumer willingness to optimize their energy consumption [8].

Recently a number of field experiments, research surveys and pilot programs have been conducted in order to analyze the determinants of successful diffusion of SMs [1,6,8,10,11]. As it turns out, there is a great discrepancy between consumer opinions and their behaviors towards various innovations in the energy market [3,12]. For example, even if consumers declare their willingness to save energy, they do not even try to reduce their electricity consumption [13]. Such an *intention-behavior gap* is often responsible for slow or unsuccessful adoption of innovative technologies or behaviors [14]. Among the reasons for this gap the literature usually mentions unstable consumer opinions, lack of knowledge and skills, lack of professional advice, general confusion of choice, distrust in new technologies and energy providers [13].

In a parallel stream of literature, *agent-based models* (ABMs) have been used to investigate the diffusion of smart technologies, for a review see [15]. For instance, the diffusion of smart meters has been examined in [16], but from a different perspective — the authors used ABMs to analyze what regulatory interventions induce the diffusion of SMs. In [9], the agent-based model proposed in [17] and built around the concept of the reservation price (representing product appraisal), has been used to analyze the diffusion of SMPs. It has been shown that social influence can either increase or decrease adoption rates and the market share of SMPs, dependent on their market value [9].

Somewhat surprisingly, most innovation diffusion models make no distinction between opinions and decisions — opinions are identified as final decisions whether to adopt an innovation or not. Yet, the literature suggests that opinions do not have to and in case of eco-innovations often are not followed by the decisions [12,18]. To address this feature, Kowalska-Pyzalska et al. [14] have proposed an ABM to study the temporal dynamics of consumer opinions regarding switching to dynamic electricity tariffs and the actual decisions to switch. The model is built on the assumption that the decision to switch is based on the unanimity of τ past opinions and offers a hypothetical, yet plausible explanation of why there is such a big discrepancy between consumer opinions and adoption rates.

In this paper, we build on and modify the ABM proposed in [14,19,20] with an objective of examining the impact of educational trainings and programs offered by energy utilities on the diffusion and adoption of the SMPs. In particular, we analyze how opinions and decisions depend on (i) social responses, like conformity or independence, (ii) skills (or know-how) required for everyday use of the SMPs, and (iii) stability of consumer opinions.

The paper's contribution is threefold. Firstly, we observe that the positive effect of educational programs and trainings depends on the level of independence in the society and agent *decision* and *memory times*. Secondly, we show that spatially concentrated 'group' trainings, e.g., for all households in a given area or district, are never worse than randomly scattered ones. Finally, we find that for intensive mass-media advertising, the type of educational trainings – spatially concentrated or randomly scattered – does not matter.

The remainder of the paper is structured as follows. In Section 2 we discuss the role of interventions on consumer behavior. In particular, we focus on the evidence from pilot programs and field experiments showing that a successful diffusion of smart technologies is not possible without a certain level of consumer knowledge and awareness. In Section 3 we introduce our agent-based model and present the Monte Carlo simulation scheme, then in Section 4 discuss the results of our simulation study. Finally, in Section 5 we conclude and discuss policy implications.

2. The role of interventions in adoption of SMPs and other eco-innovations

2.1. Slow diffusion of SMPs

The prospect of an effective roll-out of smart meters seems optimistic. It may bring a lot of advantages both for energy suppliers and consumers. From the consumer point of view the main advantage is direct access to real-time consumption data via a SMP. Using such information a consumer may optimize the energy consumption and achieve financial savings or personal satisfaction, e.g., from being pro-environmental. As Good et al. [7] emphasize, there is a great number of incentives and barriers of successful adoption of SM technologies.

Financial savings and social and personal norms are the most important incentives [10,11]. On the other hand, the major obstacles include confusion of choice and consumer resistance to behavioral change, e.g., rescheduling the daily routine in response to electricity prices dictated by a variable electricity tariff [1,4,11,12]. To reduce the latter disadvantage a