Abstract:

The Paper designs a Multi-Agent-based model to simulate the diffusion of Smart Metering in Germany. With respect to former research results of the EPRG, consumer purchase decision behavior is simulated with a combined decision tree and scoring approach. Three different scenarios prove the current open market situation and different regulatory policy options. Finally, the impact of a scrapping bonus for old Ferraris meters to promote the diffusion of intelligent meters is calculated.
1 Introduction
1.1 Background information

Information- and Communication-Technology (ICT) revolutionizes the energy supply. Worldwide, a surging hunger for energy in combination with an increasing amount of climate protection initiatives leads to a playground for the development and use of innovative technologies and business models. **Smart Grids** will enable an intelligent feed-in of small and decentralized sources like photovoltaic and Plug-In Hybrid Vehicles (PHEVs) as well as load-dependent controls and feed-ins of large-scale power plants like offshore wind-farms or Desertec. Load-dependent tariffs and home automation integrate the consumer into the value chain with impacts on sales, metering and billing processes (World Economic Forum, 2009, pp. 6–12).

A major prerequisite for this revolution and therefore key for the sustainability of power grids is **Smart Metering** (Kurth, 2009, pp. 6, Kester 2009, pp. 59-61). An Advanced Metering Infrastructure (AMI) which combines frequent measurement processes with advanced ICT will replace the legacy infrastructure of out-dated Ferraris meters. Energy consumption courses and costs can be visualized in real-time with direct feedback to the consumer through in-home displays or iPhone Apps. Bidirectional communication capabilities of Smart Meters are the enabler for an integration of metering-results into grid-control which vice versa sends load-dependent signals to households. These signals might include simple price per kilowatt-hour information or sophisticated event-based triggers to control air conditioners, fridges or pool-pumps.

Country-specific discussions about **rollout-strategies** for Smart Meters last since several years with only little progress in many European countries (European Smart Metering Alliance (ESMA), 2010, pp. 11–14). The procrastination of this trend appear to be absurd because of several successful pilot projects that prove economic and ecologic benefits (European Smart Metering Alliance (ESMA), 2010, pp. 50-54, Brophy Haney 2009, pp. 11) and despite an increasing amount of positive value drivers. Having discussed transparency, savings potential and demand response five years ago, we now tackle microgrids with the integration of PHEVs and heat-power-combinations. In principle, three different rollout-approaches can be identified. The choice for one of these strategies depends highly on environmental, technological, regulatory and even cultural drivers, which differ from country to coun-
try: “One size does not fit all” as the World Economic Forum states (2009, pp. 3, see p. 9 for an overview of the heterogeneous set of drivers).

1. **Push**: State-aided market push with focus on large-scale pilot regions (e.g. United States, China, Australia)

2. **Pull**: Liberalization of the metering market in order to promote competition and end-customer demand (especially in Germany, the Netherlands and the United Kingdom)

3. **Do-nothing**: Wait and see-approach with focus on pilots and studies but without any activity to promote the diffusion (e.g. Portugal, Hungary, Poland)

The diffusion of the technology stagnates especially in Germany, the Netherlands and the United Kingdom (European Smart Metering Alliance (ESMA), 2010, pp. 34–39). These three countries are comparable with each other regarding their liberalized energy market model and their demand-oriented, consumer-focused Smart Metering Rollout-strategy (Pollitt, 2009, pp. 6–12). The regulatory intention is to promote competition through liberalization, which leads to attractive offerings and finally accelerates the demand of the private sector.

Customer demand for Smart Meters is still very low in these three countries. The question is: **Should they adjust their rollout-strategy to a Push-approach and/or setup new regulatory frameworks in order to promote the diffusion of Smart Metering?** On the one hand, barriers like the additional costs, low product involvement, little awareness and negative press in terms of data security and data privacy discussions avoid customer demand. On the other hand, experiences from international pilot projects confirm the importance of customer centricity: High consumer acceptance leads to high demand response and therefore drives societal benefits (de Cannière, de Pelsmacker, & Geuens, 2009, pp. 33–36). Missing consumer acceptance is a major threat as shown in the lawsuit against Pacific Gas & Electric sued by Bakersfield, California. In the long-term, customers need to become co-creators of value, as Honebein, Cammarano and Donnelly summarize (2009).

There is a **tradeoff between speed and coverage of Smart Metering diffusion and the expected consumer acceptance**. A Push-strategy-shift in Germany, the Netherlands or the United Kingdom might lead to a reduction in consumer acceptance and jeopardizes the Smart Metering success in the
long-term. “[...] attracting and motivating large numbers of consumers” is critical as the United States Department of Energy (2009, p. 15) explains.

1.2 Working Paper objectives

The first objective of this Working Paper is the construction of a multi agent-based simulation (MABS) that allows a reproduction of the German Smart Metering market. As former publications of the Energy Policy Research Group (EPRG) show, such models are able to handle the complexity to simulate the adoption of Smart Meters (Zhang & Nuttall, 2008). In contrast to other MABS models, a decision tree and a scoring model are the fundament to calculate Smart Meter demand. The decision tree maps the traditional theoretical five-step consumer purchase decision making model. As results will show, each of the five steps is crucial with respect to customer demand, as major gaps can be identified already in the awareness and information search stages.

Furthermore, MABS allow scenario-based evaluations of Government policies to promote Smart Metering adoption (Zhang & Nuttall, 2008). Since the German regulator Bundesnetzagentur and its president Matthias Kurth (2009, p. 13) publicly remark possible intervention tendencies, the second objective is an evaluation of intervention scenarios.

Possible behaviours of utility companies are rarely considered in Germany, the Netherlands and the United Kingdom. Most studies concentrate on demand-side effects. In addition, the majority of studies reduce the impact of competition to pricing decisions. Product management and promotion tactics are static. The third objective is to simulate and inspect corresponding actions especially from Distribution Network Operator (DNO) companies. High Smart Metering penetration rates will show proactive rollout strategies, because it is not cost-effective to run different metering methods in parallel. If a critical level of diffusion is reached, DNOs will spark off initiatives to phase-out old Ferraris meters. This turning point affects several steps of the decision tree. To stick to the Pull-strategy, fourth objective is to find effective policy strategies that lead to this turning point through customer demand. Possible options might be buying-bonuses comparable to international car scrappage schemes.

1.3 Structure
The Working Paper starts with a Literature Review that focuses primarily on a review of available MABS research that relates directly to Smart Metering or consumer purchase decision making. Section 3 explains the construction of the MABS model from a structural perspective, while the practical implementation in NetLogo follows in section 4. The same section covers calculations including different policy scenarios. The Paper ends with a conclusion and a discussion of implications for future research.
2 Literature Review

2.1 Agent-based models in brief

For more than 20 years, social scientists, economists and researchers from other disciplines make use of agent-based simulations to build virtual markets and communities (Heath, Hill, & Ciarallo, 2009, p. 5). Suitable models are often used to reconstruct complex situations and systems when a huge number of variables and determinants affect each other (Galán et al., 2009, p. 3). The target system is being modelled in a virtual environment and what-if scenarios are simulated in numerous iterations. Impacts on the virtual system can be tracked via performance indicators. Finally, researchers map the results against the real world and try to generalize their findings (Edmonds, 2001, pp. 17–18).

2.2 Application of MABS to calculate the consumer demand for Smart Meters

Smart Metering is a very young technology which is unknown to a significant proportion of people. Market penetration depends on various factors that can hardly be prospected. Even market researchers contain themselves to communicate diffusion figures – especially in the three countries without federal sponsorship. MABS can handle complex and interdependent systems and therefore give the opportunity to tackle the question of Smart Metering adoption. Zhang and Nuttall (2007) from the Cambridge-based EPRG used a simple model to simulate consumer demand: Based upon the ‘Theory of planned Behaviour’ (TpB), households frequently receive interactions which spark off an intention to buy a Smart Meter. Price and price sensibility influence the purchase decision as well:

\[ I_i^a = \sum_{j=1}^{n} (W_{ij} \cdot Inj_j^a) - W_{ip} \cdot (P_E^a + P_S^a) \]

The formula calculates agent i’s intention to buy option a. The determining factors are frequent interactions with other agents (j...n) multiplied with the specific influence Wj of each other agent. The sum of the interaction-part is reduced by price aspects. Agent i’s price sensibility Wp is multiplied by the price of option a. Each option consists of a price for energy PE and a price for the meter PS.

An important assumption of Zhang and Nuttall’s work is the importance of price and price sensibility. Quality aspects are ignored. As a matter of fact, there might be huge differences in quality between Smart Meter offerings. For example, one supplier could offer in-home-displays for real-time control of
energy consumption while another supplier gives just a more detailed bill with some charts, comparisons and general tips on a monthly basis. Empirical evidences show the importance of product differentiation as an influencing factor: Many customers prefer their PC to track the consumption, some customers prefer in-home-displays, some prefer other ways e.g. applications for Apple´s iPhone (Donath, 2009, p. 46). The TpB-model considers accordant background factors which influence the personal beliefs (see figure 1).

Figure 1: The TpB-model (Ajzen, 1991, p. 181)

Zhang and Nuttall incorporated four scenarios to prove the importance of a random lead-user-selection and the impact of competitive pricing. The results should have helped regulatory decision makers in the arrangement of a policy framework that allows lead-user-selection and pricing under open market conditions.

Zhang and Nuttall (2008) continued their MABS research on Smart Metering adoption in a second EPRG Working Paper in 2008. It based upon the TpB-model as well, but with an extension for perceived behavioural control (Zhang & Nuttall, 2008, p. 9). Concrete policy scenarios have been simulated and evaluated. Policy options were released by the Department for Business, Enterprise and Regulatory Reform (BERR) since the UK Government understood Smart Metering as an important technology already in 2007. With regards to requirements from the EU Energy Services Directive, the four scenarios incorporated the rollout of free in-home-displays under different market conditions (see figure 2).
Zhang and Nuttall’s simulation results show a significant impact of federal grants. Adoption was fastest under subsidized conditions with advantages in an open market situation. A competitive model where electricity suppliers finance the visual displays resulted in the longest rollout period (Zhang & Nuttall, 2008, pp. 18–19).

Most important for the MABS application to simulate Smart Metering and as a validation of the model, both EPRG publications presented typical curves and characteristics for technology adoption. An ‘S-curve’ in terms of market share and a ‘Lock-In’ effect in terms of switching behaviour of households.
3 The Model

3.1 Objectives, requirements and the decision-tree approach

Objective is to construct a holistic and demand-oriented MABS model, which is capable to rebuild German market conditions and policies. In this case, holistic and demand-oriented means to address all aspects of the consumer purchase decision making process. Figure 3 visualizes the five major steps of this process:

![Chart showing the five steps in the consumer decision making process: Problem recognition, Information Search, Evaluation of Alternatives, Purchase Decision, Post purchase behaviour.](image)

Figure 3: Five steps in the consumer decision making process (Engel, Blackwell, & Miniard, 1995)

In contrast to the *EPRG*-models, demand simulation should be based upon a combined decision tree and scoring approach. This methodical switch enables a more detailed monitoring of the five individual decision steps. With respect on German market conditions, a lesser focus on the purchase decision itself and a stronger focus on problem recognition and information search allows better considerations of demand-side barriers.

3.2 Construction of the MABS model

3.2.1 Step 1: Problem recognition

End-user surveys exhibit huge barriers in problem recognition, because the technology is widely unknown (Donath, 2009, p. 5). Low-involvement for energy tariffs and metering products reduce the awareness-level of consumers to a minimum. While the *EPRG*-model bases definitely on interactions with other agents, these interactions virtually do not exist in Germany under current circumstances. Suppliers do not actively promote Smart Meters and therefore no rise in awareness is foreseeable. In addition, the *EPRG*-model assumes an existing foundation of households with intelligent meters installed who start interactions. Since there is virtually no Smart Metering-penetration yet, adequate interactions cannot spark-off the purchase intention in Germany. On the other hand, a significant media interest in the new technology can be observed. An increasing amount of news articles (see figure 4) and television reports make it necessary to introduce the media as a third agent in the MABS.
The problem recognition decision tree starts with the question, whether a Smart Meter is already installed in the household or not. In case that an intelligent meter exists, the asked agent is passed into the post purchase behaviour step 5. In case that the consumer still has a conventional meter installed, three possible interactions might increase the awareness-level: Interactions with other consumer agents, interactions with suppliers and media-interactions. The agent advances to step 2 if the concluding level of awareness reaches a necessary limit. Depending on the type of interaction(s) the consumer received, there might be a brand awareness (consumer and/or supplier interaction) or not (only media interaction). Figure 5 visualizes the decision tree for step 1:

### 3.2.2 Step 2: Information Search

The next barrier follows immediately: Granted that awareness is given, potential buyers can hardly search information about Smart Metering offerings. Although DNOs are legally forced to offer intelligent meters in their ruled areas, a first-hand analysis of DNO websites resulted in frustration: From a sample including the 30 largest German cities, in 25 cases the DNO gives no information about Smart Metering. Obviously, DNOs still do not try to market attractive customer products but focus on their pilot projects. The German regulator Bundesnetzagentur summarizes this opposing position as a deny-delay-degrade attitude (Kurth, 2009, p. 11). DNOs might blockade consumer demand for Smart Me-
tering by just not giving any information to potential buyers. Even Yello Strom, who was the only supra-regional Smart Metering supplier between 2008 and 2010, never specifically promoted its offering. Finally, in the retail market for energy tariffs information portals represent an easy way to compare tariffs and calculate potential savings. Portals like verivox.de have been established themselves as a huge driver for consumers to switch their supplier or tariff. Comparable portals or search engines do not yet exist for Smart Metering offers.

Two possible starting points for the information search exist (see figure 6). If awareness-relevant interactions from step 1 included a specific brand and the supplier of this brand promotes it, the specific brand is surely included in the evaluation of alternatives. Other brands are only considered in case of successful information search processes, which in turn are determined by the intensity of promotion activity of each supplier.

Figure 7 shows an assumption of promotion and promotion intensity in dependence of the geographic focus. Generally, a huge number of small and regional suppliers dominate the DNO landscape in Germany. Due to high investments (especially IT infrastructure) in relation to their relatively low number of customers, these municipal utilities will not promote Smart Metering offers. Market researchers expect that these suppliers will cooperate with other regional utilities to reach a critical customer mass or contract a specialized metering provider to outsource AMI processes (Gnilka & Meyer-Spasche, 2009, pp. 6–8).
Strong promotion can be expected from larger DNOs. They can benefit from economies of scale and therefore may tend to engage a regional Push-strategy. Rheinenergie, a large-scale municipal utility in the area of Cologne is a good example for this kind of rollout strategy. Rheinenergie frequently communicates the intention to promote Smart Meters and positions itself as an innovation leader. Retailers represent the third group. Basically, promotion is more important for retailers in comparison to DNOs, but wastage effects occur in supra-regional campaigns. In addition, consumers are less sensitive to retailer-marketing compared to marketing activities of their local supplier. Yello Strom´s Smart Metering offering SparzählerOnline is a good example for a product which is promoted nationwide but with low intensity. Promotion intensity is low, passive marketing through website presentation dominates the marketing strategy. Consumer attention is mostly triggered by media coverage.

3.2.3 Step 3: Evaluation of alternatives

The asked agent finished his information search on Smart Metering offerings and is now going to compare. One assumption of the model is that the current offering of conventional metering is always positioned as one alternative. Table 1 visualizes qualitative product differentiation opportunities for suppliers and different models in terms of pricing.¹ Let´s assume the following shortlist of four alternatives and represent the evoked set of the agent:

### Table 1: Qualitative product differentiation opportunities for suppliers and different models in terms of pricing

<table>
<thead>
<tr>
<th>Alt.</th>
<th>Supplier / Brand</th>
<th>Smart Meter?</th>
<th>Product specifications</th>
<th>Price and contract documents</th>
<th>Promotion intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Local DNO Brand a</td>
<td>Conventional Ferraris meter (do-nothing scenario)</td>
<td>No additional costs</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>A2</td>
<td>Local DNO Brand b</td>
<td>X</td>
<td>Smart Meter with high technical specifications (update potential for Home Automation processes)</td>
<td>Additional monthly fees: 20€ No-cost installation Unlimited duration of contract</td>
<td>Very low, but known from an interaction with a</td>
</tr>
</tbody>
</table>

¹ To reduce complexity and focus on metering, table 1 ignores different kWh prices and payment conditions (e.g. switching bonuses or prepayments).
In contrast to the *EPRG*-model, amount and influence of interactions are relevant only in step 1 and do not affect the evaluation of alternatives. Once an offer attains the evoked set of an agent, it is comprised in the evaluation. Since each consumer in the real-world features an individual socio-demographic background which significantly determines purchase decisions, it is necessary to reconstruct this diversity in our model-environment. *Ajzen* distinguishes between individual, social and informational factors in his *TpB*-model (see figure 1). *Zhang and Zhang* (2007, p. 916) transferred these factors into a simple and structured cause-and-effect picture to incorporate socio-demographic factors into the purchase decision processes in MABS environments (see figure 8).

![Figure 8: Socio-demographic attributes and the decision process (Zhang & Zhang, 2007, p. 916)](image)

The scoring of brands in the MABS model is reduced to the **four** most important factors (see figure 9):

Money in terms of **product price** and **monetary savings potential** has a significant impact on con-
sumer purchase decision (Thiemann, Passenberg, & Suer, 2007, p. 6). The reasons are low-involvement and little qualitative differentiation aspects in the field of energy related products. Many customers reduce their decision whether to switch or not to switch the tariff and/or supplier to a simple monetary benefit-cost-comparison. With respect to Smart Metering offerings, benefits denote potential savings through reduction of consumption multiplied with the kWh-price. Costs consist of one-time installation costs and additional monthly costs for the AMI.

The benefit-cost-comparison is picked up again during the purchase decision in step 4. The scoring in step 3 separates benefits and costs in order to allow different weightings and determining factors from a socio-demographic perspective: With respect to the scoring of the product price, the individual’s price sensitivity is an influencing factor that depends on the individual’s income. On the other hand, savings potential is broadly determined by the consumer’s energy consumption which vice versa depends on the housing status (de Cannière et al., 2009, p. 104).

Two other factors need to be considered in the MABS model: Brand loyalty is a trigger which affects the behaviour of consumers. Frequent surveys about switching rates of households for energy tariffs show that twice as much new contracts are closed with the current supplier (Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW), 2010, p. 4). In terms of TWh in energy supply, a significant 88% share or 116TWh were delivered by the local DNO in 2008 (de Cannière et al., 2009, p. 103). Low competition and/or missing diversity regarding the supplier landscape should not be the reason: In about 550 out of 660 distribution network areas, more than 20 suppliers compete for market shares.
Moreover, in about 35 (populous) areas, the number of competitors exceeds 100 (de Cannière et al., 2009, p. 106).

Representing the fourth and last factor and in contrast to the EPRG-model, quality sensitivity and qualitative product differentiation should be considered. Basically and with a view on the demand-side, Smart Meters fulfil different needs and expectations that delight customers. Control functions and cost savings dominate needs and expectations. Some people prefer monthly bills while others prefer their mobile phone for cost control (Donath, 2009, pp. 38 and 46). Many suppliers tailor their products to particular needs. Taking their competitive advantages and strategic market position into account, Retailers tend to focus on a cheap price without any options or value added services while municipal utilities yield their regional focus and service workforce. Since qualitative aspects are hard to compare, the introduction of a quality index (0 ... 100) enables the consideration of qualitative differentiation. Examples: Picking up the four alternatives from table 1, the index of A1 is 30. Conventional meters do not fulfil the need for real-time control. A tracking of the load curve is not possible. Anyway, the Local DNO provides a superior service. The index for A2 is 90 (superior service) and for A3 is 70 (average service). Both provide in-home-displays and load curves are possible, e.g. for browser based monitoring in the home area network. A4’s index is 50, as the real-time display on the meter provides only little information compared to in-home-displays. Meter reading is less convenient and service agreements just match the industry average. Following the implementation in the MABS of Zhang and Zhang (2007, pp. 916–917), quality sensitivity depends on income. The higher the income, the more sensitive is the customer to quality. Finally, the evaluation of alternatives results in the selection of the best scored product for the agent (see figure 10). The process ends if the best alternative is the agent’s current tariff (conventional meter). If at least one Smart Metering offer scores better than the current tariff, this product proceeds to the purchase decision point in step 4.
Here are two extreme examples – objective is to show the need for additional criteria next to pricing because of diversity in socio-demographic backgrounds:

1. Two-person-household; Couple without kids (so called DINKS – Double Income No Kids); Both working during the day and therefore consume just about 2,500 kWh per year; Energy costs per year: 500€ + 120€ base fee

2. Six-person-household; Employee, homemaker plus four underage kids; High energy consumption with 6,000 kWh per year; Energy costs per year: 1,200€ + 120€ base fee

The first household with double income will be less price sensitive and more quality sensitive than the second one. For sure, the savings potential of the second household is immense compared to the potential of the first one. Picking up the shortlist of alternatives from table 1, the four products differentiate themselves clearly in pricing: Assuming a two-year calculation, A2 is the most expensive choice with 480€ additional costs. A3 follows with 290€ (2 x 12 months x 10€ + 50€) and A4 with 220€. The cheapest choice would be A1 without additional costs. Although the second household is highly price sensitive and low in quality sensitivity, it might choose one of the Smart Meter offerings (A2, A3 or A4) because of the salient savings potential. The opposite way around, the first household might stick with A1. Although additional costs for a Smart Meter offering are of none or little relevance and although quality sensitivity is high, little savings potential and high brand loyalty could keep the first household from a switch.

3.2.4 Step 4: Purchase decision

As mentioned before, a clear distinction between the consumer purchase decision steps is one advantage of the decision tree model: The scoring and selection of the best alternative for each agent is cal-
culated in step 3. Only this specific (Smart Metering) alternative proceeds into the process of step 4. Let’s assume one Smart Meter offering brings savings potential and excels all other brands in qualitative specifications. In step 4, everything comes down to the agent’s decision to switch to this Smart Meter offering or to stick with the old contract. Real-world observations verify that consumers do not switch their tariffs anyhow, even if benefits overreach costs (de Cannière et al., 2009, pp. 103–106).

**Switching costs** represent an important factor. A consumer survey with focus on reasons not to switch from one energy supplier to another indicated that 46% do not switch just because of comfort reasons (Thiemann et al., 2007, p. 7). The force of habit and laziness are influencing factors that should be considered, especially with respect to the higher complexity of a Smart Meter installation compared to the relatively simple switch of an energy tariff. Every shift from one tariff to another brings a risk to the status quo. The result is a Lock-In effect. A situation in which another tariff or vendor promises a higher perceived value to the potential buyer, but he does not perform a switch. The *EPRG*-model already incorporated this effect (Zhang & Nuttall, 2007, pp. 25–26). Famous examples of products which use the Lock-In effect are computer software (e. g. *Microsoft*: Windows ⊛ Office), razor-blades, printers, video game consoles and coffee pod systems. Switching from one vendor to another is associated with high barriers. The impact of barriers on switching rates in the electricity sector is significant: 50% of surveyed end-users claimed, they would switch their tariff if they can save at least 10€ per month (Thiemann et al., 2007, p. 11). An impressive majority of 80% claimed they would switch if they can save 20€ per month or 240€ a year. For an average household with 3.500kWh in consumption, realistic savings are quantifiable between 150€ and 300€ only through vendor shifts (de Cannière et al., 2009, pp. 118–119). Nevertheless, in 2008 only 4.8% of residential customers switched their supplier (de Cannière et al., 2009, p. 104).

Figure 11 visualizes the basic principle of the consumer purchase decision step. Actually, it consists of just one node which calculates the switch/no-switch decision. The scoring result of the Smart Metering offering is subtracted by the scoring result of the current tariff. The higher the difference, the higher is the probability to switch to the Smart Metering offering. An S-Curve shape is assumed for the relationship between score-margin and switching-probability, which was not only observed during former *EPRG*-simulations (Zhang & Nuttall, 2007, p. 25), but matches also the results of a specific end-user survey (Thiemann et al., 2007, p. 11).
3.2.5 Step 5: Post purchase behaviour

The last step initiates interactions with other agents. Two types of interactions are performed by the proud owner of an intelligent meter: Random interactions with other consumers and ‘Small-World’-interactions with neighbours (see figure 12). Both interactions represent word-of-mouth advertising for the Smart Metering technology (including a brand, see figures 5 and 6). The MABS model assumes a reduction in word-of-mouth activity from period to period until a specific threshold is reached.
4 Simulation results

4.1 Scenario 1 – open market situation with fixed pricing and without policies

The MABS model was implemented in NetLogo 4.1. Table 2 summarizes several parameter configurations used in the five decision tree steps for scenario 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameter</th>
<th>Scale</th>
<th>Distribution</th>
<th>Additional information</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Number of patches</td>
<td>3.721</td>
<td>Fix</td>
<td>World: 61 x 61</td>
</tr>
<tr>
<td></td>
<td>Number of consumer agents</td>
<td>2.000</td>
<td>Random pxcor pxcor</td>
<td>Population density = 53.7%</td>
</tr>
<tr>
<td></td>
<td>Number of supplier agents</td>
<td>3</td>
<td>Fix</td>
<td>Number of brands: 4 (supplier A is the local DNO and provides a smart meter and the conventional tariff)</td>
</tr>
<tr>
<td></td>
<td>Number of media agents</td>
<td>1</td>
<td>Fix</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Necessary Awareness</td>
<td>0 ... 100</td>
<td>Fix</td>
<td>Initially set 0</td>
</tr>
<tr>
<td></td>
<td>Awareness impact of interaction</td>
<td>0 ... 100</td>
<td>Fix</td>
<td>To proceed to Information Search</td>
</tr>
<tr>
<td></td>
<td>Random consumer interactions</td>
<td>5</td>
<td>Fix</td>
<td>Between ‘smart’ households and any households</td>
</tr>
<tr>
<td></td>
<td>Neighbour consumer interactions</td>
<td>1</td>
<td>Fix</td>
<td>Between ‘smart’ households and any households</td>
</tr>
<tr>
<td></td>
<td>Random supplier interactions</td>
<td>15</td>
<td>Fix</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Random media interactions</td>
<td>20</td>
<td>Fix</td>
<td></td>
</tr>
<tr>
<td>Step 1: Awareness</td>
<td>Promotion intensity</td>
<td>0 ... 100</td>
<td>Fix</td>
<td>Supplier A: 30 (brand a) Supplier B: 60 Supplier C: 90</td>
</tr>
<tr>
<td>Step 2: Information Search</td>
<td>Price sensitivity</td>
<td>-100 ... 0</td>
<td>Random normal distribution, $\mu = -60$ and $\sigma = 15$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Savings potential</td>
<td>0 ... 100</td>
<td>Random normal distribution, $\mu = 35$ and $\sigma = 25$</td>
<td></td>
</tr>
<tr>
<td>Step 3: Evaluation of Alternatives</td>
<td>Quality sensitivity</td>
<td>0 ... 100</td>
<td>Random normal distribution, $\mu = 60$ and $\sigma = 15$</td>
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</tr>
<tr>
<td></td>
<td>Brand Loyalty</td>
<td>0 ... 100</td>
<td>Random normal distribution, $\mu = 50$ and $\sigma = 10$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weighting of each of the four influencing factors</td>
<td>25%</td>
<td>Fix</td>
<td>The four factors have the same weighting</td>
</tr>
</tbody>
</table>

Table 2: Parameter configurations in NetLogo 4.1

Scenario 1 simulates German market conditions without any regulatory policies. Since the market is liberalized, we assume 3 competitors and 4 products. Supplier A is the Local DNO who offers \textit{brand a} (Smart Meter) and \textit{brand b} (conventional meter). Real-market situations show a comparatively high pricing with high qualitative characteristics for \textit{brand a}-offerings. In contrast, promotion intensity is at
most low. The two other Suppliers B and C represent competitors, e. g. other DNOs or Retailers. Due to an open market situation, they adapt their market mix to deliver a product which is – from a customer point of view – at least as attractive as the current tariff (brand b). Table 3 compares the marketing mix of each alternative.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scale</th>
<th>Supplier A</th>
<th>Supplier B</th>
<th>Supplier C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Brand a</td>
<td>Brand b</td>
<td>Brand c</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Smart Metering by Local DNO</td>
<td>Conventional tariff by Local DNO</td>
<td>Smart Metering by supra-regional DNO</td>
</tr>
<tr>
<td>Price index</td>
<td>0 ... 100</td>
<td>100</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Quality index</td>
<td>0 ... 100</td>
<td>60</td>
<td>20</td>
<td>60</td>
</tr>
<tr>
<td>Loyalty index</td>
<td>0 ... 100</td>
<td>60</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Savings potential index</td>
<td>0 ... 100</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 3: Marketing mix for scenario 1 (open market situation)

The loyalty index assumes a significant loyalty for the current tariff (100). Furthermore, the Smart Metering tariff of this Local DNO incorporates high customer loyalty as well, since twice as many households tend to switch to another tariff of their current supplier and are sceptical with regards to other suppliers. To reduce complexity, the savings potential index for all Smart Metering offerings is fixed to 100 while the conventional tariff’s index is 0.

The following chart visualizes a fictive initial visualization before the first period. In other words, we assume that the awareness level of all households exceeds the necessary level and all have successfully passed the information search. The x-axis plots the 2.000 agents, while the y-axis plots the initial evaluation. Because of the four brands, each agent owns four points. Obviously, the evaluation of brand b differs only between 4.000 and 8.000 which is related to the neutrality to price sensitivity (no additional costs) and savings potential (no change of status quo). In contrast, brands a, c and d show a
significant spread between -3.000 and 13.000. Another evaluation result which can already be recorded is the low attractiveness of brand a. Most of the red dots are not only at the bottom of the spread, but also in most cases beneath the dots of the three other brands.

The simulation results show a relatively stable development with low volatility. Awareness is steadily increasing with an S-Curve-shape. The close relation between awareness and information search is self-evident. Different courses for brand a, c and d are basically caused by different promotion intensities. In this scenario, we assume that the Retailer promotes with most intensity while the Local DNO’s motivation to dispose a Smart Meter offering is low. Brand b is always included into the evoked set of the virtual agent (black line at the top of the chart).

![Figure 14: Simulation results for scenario 1 (Awareness > Information Search > Evaluation > Purchase Decision)](image)

Equal results can be recorded in the bottom-left figure as in figure 13. Both charts differ in two aspects: The course in figure 14 plots the mean evaluation for each brand. And the line-chart visualizes the progression over time. The decreasing volatility is caused by the increasing number of agents who include each brand in his evoked set. In other words: Due to fixed influencing factors and fixed prices (scenario 1), the evaluation is stable from tick 0 to tick 200. But e. g. during tick 50 a much smaller number of agents are aware of and informed about the brands compared to tick 200. Again, brand b is an exception, representing the conventional tariff. The very little variance between brands b, c and d reconstructs the liberalized market condition where all three suppliers compete. Although each sup-
plier uses his competitive advantage, the overall perceived attractiveness is almost equal. If Supplier A decides to force the diffusion of Smart Metering, a more attractive marketing mix would be necessary. The purchase decision results on the bottom-right in figure 14 shows the virtual Smart Metering adoption. The more customers get aware and informed, the higher is the demand for Smart Metering tariffs. Just a very small minority (ca. 40 households) decides to purchase brand a. This result not only matches perfectly current market conditions where the penetration of Smart Meters from Local DNOs is virtually non-existent. It also proves that even though pricing is very high and promotion is very low, there is still a percentage of households which are eager to buy brand a due to brand loyalty and quality sensitivity. Therefore Local DNO’s also need to provide the necessary AMI, even if the share of customers with monthly or more frequent billing processes is low.

After 200 ticks, the simulation results in an overall Smart Meter diffusion of 50%. Brand d conquers 28% in market share, Brand c follows with 20% and Brand a stumbles at 2%.

4.1.1 Scenario 2 – reconstruction of current policies

Two important deadlines characterize the policy landscape in Germany: On January 1st of 2010, in each new construction an intelligent meter needs to be installed. The same directive applies to each old building which is significantly refurbished (Bundesministerium für Wirtschaft und Technologie - BMWi 2007, Wulf, 2009, Wissner, 2009). Of course, the implementation of this directive is reasonable only if there is at least one Smart Metering provider in the ruled area. Accordingly, the second component of the policy is an obligation for the Local DNO to offer a Smart Metering tariff (effective January 1st 2010).

The second deadline is set on December 30th of 2010. Load-dependent tariffs have to be offered by the Local DNO. A more flexible pricing will lead to load shifts. From a customer’s point of view, savings potential increases in comparison to Smart Meter offerings without load-dependent pricing. Not only are the needs for transparency and control met by the extended offerings. In addition, households receive an effective enabler to save overall energy costs if they are eager to shift their consumption and avoid consumption during peak times.
To adopt the policies in a step by step manner, the directive which is effective on January 1st 2010 is incorporated into the model. A trigger galvanizes into action, if the simulation passes tick 20. The trigger forces 1 agent to purchase brand a and to move to another patch. The move simulates not only a new construction on a random patch but also the demolition of an old house. Therefore the population density remains the same. Figure 15 exhibits the policy-impact effective January 1st 2010.

![Figure 15: Simulation results for scenario 2 (only one policy aspect incorporated)](image)

A strong impact on awareness emerges with the policy. Due to interactions with other consumers in a random and small-world context, a significant amount of households get aware of Smart Metering. In scenario 1 the complete timeframe of 200 ticks was necessary to reach a 100% awareness-penetration. Interactions boost the awareness significantly and all households are aware of the technology until tick 80. Clearly, the affects result mainly from the strong impact (100) of consumer interactions in comparison to media (25) and supplier (50) interactions. An end-to-end analysis of the policy impact stresses the importance of further interventions, since the impact on the overall diffusion is minimal.

Although all brands quickly appear in the evoked set of the agents, identical product scorings lead to same results. Obviously, the quicker descent in brand b purchase decisions leads to a faster penetration of the technology. But the final shares in tick 200 differ only marginal from the figures in scenario 1: Brand a reaches 9%, Brand b arrives at 47%, Brand c and d stabilize at 18% and 26%.
With respect to Zhang and Nuttall’s initial EPRG-model from 2007, the effect of the policy is similar to Zhang and Nuttall’s assumption of a 10% Smart Metering distribution at the start of their simulation. In addition, same results can be observed and validate the model.

The second policy is implemented with major changes in the marketing mix (see table 4). Load-dependent tariffs are introduced by supplier A and B while Retailer C still focuses on a cheap price without bells and whistles. Passing tick 30, an increased savings potential sparks-off new competition. Higher perceived attractiveness of brand c forces suppliers A and C to increase the attractiveness of their advertised offerings. A rises the scoring by an increase of the quality index, e. g. offering value added services or an eco-label. C boosts the score through competitive pricing.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scale</th>
<th>Supplier A</th>
<th>Supplier B</th>
<th>Supplier C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Brand a Smart Metering by Local DNO</td>
<td>Brand b Conventional tariff by Local DNO</td>
<td>Brand c Smart Metering by supra-regional DNO</td>
</tr>
<tr>
<td>Price index</td>
<td>0 ... 100</td>
<td>100</td>
<td>0</td>
<td>40</td>
</tr>
<tr>
<td>Quality index</td>
<td>0 ... 100</td>
<td>60</td>
<td>30 (+10)</td>
<td>60</td>
</tr>
<tr>
<td>Loyalty index</td>
<td>0 ... 100</td>
<td>60</td>
<td>100</td>
<td>30</td>
</tr>
<tr>
<td>Savings potential index</td>
<td>0 ... 100</td>
<td>140 (+40)</td>
<td>0</td>
<td>120 (+20)</td>
</tr>
</tbody>
</table>

Table 4: Impact of the second policy on the marketing mix

Simulation results display a strong short-term effect and virtually no effect in the long-run. The product launch during tick 30 induces a rise especially in the demand for brand c. The effect on brand a is tiny, although the increase in savings potential remarks the strongest rise in evaluation score (see figure 16). Gains in market share for brand c comes primarily from brand d, which seems to be a direct substitute for consumers.
In conclusion, the current regulatory policies for the German markets have a positive effect on the diffusion of the Smart Metering technology. The first policy component tackles the missing awareness effectively. An acceleration of awareness and diffusion in 2010 can be expected. The second policy might lead to an introduction of innovative products which could become an important enabler for market competition. On the other hand, this competition might be potentially reduced to open market players that act nationwide with only little effect on the incumbent DNO.

4.1.2 Scenario 3: Ferraris Meter scrappage bonus

In contrast to the British regulator Ofgem and the Department for Energy and Climate Change, the German institutions are very passive. While their British counterpart tried to identify optimal policy options through several consultation phases during the last two years, the German regulator Bundesnetzagentur sticks to its liberalized market approach without giving any impulses. Matthias Kurth, who is the president of Bundesnetzagentur, mentioned an interesting policy option in 2009. The German Cash-for-Clunkers program was extremely successful as an impulse on the demand CO2-emission-friendly cars (Höpfner, Hanusch, & Lambrecht, 2009, Kurth 2009, p. 13) spoke about a similar program to generate demand for the Smart Metering technology. Scenario 3 will pick this idea up and simulates a simple but effective way to introduce a scrappage scheme to phase out the old Ferraris Metering technology.

Keeping in mind the existing gaps from scenario 1 and 2, a quick review of the idea draws a promising picture of the scrappage bonus idea: Basically, a demand-side intervention through bonus payments will reduce price-sensitivity of customers (see figure 17). A significant impact on the switch from conventional tariffs to Smart Metering tariffs can be expected, because price disadvantages are compensated. Furthermore, as empirical evidences from the car scrappage scheme prove, Lock-In effects are drastically reduced. Consumers switched their car manufacturer much more likely as they did before. A fierce competition between the manufacturers and marketers emerged – brand loyalty seemed to be radically reduced in buying decision processes. Transferring the idea of a reduction in brand loyalty to the MABS model (see figure 17), enormous positive impacts on Smart Metering diffusion can be expected. As results from scenario 1 and 2 showed, switching barriers impacted the purchase
behaviour process significantly. If these barriers can be reduced, households will tend to switch to other suppliers and/or tariffs much earlier.

Even if we assume just a small monetary incentive for the scrappage scheme, a strong effect can be observed. Parameters are changed as follows: If the simulation passes tick 50, price sensitivity is reduced in 25 points while brand loyalty is also reduced by 25 points. Simulation results prove the initial review of the scrappage bonus impact. A major effect starts with tick 50, when all Smart Metering brands benefit from the bonus while the conventional tariff (brand b) loses a significant part of its perceived attractiveness (see figure 18). The comparatively expensive technology becomes affordable for a much greater share of households.

In the final state, the market share of brand b drops from 42% to 16%. All other brands conquer market shares in a relatively equal amount. A diffusion of 84% for the Smart Metering technol-

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2 Since price sensitivity is a negative figure, 25 points were added to the value of each agent.
ogy is reached after 200 ticks. In less than 100 ticks, the model passed the critical 80% mark which is part of the EU Directive.

As mentioned in the introduction, at a certain point it is improvident for the Local DNO to continue the conventional manual meter reading processes in parallel to the new advanced processes. Due to process, IT and organizational costs, the DNO will change its passive Pull-strategy to a proactive Push-approach in order to phase out the legacy processes and systems. Figure 19 visualizes the impact of such a strategic shift. Assuming that Supplier A reaches a significant market share, he increases promotion intensity of brand a and vice versa reduces the intensity for brand b. In this case the share for brand a reaches about 15% of the total market share. But more important, the gap between brand a and brand b disappears – in other words, the supplier processes as much AMI installations as conventional meters.

![Graphs showing the impact of a Push-strategy by Supplier A](image)

Figure 19: Impact of a Push-strategy by Supplier A
5 Conclusion

5.1 Initial objectives

Four objectives were initially defined at the beginning of this Working Paper. All four objectives could be picked up during the research process with the following results:

1. Following former research results and models of the EPRG, a similar MABS model with focus on the German market could be conceptually designed and programmed in NetLogo. Furthermore, the combined decision tree and scoring approach allowed root cause analysis and a detailed tracking of demand-side barriers.

2. In a second step, the current set of regulatory policies was incorporated and tested in the model. Results showed the need for action unless Smart Metering diffusion cannot reach a satisfying level with the current policy setup.

3. On the other hand, the open market approach of the German regulator could be confirmed. Even in an oligopoly market structure with only three suppliers, suppliers need to challenge their marketing mix on a frequent basis due to competition. Furthermore, a phase out of legacy metering infrastructure performed by the DNO could be simulated. The MABS model was able to visualize the importance of substitutes. Exchanges in market shares occur in realistic situations with shifts between substitutes in dependence of the households individual evoked set, socio-demographic background and personal motivation.

4. Finally, the effectiveness and efficiency of a scrappage scheme-type of purchasing bonus was proved. A corresponding regulatory intervention is suitable to address the critical demand-side barriers in terms of price and the Lock-In effect.

5.2 Findings

Simulation results confirmed the importance of an expansion of the MABS model with qualitative influencing factors. Open market situations with diversified suppliers lead to competition not only in pricing but also in qualitative product differentiation. E. g. the technical capabilities of the Smart Meter, real-time displays and value added services enable different competitive strategies. Potential to
differentiate and specialize is much higher in comparison to the retail market of common electricity tariffs.

The effect of Germany’s current regulatory policy will have an effect on the diffusion. Although the objective is a liberalized market with competition, simulation results show an increase in market share from 2% to 9% only for the DNO. This increase might reduce economic wealth since the DNO benefits from its Lock-In advantages and can possibly earn monopolistic extra profits. A strategy for new constructions and refurbishes of old buildings is necessary since these households are forced to install an intelligent meter without having open market conditions in their evaluation and selection of alternatives.

A scrappage bonus would significantly accelerate the diffusion on Smart Meters. The impact on incumbents was strong positive: Their premium price strategy does not result in a low market share. Contrariwise, premium margins are still possible even in competitive setups. Even better, the DNO has the power to decide the point of time when he likes to phase out the legacy technology.

Another chance comes with the scrappage scheme: Low price vendors with discount strategies might install low quality metering infrastructures. These meters fail to enable future requirements for Smart Grids and Home Automation. The scrappage scheme can be combined with specific terms for minimum requirements. Without matching these requirements, the bonus is not paid. This is equal to the several terms for the car scrapping scheme (age of the old car, must have been privately owned, age of new car, etc.)

Awareness and switching barriers could be observed as significant influencing factors during the purchase decision process. Tackling the switching barriers is a bold venture with long-term effects. Adequate strategies might include switching bonuses or other incentives. On the other hand, tackling the awareness gap might be an easy matter with great short-term effects. Forcing the DNOs to inform their customers about their Smart Metering offerings might be an effective and efficient option?
References


