How to regulate a market-driven rollout of smart meters? A multi-sided market perspective

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Abstract

Smart (electricity) meters are regarded as a crucial element to increase energy efficiency by better balancing energy supply and demand. Nevertheless, most countries so far have not seen a comprehensive smart meter rollout. A key economic obstacle to a market-driven rollout is the fragmentation of benefits among multiple stakeholders, which disperses investment incentives. In this article we investigate how to best overcome this investment barrier by analyzing three distinct smart meter market structures. A key parameter for the analysis is the recognition that the smart meter market is multi-sided, making it essential to consider its peculiar characteristics. Our qualitative analysis indicates that a combined smart meter and grid operator, with a regulatory setup that permits the socialization of smart meter investment costs among all electricity consumers, is best suited to implement a market-driven smart meter rollout.

Keywords: multi-sided markets; smart meter; regulation

JEL Classification Numbers: L5, L94.

1 Introduction

The security of the energy supply in industrialized and developing nations is regarded as a great challenge in the upcoming decades (IEA, 2010). The origin of this challenge lies in the emerging tension between growing energy demand and the need to reduce CO_2 emissions in order to keep the global climate stable. Key elements in the envisioned solution for a sustainable energy system are a strong improvement in energy efficiency and the deployment of distributed low-carbon energy generation. A technology often

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mentioned in this context is the smart grid—the intelligent electricity network. Smart grids help to better balance energy supply and demand and to increase operating efficiency of the grid. One crucial component of such smart grids is smart meters, which are intended to replace the conventional Ferraris meters that measure the electricity consumption of residential and small commercial consumers.[1]

Although there is general consensus on the contribution of smart meters to higher energy efficiency and to the integration of renewables, a comprehensive smart meter rollout has so far been conducted in only two countries—Italy and Sweden. To accelerate its adoption, the European Parliament and the European Council target an 80% coverage for all EU member states by 2020 in their third energy package.[2] The EU directive, however, does not specify how this national rollout should be carried out. Member states can choose between a mandated or a market-driven approach. Countries such as Germany favor the market-driven approach, as they believe this will result in lower rollout costs and higher consumer cooperation, which is important to increase energy efficiency (Bundesnetzagentur, 2010). Far from being restricted to Europe the market-driven smart meter rollout is also relevant for many other nations, such as the USA or China, where no state directives are yet in place.

One of the key economic obstacles to a market-driven smart meter rollout is the split of benefits among all stakeholders.[3] According to McKinsey (2010) "fragmentation across the value chain has reduced the incentive for any single player to invest in smart meter[s]." The complexity is further increased through the characteristics of the electricity market. As Hogan (2001) noted, "electricity systems present complicated challenges for public policy [...] in providing a balance between regulation and markets, public investment and private risk taking, coordination and competition." For instance, providing the grid infrastructure is a textbook example of a natural monopoly due to the high fixed costs. Consequently, some form of regulatory intervention is required even for a market-driven rollout. In this paper, we highlight an additional complication since we identify the operation of smart meters as a multi-sided market.

Taking into consideration the key insights from the multi-sided market literature, the focus of this paper is to systematically analyze how to best regulate the smart meter market to overcome the investment barrier to a market-driven rollout.[4] Therefore, the goal of this paper is threefold. First, we demonstrate that the smart meter market is a multi-sided market. Second, we apply the lessons learnt from multi-sided market economics to the smart meter market. Third, we identify the superior market structure and the best regulatory design of this market structure to overcome the investment barrier. As the paper assesses potential smart meter market structures in general, the insights are, however, not limited only to the

[1] Throughout the document we refer to electricity meters when using the term smart meter. We are, however, aware that some types of smart meters can also measure natural gas and water consumption.

[2] The 80% target can either refer to the entire set of consumers, or, in case an economic assessment was conducted, to the sub-set of consumers for which an implementation was assessed positively (EU Directive 2009/72/EC).

[3] There are further obstacles such as stranded assets (replaced Ferraris meters before end of lifetime), no clearly defined technical standards or low consumer awareness of advantages of smart meters (European Smart Metering Alliance, 2009). These obstacles, however, can be regarded as preconditions for any type of smart meter rollout.

[4] To the best of our knowledge nobody has so far conducted a similar analysis. Baringa (2009) assessed different smart meter market structures but focused on a mandated rollout and the particularities of the UK market.

rollout but are also applicable to the general regulation of the smart meter market.

The rest of this paper is organized as follows. Section 2 starts with an introduction to the smart meter market and an analysis of costs and benefits of a rollout. Furthermore, it identifies why a market-driven rollout might be preferable to a mandated rollout. Afterwards, section 3 demonstrates that the smart meter market fulfills the requirements of a multi-sided market. Building on this, some implications for pricing are outlined. The actual analysis of the optimal regulation for a market-driven smart meter rollout begins in section 4 with an assessment of the possible market structures. Section 5 continues the analysis by identifying the best regulatory design option to yield the benefits of a market-driven smart meter rollout. Section 6 indicates possible regulatory modifications, and section 7 concludes.

2 Smart meter market

In this section we describe the smart meter market. The description starts with an introduction to the functionality of smart meters and continues with an overview of the relevant stakeholders and their interconnections. Then, we analyze the costs and benefits of the smart meter implementation for the different stakeholders and conclude with the advantages of a market-driven rollout.

2.1 Advanced meter infrastructure and stakeholder landscape

The core functionality—making a meter smart—is communication. In addition, electronic metering and data storage are basic functions that go beyond the capabilities of a conventional electricity meter. A common term for the entire set of relevant technical components and the comprehensive functionality of smart meters is Advanced Meter Infrastructure (AMI). Taking into consideration the definitions of the Federal Energy Regulatory Commission (2008) and Nabe et al. (2009b) we define AMI for our context as a system that meters and stores a consumer's electricity consumption and potentially other power quality parameters in short time intervals and communicates this information to a central data collection point from which it is also capable of receiving data. Beside the basic functions smart meters can have additional features such as detection of fraud, remote disconnect and connect functions, or load control to manage specific devices such as electric hot-water heaters and air conditioners (Bundesnetzagentur, 2010 and Department of Energy and Climate Change (DECC) and Office of Gas and Electricity Markets (OFGEM), 2011).

Building on its functionality AMI enables new applications. First, it allows for the introduction of variable tariffs.[5] In this way, electricity prices for consumers fluctuate depending on supply and demand and, thus, the market mechanism is implemented. Second, on a larger scale, it is envisioned as an essential

[5] There is a large variety of potential tariff structures. The two major categories are: Time-variable or load-variable tariffs. For a comprehensive overview on the topic of variable tariffs we point to Neenan et al. (2005) and Nabe et al. (2009a).

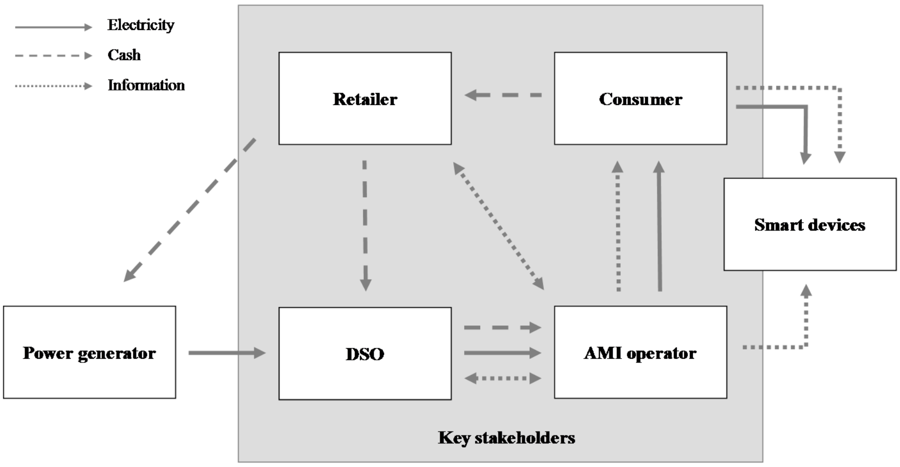


Fig. 1: Stakeholders of the smart meter market.

device for the future integration of distributed energy generation—mainly in the form of renewables—and energy storages (IEA, 2008).

The stakeholders relevant to a smart meter implementation correspond to stakeholders in the traditional electricity market. They are schematically depicted in Figure 1, which identifies six relevant stakeholders: four key stakeholders (retailer, distribution system operator (DSO), meter operator (labeled as AMI operator), and consumer) who are directly affected by a smart meter implementation and two that perform (essential) additional functions (power generator and smart devices). Note that for the description of the smart meter market we do not take into account ownership but simply focus on the functions performed. Supplementary, the figure shows three levels of interaction between the stakeholders.[6]

The first level is given by the physical delivery of electricity. Electricity is generated by a power generator and then transferred via the grid of the DSO[7] to the consumer. A meter controlled by a meter operator measures consumers' electricity consumption. As illustrated in the figure, a part of the consumption might be due to smart devices, whose functionality is described later.

Consumers do not interact with all stakeholders in the delivery chain. Instead, they simply buy electricity from a retailer, who coordinates this task for them.[8] The payment process indicated by the second level of interaction in the figure reflects the role of retailers. The consumer pays the retailer for all services she has used: her electricity consumption, access to the electric grid, and the metering service. Supposing a liberalized market, the retailer himself purchases the marketed electricity from a

[6] Note that we present a sample case and that the market setup varies from country to country. However, these alterations would not affect the main findings of our analysis.

[7] The transmission of electricity from the power generator to the DSO often also requires a transmission system operator (TSO), which covers the long distance transmission from the side of the power generation to the local DSO. However, the TSO is not relevant in the smart meter context.

[8] Consumers—for instance in Germany and the UK—may also have the option to contract an independent meter operator to measure electricity consumption.

power generator and passes the other fees on to the DSO. The DSO then keeps an amount for providing the infrastructure and passes on the metering fee to the meter operator.[9]

In addition to these two traditional levels of interaction in the electricity market, smart meters add a third level of communication among the different stakeholders. There is a two-way information flow between the smart meter and both the retailer and the DSO. In addition, consumers obtain information such as electricity consumption or billing rates through home displays or computer programs. Finally, the smart meter communicates with consumers' smart devices that can be turned on by the consumer but can also be managed remotely.

2.2 Costs and benefits

Several interested parties have tried to list and quantify the potential costs and benefits of a smart meter rollout. With respect to a monetary evaluation we focus on three studies, which provide estimates per installed meter on a yearly basis. Two of them were conducted for national agencies—Mott MacDonald (2007) for the British Department of Business, Enterprise and Regulatory Reform and Nabe et al. (2009b) for the German Federal Network Agency—, whereas the last by A.T. Kearney (2008) was written from a business perspective.[10] Additionally, we consider the qualitative descriptions of costs and benefits by Frontier Economics (2007). All values and descriptions following in this subsection have been taken from these sources. An important insight is that the variance and degree of uncertainty is higher for the benefits of smart meters than for the corresponding costs. This is particularly true for consumer benefits, which not only depend on existing consumption levels, but also on the degree of adaption in behavior. In contrast, the observed scope in rollout costs originates mainly from the variety in technologies available. We start the overview with a description of the benefits for the different stakeholders before looking at the cost side.

Apart from qualitative improvements such as fewer blackouts and no involvement in meter reading, consumers profit from a smart meter through (potentially) lower energy bills. One lever to lower the energy bill is the above-mentioned variable tariffs that encourage consumers to move their electricity usage to periods with lower prices. This consumption shift can actually be automatized with smart devices. Thus, even if overall consumption remains the same, electricity costs can be reduced by avoiding peak hours. Another lever is the visualization of energy consumption in order to reduce total consumption. Consumers are sensitized to their consumption patterns and can use the available information to identify electricity guzzlers. Moreover, because of accurate metering, consumers pay directly for their real

[9] In many countries, however, the DSO and meter operator are the same company, so no settlement takes place between them.

[10] Note that the quantitative assessment—in contrast to the generally applicable qualitative statements—is determined by distinctive regional characteristics (consumption patterns, climate etc.). The focus of the three selected studies is on Germany and the UK, so that the given values can be regarded as an illustrative example for a European nation with moderate climate.

consumption and are not billed based on (usually higher) estimates. All in all, these benefits per smart meter per year as calculated by the three mentioned sources vary substantially between €4.5 (Germany) and £5.5 (UK)[11] at the lower end and €34 (Germany) at the upper end, largely depending on the degree to which consumers (are able and willing to) adapt their behavior.

The benefits for retailers can be divided into two big groups: more efficient operation and closer customer relationship. A strong driver of efficient operation is the reduction of process costs. Smart meters allow for remote deactivation in case of a move and inter-period meter reading, reducing the organizational effort and staff required for these processes. Furthermore, they increase the quality of the consumption data. The better data quality reduces the workload and mistakes in the billing process, lowering the interaction with consumers in order to handle complaints. In addition, smart meters enable better encashment through constant monitoring, which diminishes the likelihood of bad debts. Finally, if consumers switch their consumption to periods with low prices as a result of variable tariffs, retailers can reduce the cost of procuring electricity.[12] In addition to the cost impact, variable tariffs also allow for a better customer relationship. Retailers can offer consumers new tariffs reflecting their individual consumption patterns, thereby taking into account their needs. Leveraging the increased availability of consumption data can also support relationship building. Retailers can bill more frequently and offer supplementary services such as energy consulting to consumers. All in all, retailer benefits are expected to be in the range of €4 in Germany and £8.1 in the UK.

The main benefit for the DSO addresses the quality dimension. Smart meters allow for a better and faster detection of outages. Furthermore, they monitor energy quality and consequently help to reduce voltage fluctuations. On top of the quality aspect, there are also minor reductions of process costs. The maximal grid load is lower, resulting in lesser line losses, potentially lower cost of the reserve energy, and a reduction of future grid investments. Since smart meters enable the detection of fraud, costs related to balancing supply and demand can also be reduced. Finally, assuming real load profiles, smart meters eliminate the need for consumption forecast planning and for estimates of energy consumption to determine grid usage fees. Overall, these benefits are estimated at about €2.5 in Germany and £1.5 in the UK.

The meter operator[13] profits in the form of reduced operating costs since the entire process of meter reading is streamlined. Only limited personnel are required. The planning of the reading process is facilitated as no appointments with consumers have to be arranged. The quality of data is increased, lowering the process costs as described above. The total savings from these process improvements are

[11] The value for the UK does not include savings from variable tariffs.

[12] The increased operating efficiency is first of all a benefit for retailers, but competition may force retailers to pass on a large portion of these benefits to consumers. In this case early-adopters among retailers only acquire a competitive edge whereas decreased electricity prices due to more efficient operation can be regarded as a consumer benefit.

[13] As outlined in section 2.1, the conventional Ferraris meter is either operated by the DSO or an independent meter operator, depending on the regulatory guidelines.

estimated to amount from €3.5-4 in Germany to £6.5 in the UK.[14]

All mentioned studies identify the same major cost elements: the smart meter costs (with respective communication modules), the installation costs and the operating costs. Furthermore, IT costs are named but not always specified. Our quantitative cost assessment, however, is based solely on Nabe et al. (2009b) as this is the only study that provides comparable annualized costs.[15] Contrary to the benefits, we also do not allocate smart meter costs to any specific stakeholder since, as we show in section 4, there are several potential owners depending on the chosen market structure. For smart meter investment and installation, annualized costs per meter are calculated in a range between €14-31. The variation arises because of the different types of meters (modular vs. integrated meters) and the communication technology used. For each smart meter type a minimum, maximum, and middle annualized cost is provided. The above range is taken from the middle values only, thus the overall cost range is even larger. Operating costs are not calculated explicitly in the study, but a factor of 25% of the annualized capital costs is assumed, yielding a corresponding range of operating costs between €3.5-7.8.

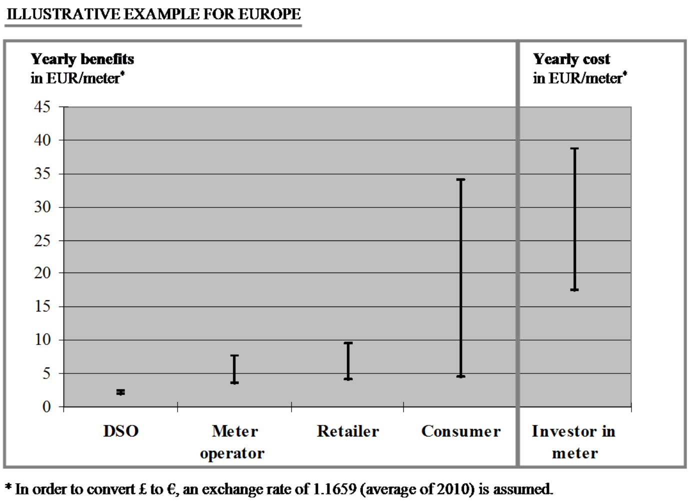


Fig. 2: Costs-benefits comparison for smart meter rollout.

Figure 2 depicts the ranges of costs and benefits of the smart meter rollout. The range of yearly benefits per meter are displayed separately for every stakeholder. This is contrasted with total yearly costs per meter in the right column. It can be seen that for most cases there are too few incentives for single stakeholders to invest in smart meters, even if it is beneficial overall—as indicated in the introduction.[16] How to address and overcome this investment barrier is a focus of the analyses in sections 4 and 5.[17]

[14] Note that the reading interval in the UK is 2 reads per year compared to 1 read in Germany. Thus, the savings potential per read is nearly identical.

[15] We avoid making assumptions about amortization periods and interest rates in order to annualize the cost of the two other studies.

[16] Counterexamples are given by Italy and Sweden. In Italy, a vertically integrated utility was able to capture all listed benefits plus savings from large reductions in electricity theft. In Sweden, the state simply decreed—for political reasons—monthly billing and thus artificially escalated process costs with conventional meters and implicitly enforced smart meters. For details see NERA Economic Consulting (2008) and Wissner (2009).

[17] A standard economic argument to solve such a situation with split benefits is the Coase theorem. However, in the

2.3 Arguments for a market-driven rollout

The comparison of costs and benefits in Figure 2 also shows that there is a wide bandwidth of potential costs and benefits, and for some consumers costs may exceed benefits. Thus, marginal costs would be larger than marginal benefits for some consumers even when taking into account network effects. If this is the case, a comprehensive rollout that forces every consumer to install a smart meter is not cost effective. This danger of inefficiently inflating the cost base is a strong argument for a market-driven rollout approach.

The second strong argument in favor of a market-driven smart meter rollout is based upon the fact that if every consumer has to make a conscious decision for the installation of a smart meter, the probability that consumers adapt their behavior increases. Specifically, as consumers' benefits can be heavily influenced through the degree of adaption. The Bundesnetzagentur (2010) and DECC and OFGEM (2011) underline in their reports that the education of consumers is a critical element to be addressed, since the simple installation of the smart meter does not make any major contribution to energy efficiency in itself. Only if consumers are aware of the potential and optimize their behavior, can the complete benefits of smart meters be locked in.

3 Advanced Meter Infrastructure as a multi-sided market

The focus of this section is on an applied review of the multi-sided market literature. This means we do not conduct the review as a discrete section, but, where possible, directly link the findings to the smart meter market described above. At first, we specify the defining properties of a multi-sided market. Additionally, we show that each of these properties applies to the smart meter market.[18] Then, we elaborate on the characteristics of a multi-sided market and their implications for the setting of prices.

3.1 Definition of multi-sided markets

There is no uniform definition of multi-sided markets in the literature. Rather, several requirements or properties are identified that define a multi-sided market. Consequently, we conduct our analysis of the multi-sidedness of the smart meter market along a set of defining properties.

The fundamental requirement for a multi-sided market is the provision of goods or services by a "platform" to at least two distinct groups of customers (compare among others Rochet & Tirole, 2003; Armstrong, 2006; Rochet & Tirole, 2006). These customers need each other in some way, but frequently the products, which the "platform" offers to the distinct customer groups, differ. The term platform is

case of smart meters the transaction cost would be extremely high due to the large number of involved agents. Taking the example of Germany there are over 30 million households, roughly 900 DSOs and hundreds of retailers in the competitive electricity market. Furthermore, the setup involves a risk of free-riding by different groups of stakeholders.

[18] Müller et al. (2010) identify the smart grid as a two-sided market, but to the best of our knowledge nobody so far identified the AMI as a multi-sided market.

not narrow, but leaves space for many types of businesses. Classical examples are night clubs or dating companies providing services to men and women; or credit cards enabling consumers possessing a card to pay with electronic cash, and merchants accepting them to get access to this consumer group. In the case of the smart meter market, retailers, consumers and DSOs are possible customer groups of the AMI platform. Furthermore, each of them receives a different service or good from the AMI. Retailers obtain prompt consumption data and can offer variable tariffs and reduce process costs. Consumers gain access to electricity and expect monetary and qualitative benefits. DSOs receive information on the stability and quality of the power distribution.

A further precondition of multi-sided markets (see among others Armstrong, 2006 and Rochet & Tirole, 2006) are indirect network effects. According to Evans (2009, p. 5) "indirect network effects exist when the value that a customer on one side realizes from the platform increases with the number of customers on the other side." In other words, the customer group on one market side exhibits positive externalities for the other market sides, and—as with all network effects—these positive externalities increase with the number of participants. These indirect network effects occur in the smart meter market. The more consumers join the AMI platform, the higher the value of platform access for retailers and DSOs. Retailers optimize their benefits from prompt consumption data the more, the higher the coverage of smart meters because of high upfront fixed costs to adjust internal processes. DSOs profit the more from information on stability and quality of the power distribution, the higher the coverage of data points. In case of an increased number of retailers, one can argue that consumers profit from the greater range of products (different tariffs matching their individual needs better) and the intensified competition, which leads to lower prices. Whether DSOs profit from an increased number of retailers, or the other market sides profit from an increased number of DSOs, seems unlikely.[19]

According to Evans (2009) and Hagiu (2009) another characteristic of multi-sided markets is the performance of at least one of three core functions to some degree. The first two reduce search costs. Here, the platform can either serve as matchmaker, facilitating the interaction when more than one market side is searching. Or by contrast, the platform may support building of audiences in case of single-sided search, thereby increasing the chances of an adequate match. In terms of the third core function, the platform potentially acts as a shared resource during the transaction, which reduces the cost of services for all market sides. Although many multi-sided platforms engage in all three functions to some degree, a focus on one function is not uncommon (Evans & Schmalensee, 2007). The AMI platform is mainly about operating as a shared resource. Its communication infrastructure is required by all market sides in order to exchange information. Consequently, a common platform reduces the cost of service for each market

[19] It is not necessary that all market sides exhibit indirect network effect in order to be classified as a multi-sided market. A classical example of two-sided markets frequently used in the literature are advertising-supported media such as newspapers or magazines. Here, advertisers value more readers, but readers may most likely not value more adverts. Compare Evans (2009) and Hagiu (2009).

side. Additionally, one could argue that the AMI engages in building audiences. The more consumers have access to the AMI platform, the more attractive the provision of variable tariffs for retailers becomes. With respect to matchmaking, the contribution of the AMI is rather limited.

Taking into consideration the three core functions above, a further typical property of multi-sided markets follows naturally. Evans & Schmalensee (2007) state that multi-sided platforms minimize transaction costs for the market sides, thereby permitting value-creating exchange. This statement is easily applicable to the smart meter market. Without the AMI platform, the constant exchange of information between stakeholders in the electricity market would not be economically feasible. The effort and time needed for all market sides would be too high. Only AMI enables frequent data exchange at reasonable prices. That this exchange is value-creating for all stakeholders is described in detail in section 2.2.

Summing up, we come to the conclusion that the AMI fulfills the criteria of a multi-sided market. It serves several market sides with different products. At least one market side exhibits indirect network effects. Additionally, the AMI platform performs the core function of a shared resource, thereby reducing transaction costs for all market sides. Thus, it enables a value-creating exchange, which is only feasible with the AMI.

3.2 General résumé from the literature

Having established that an AMI platform represents a multi-sided market, we discuss implications stemming from this finding in this section. There are several relevant peculiarities of multi-sided markets that need to be considered in the context of smart meters. Whenever meaningful, we explain the respective peculiarity by looking at other illustrative multi-sided markets.

The first peculiarity deals with the establishment of multi-sided markets. By definition, a platform operator needs to get at least two market sides on board, otherwise the platform will not be valuable to anyone. This task is specifically complicated by the fact that the positive externalities have a network character, meaning that a critical mass of participants is needed to begin with. Combined with a need to make a fixed upfront investment in the platform infrastructure it, therefore, poses a challenge to get a multi-sided market going. This phenomenon is typically referred to as a chicken-egg problem (Evans, 2009). In order to facilitate the market-driven emergence of the smart meter market, the German Government, for example, has made it obligatory for retailers to offer variable tariffs (see EnWG Section 40(3)). Thereby, one side of the market is encouraged to participate by law, which in turn is supposed to increase the attractiveness of the AMI platform for consumers.[20]

Rochet & Tirole (2003) identify a related peculiarity that needs to be considered to get both market sides on board. They argue that it is crucial for platform operators not only to determine the price

[20] The requirements of the corresponding law, however, could potentially be met without the usage of the AMI platform.

level but also the price structure—which market side has to pay how much for the service. This notion contradicts the standard result of microeconomic theory about the neutrality of price structure.[21] Thus, businesses in multi-sided markets devote much attention to how the cost burden is allocated. The result is that in many multi-sided markets one market side pays a higher price than the other side irrespective of underlying marginal costs (Evans, 2009). For instance, online search is commonly provided free of charge, while advertisers pay fees for every user clicking on their ad.[22]

Consequently, other factors—on top of production costs—need to be considered when specifying the efficient price structure in a multi-sided market. The most prominent of these factors is the positive externalities among market players (Wright, 2003, 2004a). As discussed in section 3.1, consumers exhibit indirect network effects on the other market sides of the smart meter market. Accordingly, the price structure should reflect these benefits and the other players should shoulder some costs of consumers (European Smart Metering Alliance, 2009). Besides, Armstrong (2006) argues that the best way to internalize the indirect network effects is to use a pay-per-transaction scheme rather than to have a fixed fee for access to the platform. This way, every time the other market side actually benefits from the positive externality, it has to pay for it and thus best internalizes it.

An additional factor relevant for the price structure is potential obstacles for certain market sides. In the smart meter market consumers face difficulties in assessing their true savings potential. With conventional Ferraris meters, they know final prices consist of a relatively complex combination of metering charges and electricity prices, but they have only a limited overview of their consumption pattern. If they switch to smart meters, fixed metering charges will increase, whereas variable electricity tariffs and consumption information allow for savings. Under such vague circumstances, risk-averse consumers may need further inducements to invest. Thus, both factors—indirect network effects and obstacles—suggest a benefit transfer from other market players to consumers. Thereby, the investment barrier, which was identified as a key obstacle for the market-driven rollout, could be overcome through a rebalancing of benefits as consumers would have sufficient incentives to invest.

Finally, there is another phenomenon with respect to a socialization of costs that is relevant in the smart meter context. Taking the well-studied case of credit cards as an illustrative example, processing card payments is more costly for merchants than processing cash payments. Nevertheless, payment networks have imposed a no-surcharge rule prohibiting merchants from charging higher prices for card payments compared to cash payments.[23] In other words, the costs of the payment card system are socialized over all consumers and this leads to more card usage in equilibrium.

[21] The introduction of a sales tax is an example for the neutrality of price structure, as it leads to a new market equilibrium which determines to what extent the burden of the tax falls on each market side—consumers or merchants—independent of who is obliged to actually pay it.

[22] Other examples include ladies-night in discos and nightclubs, or free-to-air TV and radio.

[23] No-surcharge rules are forbidden in some jurisdictions, but empirical evidence is available suggesting that even in the absence of no-surcharge rules most merchants demand the same prices (ITM Research, 2000 and Chakravorti & To, 2007).

There has been some discussion about whether or not such socialization is beneficial in the credit-card market[24], but for the smart meter market, three arguments favor a socialization of costs—meaning to let owners of conventional Ferraris meters share part of the smart meter costs.[25] The first argument is that some of the benefits of smart meters are also socialized. If DSOs can reduce their investments into grid capacity, and retailers can monitor consumption more efficiently and thus avoid costs, this reduces overall prices for all consumers. The same socialization of benefits is also true for major qualitative improvements such as less blackouts. Thus, if some benefits are socialized, so could some of the costs. The second argument is based upon the limited market knowledge of consumers. Because of indirect network effects and economies of scale, average costs in the whole market are reduced if many consumers install smart meters. Individually, consumers do not take this into account. For this reason, there is more likely to be an underprovision of smart meters absent any regulatory incentives. In addition to these two arguments, a socialization of costs could help to overcome the chicken-egg problem in this particular market as it reduces investment barriers. The main argument against socialization is based on the fact that it induces a cost increase without choice for those consumers who do not switch to smart meters. This has to be observed critically from an equity perspective. However, it appears that the advantages of socialization of cost outweigh the disadvantages.[26]

Summing up, multi-sided market economics provides some key insights for the regulation of the smart meter market. Wright (2004b) recognized that being unaware of these insights can lead to typical regulatory fallacies. The most relevant fallacy in the smart meter context is the assertion that an efficient price structure should reflect the relative cost of service for each customer group. In contrast, multi-sided market economics reveals that there is a rationale to transfer some of other market participants' benefits to consumers and that this benefit transfer is best based on a per-transaction basis. On top of that, there are reasons for the socialization of costs so that even consumers who stick with their old Ferraris meters share in the smart meter costs. A second relevant fallacy is the idea that an increase in competition necessarily results in a price structure that better reflects the relative cost of service for each customer group. This is generally not true for multi-sided markets. An optimal price structure is independent of the level of competition.[27] Thus, we can apply the same general lessons learnt to different market structures independent of the level of competition. This is what we do in the following analysis of potential smart meter market structures.

[24] Rochet & Tirole (2002) find in a theoretical setup that a no-surcharge rule can be welfare enhancing or reducing. While the theoretical result is ambiguous, Guibourg & Segendorf (2004) and Bolt et al. (2010) have argued, based on empirical results, that the socialization of costs is socially beneficial in the case of credit cards.

[25] How a socialization could be implemented is discussed in detail in section 5.

[26] Socialization of costs is not uncommon in environmental regulation, compare for example feed-in tariffs to promote renewable energy sources.

[27] However, competition may have other beneficial effects such as high cost pressure.

4 Market structure analysis

In this section we apply the insights from multi-sided market economics to the potential smart meter market structures. This is important as the chicken-egg problem as well as the pricing structure have a strong influence on the emergence of a market. Consequently, when analyzing the optimal regulation for a market-driven smart meter rollout they have to be considered. Before starting the analysis, we first explain why regulation is required independent of the type of market structure and then present the potential market structures.

4.1 Potential market structures

From a public policy perspective, it is difficult to determine the extent to which the market structure development can be left to the free market. This is mainly because of the fact that one important market player—the DSO—is running a natural monopoly and, consequently, is acting under regulatory oversight. In other words, the DSO is not free to independently perform business strategies that might otherwise be spontaneously developed in a free market environment. Thus, the regulator intervenes to some degree even when the smart meter market is liberalized. We argue that an informed decision about how to intervene should take into account the lessons learnt from multi-sided market economics.

For the purpose of the analysis we view the stakeholder that is operating the AMI as the defining element of a market structure. The regulator can either select one market side to operate the smart meters or liberalize the market and leave the process of determining the operator to the market. From the key stakeholders identified, three could potentially perform this function and, in fact, are asked to do so in different countries: (1) retailers, (2) (independent) meter operators, and (3) DSOs.[28] For illustrative purposes they are depicted in Figure 3. Note that we suppose a competitive retail market in all three market structures; a definitive objective of regulation in the EU and also applicable in some states in the US (Brennan, 2009).

In the first market structure, the regulator only allows retailers to operate smart meters. When consumers then switch their retailer, they automatically switch their meter operator. Hence, retailer competition and metering competition are identical in this market structure. This case is comparable to the UK. The second market structure is the result of a complete meter market liberalization as attempted in Germany. Whoever wants to enter the market is allowed to do so and can compete for consumers. To stringently distinguish market structures, we assume that ownership of the independent meter operator does not play a crucial role. In other words, in the competitive environment of the second market structure, the results of our analysis are independent of whether the meter operator is owned by

[28] The UK opts for establishing a unified data and communication provider that supports retailers in their function as platform operators (DECC and OFGEM 2011). This can be regarded as another way of implementing a unified communication standard but it does not reflect another market structure as defined in our approach. Additionally, we rule out the case that every consumer runs her own AMI due to the immense transaction cost.

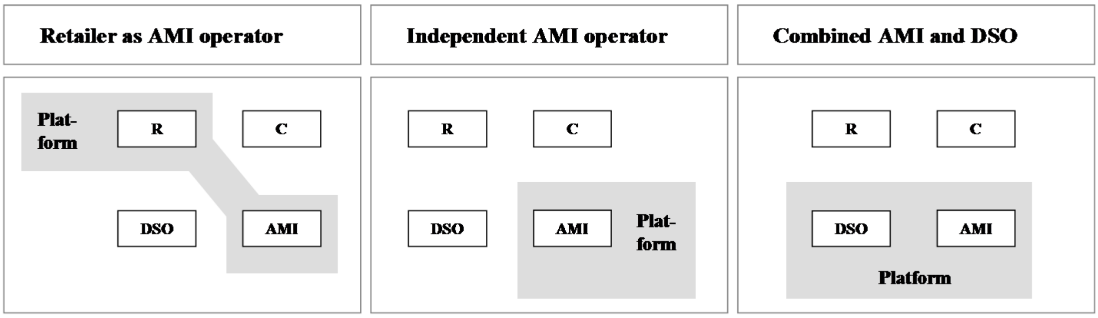


Fig. 3: Potential smart meter market structures.

a retailer, a DSO, or any third party. In the third market structure the regulator simply extends the natural monopoly of the DSO in the grid market to the meter market as is done in Sweden and Italy. Note that we compare idealized forms of market structures in order to conduct a thorough analysis and that in reality hybrid forms may also emerge in which the observed differences blur.

There are also two commonalities among all market structures. Firstly, all market structures allow for a limited reduction of obstacles for consumers by addressing the investment costs of the smart meter. This can be achieved through two different channels: the state or retailers. Since the increase of energy efficiency due to the installation of smart meters reduces CO_2 emissions, governments may be interested in providing monetary incentives to consumers for the installation of smart meters.[29] Thereby, governments would pay for the more efficient achievement of CO_2 emission reductions that could be obtained by a smart meter rollout. In contrast, retailers have a different motivation. The installation of smart meters allows for the offering of new products, which gives access to new consumer groups, and also has the potential of reducing operating costs. Consequently, a partial transfer of the investment cost from consumers to retailers seems possible in the course of consumer acquisitions. Secondly, a definition of communication standards is required independent of the chosen design option.[30] The communication standard ensures that all stakeholders in the smart meter market can consistently exchange data. Only if this is the case, retailers serving consumers from different distribution grids can generate the greatest possible benefits from the implementation of smart meters, which can then (partly) be passed on to consumers in the form of lower prices for electricity.

In the following, we assess each of the three market structures with respect to five common evaluation criteria that reflect classical regulatory considerations of static and dynamic efficiency as well as aspects resulting from multi-sided market economics. In more detail, this means we investigate whether a market structure provides incentives for operating efficiency and meter innovation; regarding multi-sided market

[29] Some economists argue that states should only define an emission target and introduce an emission trading scheme. CO_2 reductions should then be left to the market mechanism and therefore states should not provide any subsidies (for an overview of the discussion see Fischer & Preonas, 2010).

[30] The definition of a standard data format for communication was a key element of the Swedish smart meter rollout (Wissner, 2009) and Italy and Great Britain for example are thinking about the implementation of communication standards (Nabe et al., 2009b).

implications, we examine whether the chicken-egg problem can be solved by overcoming the investment risk and/or socializing some of the costs, and analyze whether the right price structure can be imposed in order to account for the positive externalities that consumers exhibit. These positive externalities are the benefits for the retailer, and the DSO described in section 2.2.

Note that depending on the market structure, these benefits are either internalized through the operation of the AMI platform itself or a benefit transfer between market sides. For instance, if retailers operate the AMI, their benefits are internalized through the platform operation. If another stakeholder operates the AMI, the retailer—who is now a market side to the platform—passes on the same benefits, but denoted as indirect network effects. We keep this distinction in nomenclature for the sole reason of being consistent in the analysis of multi-sided markets.

4.2 Retailer as Advanced Meter Infrastructure operator

Suppose that retailers operate the AMI infrastructure independent of who operates the conventional meters. This means that retailers serve consumers on one side of the platform and the respective DSO on the other side. As already indicated above, we also suppose retailers act in a competitive environment and consumers can easily switch their retailer. As a result, the operation of smart meters happens under competitive conditions as well. Thus, every retailer has good reasons to improve the operating efficiency of the platform. In addition, retailers have incentives to innovate in the market and offer new products and services that go beyond the standard functions in order to tie consumers. Another aspect of retailer competition is that the benefits of the retailer mentioned in section 2.2 are then passed on to consumers through the competitive pressure to lower prices.

On the downside, retailers are not well equipped to deal with the chicken-egg problem that is essential in a market-driven rollout. One way to get the consumers on board is by socializing some or all of the smart meter costs. In that case, all existing consumers bear the cost of the AMI infrastructure, not just those who actually install such equipment. At best, some retailers could exploit the fact that they are the default providers of electricity in an area and that switching retailers involves transaction costs. Thus, socializing investment costs is feasible as long as prices for all consumers increase only slightly. Nevertheless, because retailers have to act in a competitive environment, this option is limited.

Another way to induce consumers to install smart meters involves the platform operator (in this case the retailer) taking on some of the investment costs of the smart meter and then recovering the investment over time. This business strategy suffers from a typical holdup problem as an investment risk results from the fact that consumers can easily switch retailers. Thus, retailers are hindered in covering part of the investment costs of consumers, which creates a major hurdle for market entry.[31] The

[31] Another perspective to this issue is based on transaction costs. Retailer ownership of smart meters increases transaction costs when consumers switch retailers. If retailers are burdened with these costs to ensure a competitive retail market, then

European Smart Metering Alliance (2008) sees evidence of this in the UK's unbundled market, where retailers are anxious to invest for fear of stranded assets when losing customers to the competition. But because retailer competition is regarded as an important element of the liberalized electricity market (NERA Economic Consulting, 2008), it may not be desirable to reduce this competitive pressure in order to increase investment security.

Another downside covers a further challenge of multi-sided markets. We have stated that other market participants should pay for the indirect network effects (positive externalities) they receive from consumers' participation. This appears to be difficult for the case of the DSO. The DSO is currently being regulated to provide the grid infrastructure in a cost-efficient manner. The regulator would have to adjust this regulation to account for the benefits the DSO receives and reduce prices—potentially a delicate task. Even if this can be achieved to some extent, cost reductions are more likely to materialize for all consumers rather than for individual consumers who decide to invest in a smart meter. This is because of the nature of the benefits (enhanced quality, lower maximal grid load, reduced investment in energy generating capacity etc.) that can hardly be allotted to individual consumers. The grid benefits are thus socialized, while the investment costs remain private.

As a result, we find that the cost pressure on retailers fosters operating efficiency and innovation. However, it is unlikely that such a market ever materializes. Because of the high investment risk, due to the competitive meter market and the inability to socialize the AMI costs, retailers have difficulty in overcoming the chicken-egg problem. Furthermore, the price structure in this market is not optimal as grid benefits can hardly be passed on to consumers.

4.3 Independent Advanced Meter Infrastructure operator

The second possible market structure relies on an independent AMI operator, which is the consequence of a liberalized smart meter market. This independent operator could act as a subcontractor to a retailer or a DSO or be completely independent from the other market participants, but we assume that ownership does not matter. In any of these cases, the platform would then have three market sides: supplying advanced electricity consumption data to the consumer, the DSO, and the retailer. We could accordingly speak of a three-sided market. If meter operation is the only service an independent operator is offering, the incentives for operating efficiency and platform innovation would be larger than in any other case since this is the only value proposition such a business could offer.

This biggest strength, however, is also a weakness with regard to the economics of multi-sided markets and solving the chicken-egg problem. In effect, because meter operation is all the platform operator is offering, there is no chance of letting other consumers with old meters share in the investment cost.

retailers will be hesitant to invest.

The market's cost pressure would not allow for a strategy of socialization. The market competition also translates into a certain investment risk. Independent AMI operators could offer longer-term service contracts to consumers, take on the investment costs and recoup them over the contract period. This business strategy would theoretically be feasible because switching the retailer would still be possible without switching the meter operator. However, it would reduce the investment risk for operators only to a limited extent, as increasing prices for meter operation is a difficult task when entering a new competitive market.

With respect to indirect network effects, the retailer benefits are passed on to the consumer through competition in the form of lower electricity prices. Here, retailers are one side of the market. To that effect, we can assume that the positive externalities consumers exhibit on retailers are being paid for by retailers. For the benefits of the DSO, nothing changes in comparison with the first market structure. In fact it is difficult to pass on their benefits to consumers—especially to the respective consumers who make the investment. Those DSO benefits that are passed on are rather shared by all consumers.

All in all, this market structure suffers from similar problems as the first option. The investment risk and lack of socialization may still hinder a market-driven rollout. Furthermore, the price structure is not optimal as not all indirect network effects are accounted for. However, the competitive environment creates strong innovation incentives and cost pressure for retailers and AMI platform operators. Thus, overall, this makes for a more attractive market structure than the first alternative.

4.4 Advanced Meter Infrastructure and Distribution System Operator

As discussed earlier, running the electricity grid is a natural monopoly. On top of that, DSOs in most countries have traditionally held a monopoly on operating meters in their area. Therefore, it is natural to suppose a monopolistic DSO running the AMI infrastructure. In that case, we face a monopolistic combined Advanced Meter Infrastructure and Distribution System Operator (AMI-DSO) that enables retailers and consumers to exchange information.

Thus, there is less pressure for high operating efficiency and to innovate because of a lack of competition (Jamasb & Pollitt, 2001 and Baringa, 2009). These are important reasons why some countries have tried to break up this monopolistic position and introduce competition in the meter market.[32] However, the economics of multi-sided markets also reveals significant advantages of this market structure.

The first advantage is that all benefits identified above are accounted for. The retailer's indirect network benefits are passed on to the consumer through competition, and the DSO's benefits are internalized because it is operating the AMI platform. Both players can thus pass on these benefits to individual consumers to entice them to invest in smart meters. For the retailer, this will naturally happen through

[32] Examples are Germany, the UK and until 2010 the Netherlands (European Smart Metering Alliance, 2009).

competition just as in the other market structures. For the DSO, this involves regulation, which is easier to perform in this market structure than in the others. When regulating the prices that may be set for the operation of smart meters, benefits and costs can be cleared and thus both elements will be accounted for.

Another positive aspect of acting in a monopoly is that investment risk is low. Ownership of the smart meter does not change, even if consumers change retailers. If DSOs act in a reliable legal environment where the long-term requirements for smart meters do not change, they can recoup their investment over a long period.

On top of that, DSOs could easily socialize the costs of smart meters to all consumers—those who have smart meters and those who do not. This is a critical aspect and we have already explained in section 3.2 why such a feature might be desirable in the context of a multi-sided market. Of course, the degree of socialization would have to be subject to regulation lest a complete rollout of smart meters with full functionality immensely drives up the costs.[33]

Summing up, the biggest strength of this market structure is that it incorporates the characteristics of multi-sided markets, which facilitates a market-driven rollout. The chicken-egg problem is approached through socialization of costs and high investment security. Furthermore, an optimal price structure, which accounts for indirect network effects, provides investment incentives. This comes at the expense of a monopoly position for the AMI platform operator and, consequently, fewer incentives for operating efficiency and innovation.

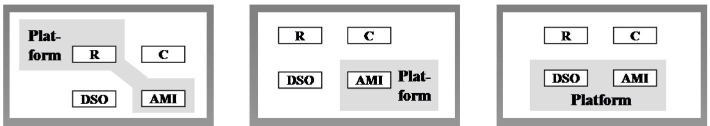
4.5 Summary and comparison

A summary of the different market structure characteristics can be seen in Figure 4. On the left, the different evaluation criteria are listed. The rest of the table summarizes how well the three potential market structures fare with respect to these criteria. Note that since the evaluation criteria are assessed qualitatively, it is not sensible to compare market structures by simply adding up given values. It is rather necessary to weigh the relevance of the different criteria and to make an informed decision based on this weighing.[34]

The first column shows the retailer as the platform operator. In this setup, there is an incentive for operating efficiency and innovation, but there is a high investment risk because consumers can easily switch retailers. A socialization of costs is only possible to a limited degree regarding the existing consumer base. The positive externalities consumers exert are internalized by the retailer in the operation of the platform but are difficult to grasp in the form of indirect network effects to the DSO. The latter would

[33] We discuss this point in more detail in the design options in section 5.

[34] The criteria with high relevance for a market-driven rollout are investment risk, socialization of cost and accounting of indirect network effects.



Market sides	Consumer, DSO	Consumer, Retailer, DSO	Consumer, Retailer
Incentive for operating efficiency	+	++	–
Incentive for innovation	+	++	–
Investment security	––	–	++
Socialization of cost	0	––	++
Benefit transfer for network effects	–	+	++
Platform operation internalizes benefits	++	0	+
Regulation required	DSO benefits	DSO benefits	Smart meter fee

Fig. 4: Evaluation of smart meter market structures.

have to be regulated.

The liberalized smart meter market is evaluated in the second column. Here, incentives for operating efficiency and innovation are largest, but investment security is rather low due to the difficulty in selling long-term contracts. There is effectively no possibility to socialize costs because companies are acting in a competitive environment. Positive externalities from consumers are internalized to a similar degree as in the first structure, albeit in a different fashion. The platform operator cannot himself internalize benefits, but the retailer's benefits are passed on through competition. Again, the DSO's benefits are difficult to account for, even with regulation.

The combined AMI-DSO offers a different picture as shown in the third column. The low level of incentives for operating efficiency and innovation are clear disadvantages. On the upside, all positive externalities from the consumer are accounted for, and beyond that, a socialization of smart meter costs is feasible—if the regulator allows it. Furthermore, DSOs have a high level of investment security giving them an incentive to proceed speedily.

Summing up, the market structure analysis yields the result that having a combined AMI-DSO is best suited for a market-driven rollout of smart meters. Overcoming the chicken-egg problem is facilitated and it is possible to achieve a sensible price structure around the AMI platform. The characteristics of multi-sided markets are thus accounted for, albeit at the expense of having fewer incentives for operating efficiency and innovation.

5 Regulatory design options

Having identified the combined AMI-DSO as the most suitable market structure to account for the characteristics of multi-sided markets and thereby to foster a market-driven rollout of smart meters, there are four different design options with respect to a socialization of smart meter costs that the regulator can choose from. Remember that the regulator needs to choose and directly allow for any level of socialization. In this section we analyze in how far each regulatory design option is appropriate to overcome the chicken-egg-problem and to yield the potential benefits of a market-driven smart meter rollout—cost effectiveness and consumer education. The four options, which differ only to the degree to which they allow for a socialization of costs, are:

- **No socialization of costs**: The individual consumer has to bear the full costs of the smart meter, meaning investment costs as well as operating costs.
- **Socialization of operating costs**: The individual consumer has to bear the investment costs of the smart meter; the (increased) operating costs, however, are socialized and distributed over all consumers of the respective DSO.
- **Socialization of investment costs**: The (increased) operating costs of the smart meter are billed to the individual consumer, whereas the investment costs of the smart meter are socialized and distributed over all consumers of the respective DSO.
- **Total socialization of costs**: Both investment and operating costs of the smart meter are socialized and distributed over all consumers of the respective DSO.

Before analyzing the different regulatory design options, it is meaningful to outline the characteristics all options have in common. Firstly, because of the combined AMI-DSO's natural monopoly the regulator has to define the cost base for the smart meter rollout. This includes the recognition of costs for the smart meter communication infrastructure for all regulatory design options. Additionally, it comprises a specification of cost components—operating and/or investment costs—that are to be socialized. For the case that the smart meter investment costs are socialized, it also requires a definition of a technical standard configuration with a respective limit of compensable costs, lest there be a complete rollout with the highest functionality the market offers. Secondly, the DSO, being the AMI platform operator, is in charge of the defined socializable smart meter investments. This means that the DSO not only pays for the smart meter communication infrastructure upfront, but depending on the design option, also for the smart meter itself. The compensation for these investments occurs through increased fees for meter operation in the upcoming years, which are billed to the retailers, who then (partly) pass the fees on to the consumers. Thirdly, consumers have a veto power in case of higher costs due to the installation of a smart meter. This veto power—defining the consumer as the decisive player—underlines the reliance on a market decision for smart meter implementation. But because it only applies if the consumer faces higher costs, it is ensured that the rollout is not slowed down in case a DSO has the capabilities for a cost-neutral rollout.[35]

5.1 No socialization of costs

The first design option assigns the full cost burden to consumers. This means that most relevant decisions are driven solely by market forces, impacting the cost effectiveness of the rollout threefold. Firstly, the market decides on the degree to which smart meters are rolled out. No mandatory rollout targets are given by the regulatory regime or indirectly by the government. It is rather the conscious decision of every single consumer to opt for a smart meter. Secondly, neither is there a need to define a technical standard configuration with respect to the functionality of the smart meter. The market process will both demonstrate which features have real benefits for consumers or retailers and ensure that these are offered at reasonable prices. Consequently, the regulatory market intervention is limited to the communication standard and the cost of the communication infrastructure, which are both required for any design option. From this perspective, costs are kept low.

Thirdly, a potential downside with respect to cost effectiveness is the presumably large variety of smart meters in use—assuming a lack of a technical standard specification by the regulator. This could result in less specialization of technicians, which increases the time needed to identify and solve problems. Potentially, stocks of spare parts have to be increased, resulting in higher capital cost than necessary. Furthermore, the interoperability between different types of smart meters and the communication infrastructure could increase the complexity of the whole system, requiring a larger effort for smooth operation. Finally, there is a higher risk of investing into an island solution that would altogether retard the rollout process and increase costs.

Regarding consumer cooperation, the fact that every consumer has to make a conscious decision for the installation of a smart meter increases the probability that consumers adapt their behavior. Specifically, as the consumer's benefits can be heavily influenced through the degree of adaption. As discussed in section 2.2, the education of consumers is a critical element to be addressed, since the simple installation of the smart meter does not make any major contribution to energy efficiency in itself.

Whether the limited reduction of obstacles in this design option resolves the chicken-egg problem remains, however, questionable. Consumers will still be faced with a substantial amount of upfront investment and also face higher meter operating costs. The examples of countries with primarily market-driven rollouts, such as Germany and the UK (until 2008), support this negative conjecture. In both

[35] The limited veto power, restricted to the case of higher cost, is already an element of the refined market-driven approach of the German Federal Regulatory Agency (see Bundesnetzagentur, 2010).

countries, the penetration of smart meters is low and numbers are not expected to increase quickly without adjustments to regulation in the upcoming years.[36]

Summarizing, a DSO in charge of the AMI infrastructure but no socialization of costs is similar to the status quo in Germany[37], where the DSO still operates the majority of meters. The regulatory design option offers several advantages due to the strong reliance on market forces, but it appears rather unlikely that it will generate sufficient incentives for consumers to overcome the investment barrier for smart meters.

5.2 Socialization of operating costs

The advantages of the second design option, in which a socialization of operating costs takes place, are similar to the ones in the first design option. It too relies heavily on market forces. Both the degree of rollout—as no mandatory target has to be enforced—and the optimal functionality of the smart meter are left to the market. Consequently, the only specified regulatory parameters are the communication standard and the cost limit of the communication infrastructure. Because of the market mechanism the cost effectiveness in this design option should be high, albeit with the caveat of having a large variety of smart meters in use. Since consumers have to make a conscious decision for a smart meter, chances for an adaption of consumer behavior are again high, as explained above.

However, with respect to the reduction of consumers' obstacles for investment there is a difference. This design option addresses the increase in operating costs resulting from the usage of a smart meter. Due to the socialization, the marginal consumer making a smart meter investment does not face any increase in operating costs based on her decision. Her costs are split among all consumers independent of whether they possess a smart meter or not. Considering that many consumers are switching to smart meters, the overall operating costs will, however, increase. Note that the result of this process is a lower fee for the operation of the smart meter for the individual consumer who invests in a smart meter compared to the first design option; assuming that not all consumers upgrade to the smart meter. Consumers deciding against the installation of a smart meter likewise face a cost increase as a consequence of the socialization of the operating costs—raising questions about equity as described in section 3.2.

It is evident that this design option does not completely eliminate the need for initial investments by consumers. The remaining investment costs are, therefore, still a potential barrier to a market-driven rollout. However, compared to the first design option, this barrier is lower, since the increase in operating costs is socialized.

[36] The market-driven penetration rate of smart meters in the UK was only 0.5 % in 2007, so that the government at the end of 2008 decided in favor of a mandatory rollout until 2020 (see Wissner, 2009). There are hardly any smart meters installed in Germany yet and the installed ones are due to direct government mandate. But so far the German Federal Regulatory Agency adheres to a market-driven rollout and simply suggests to refine this approach (Bundesnetzagentur, 2010).

[37] However, the German regulator is trying to enforce competition and move towards independent AMI operators.

Summing up, this regulatory design option leverages the power of the market leading to cost effectiveness and consumer cooperation, while it increases the incentives for the installation of smart meters by addressing operating costs. Thus, the need for an upfront investment by consumers is still present and must be regarded as a serious barrier to a market-driven rollout.

5.3 Socialization of investment costs

Socialization of smart meter investment costs, which is the third design option, has major differences to the two previous ones. Its biggest advantage is the full elimination of investment costs for consumers. The DSO is in charge of the smart meter investment, for which it gets compensated through adjusted future fees for the meter operation. Consumers still decide to opt for a smart meter, but the corresponding investment costs are socialized over all consumers of the respective DSO. Accordingly, the marginal consumer only faces (slightly) increased fees for the meter operation, but no initial investment. However, the switching of many consumers leads to an additional increase in operating fees for all consumers conforming to the compensation of the DSO for the investment costs. This increase in operating fees is higher than for the previous regulatory design option, because of the larger annualized costs of the smart meter investment compared to the operating costs (see the smart meter cost split in section 2.2). Thus, consumers not migrating to a smart meter are confronted with an even higher increase in operating fees.

Besides, the billing of operating fees for the use of the AMI platform to retailers and indirectly to consumers, reflects the logic of pay-per-transaction—which is one of the implications for the price structure from multi-sided market economics in section 3.2. Users of the AMI platform pay only for the platform when they actually benefit from it and thereby internalize the positive externality of the other market side. Translated into the context this means retailers and indirectly consumers pay only for the use of the AMI platform when a value-creating exchange between them takes place.[38]

With respect to cost effectiveness, the continuing reliance on the market mechanism has to be evaluated positively. It is still the market that determines the degree of the smart meter rollout. The regulatory regime does not prescribe any mandatory rollout targets, but it is again the conscious decision of every consumer to opt for a smart meter. In contrast to the two previous design options, the optimal set of features, however, is not determined through a market-driven trial-and-error process, but defined by the regulatory regime. Only Extras on top of the defined standard are still available through the market.

Thus, the decision for the optimal meter is transferred from the market to the regulatory authority. Thereby, the regulator has to define the optimal functionality upfront for a certain period to generate investment security for the DSOs. This should reduce the variety of smart meters in use and thus have a positive impact on cost effectiveness. Beside the technical standard, the regulatory regime also has to set a

[38] Obviously, this argument applies to consumers migrating to the smart meter. Consumers with conventional Ferraris meters pay higher fees but profit only to a limited degree.

cost limit for the envisioned standard meter.[39] Evidently, it is questionable whether the regulatory regime will always find the best solution and the correct price—a common problem of incentive regulation.[40]

Since consumers go through a conscious decision-making process in favor of the smart meter, weighing increased operating costs against potential benefits from the installation, an adaption of the consumers' behavior can be anticipated. Thus, energy efficiency is likely to increase.

To recap, this regulatory design option fully eliminates the upfront investment need for consumers, while it (greatly) conforms to the advantages of a market-driven rollout; market-driven because consumers with a smart meter face higher operating costs. Additionally, it also reflects the pay-per-transaction logic from multi-sided market economics. Thus, it seems suitable to foster a market-driven rollout.

5.4 Complete socialization of costs

The fourth design option of socializing the complete smart meter costs has several similarities with the previous design option, but goes beyond it in an important dimension. Obviously, as with the last option, the investment barrier for consumers is eliminated completely. The DSO is responsible for the smart meter investment costs and gets compensated through an increased fee for meter operation. Consumers, in return, have no upfront investment for a smart meter installation. Furthermore, even the increased operating costs are distributed over all consumers of the respective DSO. Consequently, consumers in this design option have no incentive to decide against an installation, as their decision does not directly lead to any increase in costs, in contrast to the two previous design options. This means a complete socialization of costs overcomes the chicken-egg problem and de facto leads to a comprehensive rollout of smart meters.[41]

However, a major disadvantage of the de facto comprehensive rollout is the low cost-effectiveness. Every consumer is equipped with a smart meter independent of whether individual consumers benefit or not. Only extras above the standard meter defined by the regulatory regime are a result of the market mechanism. Furthermore, the regulatory regime needs to define the functionality of the standard smart meter and to set a cost limit for it, which can also have negative effects on the cost effectiveness as described above.

Since the complete socialization of costs leaves no "real" decision power to consumers, the degree of consumer education is rather low. Consumers are not encouraged to engage with the potential benefits of smart meters. As a consequence, it seems reasonable to assume a lower rate and degree of adaption in behavior compared to the previous design options, resulting in lower gains of energy efficiency than possible. Thus, this approach inflates the cost base without yielding all the potential benefits.

[39] The definition of the standard functionality can be regarded as a quality incentive defining an envisioned service level, which is a standard element of modern incentive regulation.

[40] For an overview of challenges in incentive regulation due to information asymmetries compare Joskow (2008).

[41] The comprehensive rollout thus fulfills the EU 2020 rollout target described in the introduction. Thus it can be regarded as a further advantage for European countries.

Summing up, this design option is comparable to the Swedish approach to smart meter regulation. Although not stated explicitly, the regulatory guidelines result in a comprehensive rollout; with its disadvantages with respect to cost-effectiveness and consumer cooperation. Whether this design option can be classified as a market-driven rollout at all is questionable.

Comparing the four regulatory design options, a pattern emerges. Neither a total socialization of costs nor a complete lack of socialization is suitable to yield the benefits of a market-driven smart meter rollout. An intelligent regulation combines elements of a market-driven approach with incentives for investment. It offers incentives to invest through a socialization of costs and accounting for indirect network effects, but leaves the investment decision to the consumer. In deciding between socialization of operating costs and socialization of investment costs, the latter appears superior since it diminishes investment obstacles to the consumer more effectively and also allows for the pay-per-transaction logic of multi-sided market economics. Thereby, users of the platform—retailers and consumers—do not pay for access to the platform; they only pay if they actually use the platform. However, it should be noted that the regulatory regime has to take on greater responsibility since it has to define a standard smart meter, which could result in lower cost effectiveness.

6 Policy Outlook

The analysis so far has demonstrated that the combined AMI-DSO is the market structure with the best characteristics to foster a market-driven rollout. Furthermore, the comparison of regulatory design options has revealed that socialization of investment costs exerts the advantages of a market-driven rollout best while providing high investment incentives. In this outlook three modifications are presented, which a regulator can apply to shift the balance between the advantages and disadvantages of the above described market structure and design options.

In the previous sections, we assumed that costs are socialized evenly among all consumers of the respective DSO. An alternative to this approach is socialization according to individual electricity consumption in kWh. A consumer with higher than average electricity consumption would then pay a larger portion of the costs to be socialized, whereas a consumer with a lower than average electricity consumption would pay a lower portion. Thus, the incentives to opt for a smart meter in order to participate in the benefits are lower for low-consumption consumers and higher for high-consumption consumers. At first glance, this uneven cost split may seem unfair. However, a consumer with higher electricity consumption may also benefit more by installing a smart meter.[42] Thus, by applying a socialization of costs according to energy consumption, incentives are adjusted with respect to potential benefits from

[42] This assumes a constant savings factor for the implementation of the smart meter, e.g. x% savings per consumer. Calculations of consumers' savings potential frequently apply this type of constant savings factor (see Frontier Economics, 2007).

the smart meter installation. This modification of socialized costs thereby allows the regulator to gauge incentives according to the potential impact of consumers on energy efficiency.

The second possible modification concerns the competitive environment of the DSO. In the described market structure of the combined AMI-DSO in section 4, there is no competition with respect to the AMI infrastructure. A soft form of competition, however, would be possible by allowing DSOs to install and operate smart meters in regions where they do not own the distribution grid.[43] Thereby, the regulator can trade off advantages of the different market structures against each other. The competition would create a certain degree of cost pressure, encouraging DSOs to operate the AMI platform efficiently and to strive for innovations. The downside of this modification would be that the investment security for DSOs would be reduced. Consumers could change the meter operator, which would leave the DSO with stranded assets. More importantly, the trade-off would also affect the possibility for socialization. If an increase in fees for meter operation is too great due to socialization, consumers would have the power to mandate a DSO from another area with the operation of the (smart) meter.

The last modification involves a time component. Depending on the degree of the smart meter rollout, the ranking order of the market structure's characteristics may change. A characteristic such as socialization of smart meter costs, which affects the possibility of a market structure to address the investment barrier for consumers, is more meaningful in the early stages of the rollout. Once a bulk of consumers is equipped with a smart meter, this characteristic could be neglected. In contrast, incentives for operating efficiency and innovation become more important the more smart meters are in place. A regulator that regards this shift in ranking order as relevant could switch from one market structure to another. For example, the regulatory frame could start with a combined AMI-DSO for the rollout period and announce upfront that after a specified period the market would be open to competition to leverage the advantages of the independent AMI operator market structure.

A general recommendation on which modifications to carry out is not meaningful as the decision depends highly on the current market structure and, above all, on the goals of the regulatory authority.

7 Conclusion

The electricity market is a complex network of multiple stakeholders performing different functions. The fact that grid operators manage a natural monopoly further adds to the complexity. Smart meters are expected to increase the overall efficiency of this market, but respective benefits may not outweigh costs for every consumer. As a consequence, several countries try to pursue a market-driven rollout and thus let the market decide on a smart meter's usefulness in each distinct case. However, because the infrastructure

[43] This form of competition is only meaningful if the data transfer from the smart meter to the data center takes place via radio-based or independent IP-based wire bound communication technology. In case the data transfer requires powerline communication, true competition would probably not develop.

provider has to be regulated, there is a definite need for some form of regulatory intervention. In this paper we argue that regulators should realize that smart meters, in contrast to conventional Ferraris meters, introduce a multi-sided market. Therefore, they have to deal with the corresponding peculiarities to avoid typical regulatory fallacies with respect to the price structure in such markets.

The market structure that is best suited to deal with these peculiar features places the responsibility for installing and operating smart meters on the DSO. The combined AMI-DSO can capture all network effects—either through the operation of the AMI platform or through competition in the retail market. Furthermore, it can provide strong investment incentives to solve the chicken-egg problem. This is achieved mainly through a socialization of costs related to the rollout—if the regulator allows it. The justification for a socialization of costs is primarily based on the fact that some positive externalities such as improvements in quality accrue to all consumers. We argue that the smart meter investment costs should be socialized, while the operating costs should remain with individual consumers, as this reflects the pay-per-transaction logic to internalize indirect network effects and also exerts the benefits of a market-driven smart meter rollout.

However, our market structure analysis also covers aspects such as operating efficiency or incentives for innovation. The combined AMI-DSO—as a regulated monopolist—does not perform as well in these categories. Consequently, a regulator may choose to enact hybrid forms of the pure market structures we discuss or open up the market for more competition after some time when the emphasis shifts from facilitating smart meter diffusion to operating efficiency or innovation. Summing up, the optimal regulation of the smart meter rollout depends on the preferences of the regulator. If the regulatory focus is on a market-driven rollout—to achieve cost effectiveness as well as energy efficiency through strong consumer cooperation—the insights of this paper are highly relevant.

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