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Co-evolution of legal and voluntary standards: Development of energy efficiency in Swiss residential building codes

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ABSTRACT

Improving the level of energy efficiency required by building codes for refurbishments and new construction is a powerful lever for reducing greenhouse gas emissions. This paper explores how technological, social, political, and economic factors interact and shape the evolution of the energy efficiency in building codes. Existing approaches to the evolution of standards focus primarily on adopting individual or multiple technologies or products, but only peripherally explore the feedback dynamics between innovation, diffusion, and standardization (IDS.)[2] To fill this void, I draw on the revelatory case of Switzerland, because the Swiss standards have continuously improved since 1970, whereas in many other countries improvements have stagnated after the recovery from peaks in energy prices. The paper's contribution is, first, a qualitative, structural model which endogenously formalizes the IDS-dynamics of standard improvement. I find that the co-evolution of voluntary and legal building codes have enabled a continuous improvement of the standards even in the absence of economic pressures. And second, I use the model for policy analysis, which indicates that several obvious policies might cause policy resistance and could result in uneconomical, counter-intuitive outcomes. Policy interventions have to dynamically balance the speed of innovation and the ability of system agents to change.

1. Introduction

Mitigating global warming and securing a mid- and long-term energy supply are relevant topics for policy makers. To limit the increase in temperature to acceptable levels, greenhouse gases (GHG)-emissions must be approximately halved by 2050 relative to 1990-levels [1–3]. The energy required for residential buildings greatly contributes to those emissions [4,5]. Therefore, improving the energy efficiency (EE[3]) of the residential building stock by diffusing more innovative EE technologies, e.g., insulation and heating technologies for new constructions and renovations [6], are cost efficient options to lower GHG emissions [7,8]. Thereby, the improvement of the average EE of a building stock significantly depends on the energy requirements of building codes. A residential *building code* is a voluntary or a legal standard that defines the required level of EE (measured by the metric *Energy Demand per New Constructed Housing Unit* in MJ/m^2/year; see Fig. 1) in a residential building for space and water heating. History has shown that these requirements can improve over time. Innovation is the improvement in building technologies, e.g., insulation or controlling technologies [9]. Now, what causes the EE improvements in building standards?

Relevant literature stems from innovation diffusion, co-evolution, innovation and standardization, and technological innovation systems. For the first body of literature, Higgins et al. [10] have outlined the extensive literature on innovation

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[2] Innovation–diffusion–standardization (IDS).
[3] In the paper, I use EE to abbreviate both “energy efficiency” and “energy efficient”.

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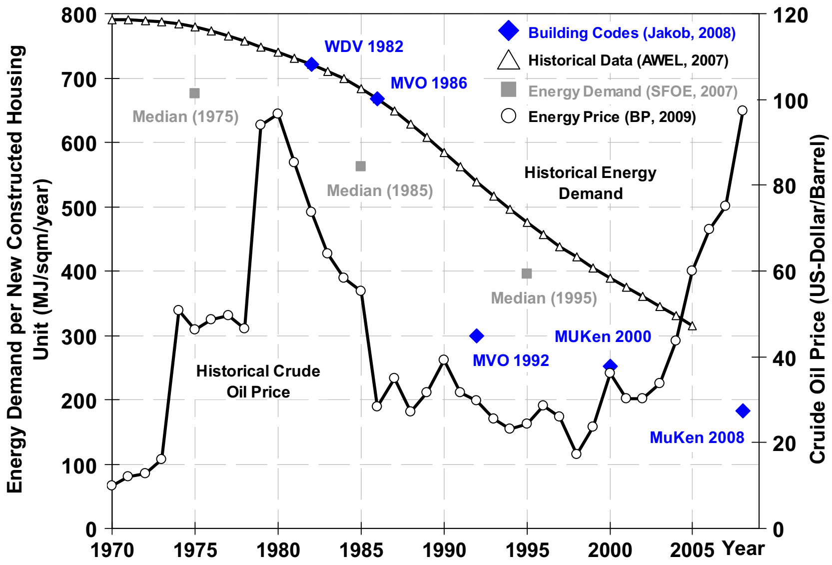

Fig. 1. Historical energy demand of legal building code and oil price. The data available does not allow for precise estimates of energy demand or energy efficiency due to different measurement methods. For instance, the empirical analysis of the average energy efficiency in residential building undertaken by the Swiss Federal Office of Energy resulted in values lower than the legal building code prior to 1986, and in values higher than the legal building code thereafter [50]. The historical data available for the Statistical Office of the Canton Zurich [38] shows values significantly higher than the legal building codes [49]. For the purposes in this paper, I use the values of the building codes.

diffusion research and then used it to analyze policies for GHG-reductions in housing stocks. Although they consider voluntary and mandatory adoption of reduction technologies to evaluate the effectiveness of different intervention schemes, they assume that both technologies are independent from each other—a fact which seems to be an oversimplification as this paper will show. The second body of literature explicitly accounts for the co-evolution of innovations, e.g., supply and demand [11,12], two complementary innovations [13], clinical knowledge and technological capabilities [14], scientific and technological networks [15], or capabilities and preferences [16]. Specifically relevant is Dijk et al. [11] who provide a co-evolutionary analysis of the emergence of hybrid-electric cars. Their analysis integrates actor perspectives, feedback effects, and competition between products. The approach I use can be viewed as a more formal version or an extension of their approach. The `third body of literature deals with innovation and its standardization, specifically for processes of technology transfer and standardization [e.g., 17–19], and driving forces of standardization activities [20,21]. This paper contributes to the third body by providing a systems model with a broad model boundary which accounts for multiple agents. Thereby, it supports the most recent research on standardization cycles [19]. The fourth body of literature is on technological innovation systems. It addresses the question of how technological innovations develop [22–25] from a systems perspective. Although this literature provides insightful concepts, e.g., functions [26] or the multi-pattern approach [27], it often lacks a clear conceptualization of the process of standard development at a detailed causal level. To summarize, although the understanding of the co-evolution of EE standards is relevant from a policy perspective, it has not been directly addressed by current research.

The objective of this paper is, first, to explain the evolution of EE in building codes for the residential building sector. Innovation systems literature reveals that feedback rich models with a broad model boundary are required to adequately address such phenomena [23]. In this paper, I use the methodology of qualitative system dynamics [28,29] which, in addition to feedback dynamics, also accounts for important accumulations as well as nonlinear and delayed interactions. To understand the evolution process, I study the revelatory case of the Swiss residential building sector. The empirically grounded model[4] interconnects economic, technological, and political aspects and accounts for the dynamic complexity of that system [31]. After developing a structural model based on historical case data, I use the model to discuss the likely impact of future policy interventions on the development of EE standards in building codes.

I maintain that the evolution of the level of EE in a legal building code occurs in co-evolution with a voluntary building standard. Moreover, I argue that reoccurring dynamics of innovation, diffusion, and standardization (IDS) form the core of this co-evolutionary process. And finally, I argue that, due to the system's dynamic complexity, and a lack of transdisciplinary and integrated systems models for norm evolution, unbalanced policy interventions could cause policy resistance and counterintuitive outcomes.

The paper is organized as follows: The research methodology is described in Section 2. Section 3 develops the case model which is then analyzed in Section 4. Section 5 uses this model to conceptualize the likely outcomes of policy interventions. Section 6 discusses the theoretical and practical contributions and implications of the results and addresses the model's

[4] In the paper, I use "model" and "theory" interchangeable [30].