ADVANCING REGULATION WITH RESPECT TO DYNAMIC EFFICIENT NETWORK INVESTMENTS: INSIGHTS FROM THE UNITED KINGDOM AND ITALY

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Abstract

Environmental policy targets considerably affect the energy sector and change its structure substantially. For the electricity distribution sector, the prospective key will be a technological upgrade towards an intelligent network infrastructure, commonly denominated as smart grids. Their development, however, will require an ample amount of investments. Being (natural) monopolies, network operators invest in a regulatory environment. Therefore, the crucial question is whether current regulation provides the right investment incentives to enable technological progress and dynamic efficiency in electricity networks. Hence, the discussion if there is a need of a realignment of the regulatory framework including reconfigured investment incentives is one of the key debates at stake. In order to enrich the discussion, this paper reviews pertinent international experiences to see what kind of approaches are taken to advance the regulatory framework. It refers to two examples, the United Kingdom and Italy.

Keywords: dynamic efficiency; electricity networks; investments; regulation; technological progress

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[1] IRIN is a cooperation of the following institutes: Bremer Energie Institut at Jacobs University, Institute for Applied Ecology Freiburg, WIK (Wissenschaftliches Institut für Infrastruktur und Kommunikationsdienste) and Institute for Energy and Mining Law at Ruhr-University Bochum. The project (2009–2011) was funded by the German Federal Ministry of Economics (BMWi).

institutional framework that supports efficient and effective network development towards smart grids within the German regulatory framework.

1. INTRODUCTION

Increasing energy demand, dwindling fossil energy resources and climate change have led to political objectives to reduce CO_2 emissions and to increase the share of renewable energy sources (RES). The long-term target of the European Union is to become carbon neutral by 2050 and the medium-term targets imposed by the 20–20–20 agenda (Lisbon Treaty) stipulate: (i) a reduction of CO_2-emissions by 20 percent; (ii) an increase of energy efficiency by 20 percent; and (iii) that 20 percent of energy demand is to be met by RES by 2020. Hence, underlying environmental policy targets will considerably affect the energy sector and change its structure substantially.

As a consequence of these policy changes, physical principles of the energy system change and its conventional value-chain breaks up. For example, distributed generation units closer to end users emerge (e.g. photovoltaic (PV) and combined heat and power (micro-CHP)) and generation arises remote from the load center (e.g. offshore wind). Moreover, renewable energy plants depend on the fluctuating availability of RES. Notably, the electricity distribution sub-sector plays a key role in integrating intermittent, decentralized low-carbon technologies, enabling new forms of demand-side management and handling electric vehicles. This requires networks to respond to intermittent generation schedules, to enable bi-directional energy flows and to implement new forms of communication and network control. The key will be a technological upgrade towards an information and communication technologies (ICT)-based infrastructure, commonly referred to as smart grids.[2] Their development, however, will require a significant amount of investment and innovation in distribution networks.[3] Being (natural) monopolies, network operators invest in a regulatory environment. The crucial question, therefore, is whether incentive regulation provides the right investment incentives to enable technological progress and dynamic efficiency in the network infrastructure. Thus, the discussion if there is a need of a realignment of the regulatory framework including reconfigured investment incentives is one of the key debates at stake.

In order to further explore this issue, the remainder of this paper is organized as follows: chapter two points the reader to the dilemma of incentive regulation to promote technological progress and dynamic efficiency. Chapter three presents and chapter four analyses international experiences from the United Kingdom and Italy advancing their regulatory regime to tackle these challenges. Chapter five concludes and highlights policy implications.

2 European Commission (2011).

3 Ibid.

2. INCENTIVE REGULATION – THE DILEMMA OF DYNAMIC EFFICIENT INVESTMENTS

Investments are the Achilles' heel in a regulatory environment. When it comes to investments aiming at technological progress, anchoring targeted regulatory incentives becomes a major challenge. Academic literature elaborates on this issue. A synthesis can be found in Müller et al. (2010). Special attention is paid to how far technological progress in the network infrastructure can be stimulated by certain regulatory regimes and whether these measures lead to dynamic efficiency.[4] The main findings are briefly presented in the following.

Overall, academic literature discusses the issue, especially in grid-bound energy supply, rather cursorily and mainly refers to generic, theoretical considerations and models as well as experiences from other network industries (in particular, telecommunications). Magat (1976) was among the first to examine the effects of cost-based regulation and incentive regulation on speed and direction of technological progress. Likewise, Cabral and Riordan (1989) and Clemenz (1991) address this issue. The authors emphasize the challenge of anchoring adequate regulatory instruments to enhance dynamic efficiency.

Bailey (1974) shows how longer regulation periods urge monopolistic firms to boost technological progress by allowing them to benefit for longer from efficiency gains due to asset innovation. Sweeney (1981) deals with the resulting trade-off – does it pay for a profit-maximizing company under regulation to implement cost-reducing innovations or to postpone them? Sweeney shows that the detailed design of the regulatory regime becomes a critical factor, in particular the length of the regulatory period. Lyon and Huang (1995) point out that the problem of an optimal regulatory response to technological progress and incentives to innovate – especially regarding a possible regulatory imitation of innovation – has not yet been solved.

4 To set the scope and focus of this paper, technological progress is defined as a technological upgrade of the conventional, copper made electricity network infrastructure by means of ICT (synonym: asset innovation). This upgrade enables networks to better integrate and manage the increasing amount of intermittent and distributed electricity flows. Technological progress/asset innovation involves capital intensive investments. From the perspective of economic theory, technological progress requires a dynamic consideration of associated investment costs and implies that welfare reaches a maximum over time (dynamic efficiency). This allows for temporary static inefficiencies assuming that dynamic efficient investments are not always cost efficient from a short-term perspective. This is mainly due to long amortization cycles and a certain lag until the expected benefits from technological progress unfold. A second type of innovation is process innovation, i.e. innovations that mainly affect the more efficient operation of electricity networks. This increase in efficiency often leads to a reduction of operating expenditures (OPEX). In economic terms, a fixed output is reached with minimum cost or – vice versa – a maximum output is reached with a fixed input (productive efficiency). This implies a static, short-term interpretation of efficiency. The focus of this article is on how regulation deals with technological progress and enables a dynamic efficient resource allocation of associated capital expenditures (CAPEX).

Within the context of a fundamental debate, Armstrong and Sappington (2006) indicate that, even though incentive-based regulation can generate substantial incentives for process innovation, it does nevertheless barely provide incentives for dynamic efficient investments promoting technological progress. Bourreau and Dogan (2001) point out that, from a welfare-economic point of view, price-cap regulation can result in a higher consumer surplus in the long run if technological progress is implemented as a continuous process. Hence, the authors consider this approach, among all kinds of regulation (e.g. cost-based regulation), to be the most suitable regime for stimulating innovation. Meeus et al. (2010) discuss what is smart regulation for smart grids in the context of the transformation of the energy system. In their analysis, the authors point out different issues in regulatory frameworks with regard to asset innovation. This includes the hysteresis between inputs (investments) and the resulting outputs (i.e. quality improvements in electricity networks or asset innovation). This lag implies that the related expenses may be realized in a different regulatory period than the related benefits occur (dynamic efficiency). Therefore, it seems more difficult to adequately anchor cost cutting incentives for CAPEX than for OPEX as the latter cost category features a stronger short-term potential to raise efficiencies. Consequently – so the argumentation of the authors – OPEX are subject to stronger incentives than CAPEX. The authors point out that under regulatory frameworks with strong cost cutting incentives, network operators may have a tendency towards asset innovation retention as the potential for efficiency gains due to technological progress is low because of the missing dynamic time frame.

Reviewing the academic literature leads to the conclusion that incentive regulation puts a strong focus on productive efficiency. In contrast, long-term incentives for investments into a technological upgrade of the network infrastructure (technological progress), which require a dynamically efficient resource allocation of CAPEX, are not sufficiently promoted. A regulatory dilemma emerges *vis-à-vis* the on-going transformation of the energy system.[5]

In order to enrich the debate, this article now reviews pertinent international experiences seeking for appropriate practical solutions to address this dilemma. Reference is made to two examples, namely the United Kingdom and Italy. These countries currently revise or plan to revise their regulatory approach towards investments and technological progress in different shapes. This treatise is presented in the following two chapters.

[5] Müller et al. (2010).

3. INTERNATIONAL EXPERIENCES

3.1. UNITED KINGDOM: REGULATORY REFORM TOWARDS THE RIIO MODEL

The United Kingdom can be characterized as a pioneer in the regulation of energy markets. The process of liberalization and privatization of the British utilities started in 1983. The famous RPI-X-regulation[6] was implemented in 1990 and shows a transparent history in the continuous enhancement of the regulatory approach. Therefore, the British approach serves as a pertinent example due to the long experience and pioneering features in their regulatory approach and provides useful lessons for the revision of regulatory regimes.

An independent regulator, the Office of Energy Regulation (Offer) was established in 1990. In 1999, Offer merged with the Office of Gas Regulation (Ofgas) to form the Office of Gas and Electricity Markets (Ofgem). The first regulatory period (price control review) started in 1990/1991 with the objective to promote efficiency and hence lower tariffs of distribution companies. Albeit lacking effectiveness at the beginning, the second and third price control reviews (1995–2000 and 2000–2005 respectively) significantly reduced distribution charges. Studies show empirical evidence that distribution companies succeeded in achieving significant efficiency improvements and delivering gains to customers.[7]

The incentive regulation model of distribution networks in Britain features a hybrid approach since 1990. Under the current arrangements, OPEX, CAPEX, and quality of service (including network energy losses) are incentivized separately within the so called 'building blocks' approach. That is, the different cost components receive diverse regulatory treatment.[8]

Dipping more thoroughly into Ofgem's approach towards investments it becomes visible that the option for the fragmented regulatory approach allows for a flexible regulatory treatment of capital expenditures. This is, first of all, due to the fact that Ofgem opted for a pure OPEX benchmarking. This approach eliminates the economic pressure to also keep CAPEX low that regulatees face when a total cost-based (TOTEX) benchmarking approach applies. In other words, the TOTEX approach implies that

6 RPI-X-regulation denominates the approach of price-cap-regulation employed in the United Kingdom. The allowed tariffs (price-cap) are determined ex ante by the regulator and are corrected for the rate of inflation, measured by the Consumer Price Index (UK Retail Prices Index, RPI) and for expected efficiency savings x (x-factor). The x-factor is determined by benchmarking the network operators cost vis-à-vis its peers. The individual x-factor of a network operator reflects the efficiency potential to catch up with the best in class. The network operator receives a reward when he outperforms its efficiency target and a penalty in case of underperformance. This constitutes the heart of incentive regulation. The inherent logic of this regulatory approach has been adopted in many other countries worldwide.

7 Jamasb and Pollitt (2007).

8 Please refer to Müller (2011) for a detailed description of the 'building blocks' approach.

efficiency targets will be derived from both operational and capital expenditures. This may hamper the network operator in undertaking the necessary investments in favor of reducing its cost of capital to realize higher efficiency gains. A pure OPEX benchmarking, however, stimulates short term-efficiency only with regard to operational expenditures and leaves room for regulatory flexibility to deal with investments. In order to provide for a reasonable level of CAPEX (old assets fall out of the regulated asset base due to depreciation as new investments are added due to reinvestment cycles) Ofgem introduced the so-called 'menu of sliding scales' to individually assess the required level of CAPEX as from the fourth price control review (2005–2010). According to their investment strategy, network operators may choose between a regulatory menu of a rather cost-based driven regulation of their CAPEX or a rather incentive-based approach.[9] Although different shortcomings should be noted with regard to the menu approach, three essential positive features should be acknowledged: i) the provision for the network operator's individual investment cycle (high vs. low investment needs), ii) regulatory room for corporate optimization between OPEX and CAPEX and iii) the possibility to receive a bonus when outperforming regulatory targets.[10]

In addition to this, Ofgem's approach allowed an ample increase in the allowance for investments for network modernization within the fourth regulatory period. This allowance boost has resulted in a positive x-factor for the sector as a whole and can be interpreted as a strong incentive to stimulate investments.[11] Over and above a specific treatment of investment, Ofgem also implemented regulatory provision for innovation. Basically this includes the introduction of an innovation funding initiative (IFI) to recover research and development (R&D) expenditures via regulated tariffs. Moreover, the instrument of so-called registered power zones (RPZ) involves the option to create tariff space for demonstration projects aiming at the connection of distributed generation.[12]

Empirical evidence[13] and Ofgem's[14] overall appraisal suggest that RPI-X regulation significantly reduced distribution charges and improved the network operators' efficiency. However, critical reflection about the British regulatory approach with all its multifaceted features initiated a review of its 'fit for purpose' given the upcoming challenges for networks triggered by ambitious decarbonization and sustainability targets[15] and the required technological paradigm shift of all energy related activities.

9 Please refer to Müller et al. (2010) for a detailed description of the 'menu-of-sliding-scales' approach.

10 Ibid.

11 Jamasb and Pollitt (2007).

12 For an in-depth overview of the British regulatory approach towards these two instruments and the current and upcoming regulatory treatment of R&D expenditures, please refer to Bauknecht (2010).

13 Jamasb and Pollitt (2007).

14 Ofgem (2010a).

15 The targets set by the British Government stipulate a 80 percent reduction in greenhouse gas emissions by 2050 and a decarbonised electricity generation by 2030.

With Ofgem's RPI-X@20 initiative, an in-depth review of energy network regulation aimed at finding an optimal framework enabling energy network companies to operate networks required for a sustainable low carbon energy sector took place.

The new regulatory framework, which will come into effect as from 2013, is known as the RIIO model, abbreviated for **R**evenues set to deliver strong **I**ncentives, **I**nnovation and **O**utputs. The underlying regulatory formula can be synthesized as the following equation: Revenues = Incentives + Innovation + Outputs.[16]

Overall, the RIIO model is based on the RPI-X framework. Whilst some existing features were enhanced, others were retained and new dimensions were added. The following sections briefly point out the key features of the RIIO model[17]:

3.1.1. Revenues and outputs

Revenues are set upfront during the price control review process based on a revised 'building blocks approach'. These are the revenues a network operator is allowed to recover to efficiently deliver pre-defined outputs. These outputs will form the central regulatory reference value. The outputs to be delivered are defined during the review process. They are based on the following six categories: 'customer satisfaction', 'reliability and availability', 'safety', 'conditions for connection', 'environmental impact', and 'social obligations'.

In each category, a subset of so-called primary outputs is defined reflecting customer expectations with respect to the operational business of the network operator. An example should illustrate the approach: taking the output category 'reliability and availability', the sub-categories 'customer interruptions' and 'customer minutes lost' could constitute primary outputs. For the category 'environmental impact', the sub-category 'carbon footprint of networks including losses' would be a further example for primary outputs. These primary outputs can be usually measured in quantifiable units (e.g. customer minutes lost or CO_2 emissions). Output delivery is encouraged by incentives directly linked to primary outputs and the allowed revenue in the price control. This means, at each price control review the regulator determines a specific level of performance at which the network operator is expected to operate. In return, the network operators specify in their business plans what primary outputs they plan to deliver and what they expect to be the associated cost. The regulator sets the allowed revenues accordingly assuming an efficient funding of the determined outputs.

3.1.2. Holistic and time-limited innovation stimulus

As a matter of fact, long-term thinking takes a central role in setting the output categories. Therefore, the new regulatory framework includes a flexible instrument to

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16 Ofgem (2010a).

17 In the following, please refer to Ofgem (2010b).

proactively provide for dynamic efficiency. The instrument 'secondary deliverables' was implemented to protect against the risk that pure delivery of primary outputs might be inefficient for certain activities and hence the required performance level in a certain category could not be reached within the eight years horizon of the regulatory period. With this instrument, the framework provides the opportunity for network operators to include expenses in their business plans aiming at innovative projects of which costs would occur immediately but benefits would only materialize within a longer time frame. To capture the horizon of dynamic efficiency, milestones in project delivery are defined. With regard to the price control, this implies that network operators will merely be allowed to raise revenues from consumers given a specific milestone is reached. On the one hand, this approach has been chosen to provide certainty to network operators to engage in long-term investments and on the other hand that customers do not overpay and their money is only raised when there is certainty that network operators will deliver benefits in the long run. However, this instrument requires a deep level of involvement and scrutiny for both network operators and Ofgem. Therefore, it will only be applied to ample investments associated with a high level of uncertainty.

In addition to this holistic approach the RIIO model includes a time-limited 'Innovation Stimulus Package' based on the Low Carbon Network (LCN) fund that is already applied in the current regulatory period. Broadly speaking, this instrument provides the opportunity that network companies or third parties may apply for a fund aimed at demonstration projects. Moreover, it explicitly encourages third parties to apply if they can carry out a specific task more innovatively and efficiently than network operators.[18]

In order to provide consistency with the regulatory features described above the following further enhancements have been made.

3.1.3. Extension of the regulatory period (price control review) to eight years

The extension of the regulatory period to eight years has been realized to provide network operators with more flexibility to efficiently optimize their delivery of outputs in a longer perspective and to reduce regulatory risks. This vision also involves drawing on longer-term business plans. If necessary, the regulatory scheme includes the option of a tightly-scoped mid-term review. This review will, however, not involve any new review of capital cost or existing output incentives. This approach goes hand in hand with a long-term regulatory commitment to the WACC and the network operators individual risk situation.[19]

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18 For a detailed overview of the 'innovation stimulus package' planned within the RIIO model, please refer to Bauknecht (2010).

19 Ofgem (2010b).

3.1.4. *Business plan review as core instrument of the price control review process*

In their business plans, network operators demonstrate how they plan to deliver the determined outputs. Within this appraisal, the onus is on the network operator to justify that its plan to deliver output constitutes the best option to meet the RIIO targets. Depending on the quality of justification, the regulator employs an assessment tool-kit to evaluate the business plans. This tool-kit is associated with an increased level of regulatory scrutiny. If the companies provide a reasonable, well-argued justification in its business plan, the company will be fast-tracked through the price control review process. If however the regulator has certain doubts, he may choose to apply additional regulatory instruments (comparison with performance in former regulatory periods, TOTEX benchmarking techniques) evidencing the network operators efficiency situation.[20]

3.2. ITALY: CONTINUOUS AND PRAGMATIC ENHANCEMENT OF INCENTIVE REGULATION

Italy reflects upon one decade of quality and incentive regulation both starting in 2000. Tariff regulation is implemented through a price cap mechanism with efficiency goals for transmission, distribution, and metering services set by the Italian regulator Autorità per l'energia elettrica e il gas (AEEG) over a four-year regulatory period. The electricity sector has currently undergone the third regulatory period (2008–11). The planned productivity gains (x-factor) for this period amounted to 2.3 percent for transmission, 1.9 percent for distribution, and 5.0 percent for metering.[21] Nota bene that these efficiency targets only apply to operating costs as from the third regulatory period. In the previous ones, the price-cap mechanism was also applied to amortization and depreciation (regulatory period 2004–2007) and additionally to the return on capital (regulatory period 2000–2003).[22]

The AEEG updates the price cap (the allowed tariffs) on an annual basis. This update provides for two cost categories. Firstly, taking into account the reduction in real terms regarding operating costs and, secondly, a review of depreciation and return on invested capital, to adapt for new infrastructure investments to improve security of supply, competition, and quality of service.[23] As regards the investment update, companies annually report their investments made in the year t – 1, which will be allowed in the tariffs for the year t + 1.[24]

20 Ibid.
21 AEEG (2009).
22 AEEG (2008).
23 Ibid.
24 Ibid.

Over and above this regulatory change to solely focus on OPEX efficiency as from the third regulatory period, the Italian regulator also revised the approach towards investments. As from 2011, the regulator discriminates between different investment categories for transmission and distribution investment respectively, which are associated – provided they fall in a certain category – with an extra rate of return. On the transmission-level this new incentive system allows an extra rate of return for i) investments dedicated at the development of transmission capacity in order to reduce congestion between market zones and intrazones and ii) investments in Net Transfer Capacity (NTC) on electricity borders. The extra allowance amounts to three percentage points extra return on invested capital for 12 years over the 6.9 percent base rate of return. On the distribution-level, this new regulatory instrument grants an extra return of two percentage points over the 7 percent base return for crucial investments for the distribution system such as new high-voltage/medium-voltage transformation stations, replacement of existing transformers with low loss transformers as well as medium-voltage active grid automation, protection and control systems. The additional rate of return is recognized for a period of 8 or 12 years.

In parallel, the AEEG introduced efficiency indicators in order to measure, on an experimental basis, the extra benefit an individual investment from the abovementioned categories brings to the system. The objective of these indicators (relevant for both transmission and distribution investments) is to define an order of priority for infrastructure investments and to provide objective criteria to grant an adequate extra rate of return.[25]

Originally, quality regulation has been implemented in Italy in order to improve the continuity of supply level compared to other European countries and to bridge national differences between North (higher quality level) and South (lower quality level). Overall, quality levels steadily decreased in Italy as confirmed by the statistics. However, exceptional events were responsible for increases in SAIDI values in 2003 and 2008.[26] For the regulatory period 2008–11, the Italian regulator introduced a new scheme of penalties and incentives providing for both the duration of power outages (similar to the previous years) and to the number of both long and short outages, so that all outages lasting more than one second are now covered. Moreover, service quality regulation is applied.[27]

Smart meter roll-out is quite advanced in Italy, it having the largest smart meter base in the world.[28] This is mainly due to Enel's initiative that equipped 30 million households with smart meters between 2001 and 2005. A nationwide rollout should be realized by the end of 2011. Smart meters are used to give feedback to consumers

25 Ibid.

26 AEEG (2009).

27 CEER (2008) and AEEG (2009).

28 Meeus et al. (2010).

and to introduce new business models and services based on the metering data. A recent government decree enjoins distribution companies to install visual displays for its consumers.

All smart metering activities fall under the network operators' responsibility. Related tariffs are determined by the regulatory authority and include OPEX and CAPEX with a smart metering specific WACC amounting to 7.2 percent in the third regulatory period. The Italian regulator adjusts metering tariffs on an annual basis and adjustments refer to OPEX only. They also have a specific x-factor, which is 5 percentage points higher than the x-factors for distribution (1.9 percent) and transmission (2.3 percent). Moreover, smart metering activities have a link to quality regulation. The network operator receives a bonus of 15 euro per customer when using smart meters to record unplanned interruptions longer than three minutes. Getting this reward, however, requires that the network operator fulfills ambitious smart metering roll-out provisions. By 31 December 2011, 95 percent of smart meters should be installed.[29]

In parallel, the Italian regime includes instruments to promote innovation. A first instrument has existed since 1999 consisting of a general R&D component in the network tariff, which is paid by all consumers. The Italian regulator is responsible for determining this levy, which currently amounts to 0.03 c€/kWh. The objective of this levy is to fund R&D activities that have an impact on the electricity system.[30] Above all, the regulatory authority incentivizes demonstration projects within a competitive procedure. Selected projects will be awarded with an increased WACC of 2 percentage points for 12 years.[31]

4. ANALYSIS

The objective of this chapter is to analyze the previously described approaches in the United Kingdom and Italy. To this end, reference is made to the challenges of incentive regulation addressed in chapter two. Reflecting on these insights and the approaches presented in chapter three, the following critical factors of incentive regulation may serve as evaluation criteria to compare and scrutinize the regulatory features in the two reference countries.

- Separate regulatory treatment of CAPEX: does the regulatory regime account for an individual treatment of CAPEX?
- Provision for technological progress: does the regulatory regime account for asset innovation/a technological upgrade of the infrastructure?

29 Austrian Energy Agency (2011).

30 More information here: www.ricercadisistema.it/.

31 Meeus et al. (2010).

- Long-term perspective: does the regulatory regime put related investments in a long-term context, i.e. does it account for dynamic efficiency?
- Output vs. input oriented regulation: does the regulatory regime focus on input or on output oriented regulation?
- Level of complexity: does the regulatory regime pursue a heavy-handed or a light-handed approach?
- Level of regulatory scrutiny: how deeply is the regulator involved in the corporate activity?
- Technology preferences by regulator: does the regulator explicitly incentivize certain technologies?
- Level of regulatory commitment: how strongly does the regulator commit to given incentives?
- Transformation of policy targets in regulatory incentives: does regulatory action reflect overall policy targets, e.g. reduction of CO_2 emissions or increase the share of RES?

This list is neither exhaustive nor are the criteria necessarily mutually exclusive. The indicators rather determine one another. Taking this as a given, the following evaluation matrix gives a starting point to objectively assess the approaches taken in the United Kingdom and Italy. However, the objective of this analysis is not to provide a statement of the quality of the respective approach (the actual implementation of RIIO is yet missing) but to elicit to what extent and in which way the critical factors of incentive regulation address the identified regulatory dilemma.

Figure 1. Evaluation Matrix

Evaluation criteria	United Kingdom	Italy
Seprate regulatory treatment of CAPEX	++	+
Provision for technological progress	++	++
Technology preferences by regulator	–	+
Long-term perspective (dynamic efficiency)	++	+
Transformation of policy targets in regulatory incentives	++	–+
Output oriented regulation	++	+–
Input oriented regulation	++	–+
Level of complexity	++	–+
Level of regulatory scrutiny	++	–+
Level of regulatory commitment	+–	+–

Source: own depiction.

Separate regulatory treatment of CAPEX – Both countries apply a separate regulatory treatment of CAPEX, albeit with different intensity. Italy used to limit the regulatory involvement to a CAPEX exemption from efficiency targets and directly transformed capital expenditures in regulated tariffs. Recently however, the AEEG slightly increased the separate regulatory appraisal of investments with an increased rate of return for specific investments and the simultaneous introduction of an efficiency assessment. In contrast, the UK initiated an in-depth CAPEX appraisal with the 'menu-of-sliding-scales' approach and pursues this path within the RIIO-model. With its implementation, the network operator is supposed to set out its investment strategy to meet the long-term regulatory targets. This involves a well-justified business plan linking anticipated capital expenditures to the delivery of primary outputs. With the instrument of 'secondary deliverables' the framework moreover provides the opportunity for network operators to include expenses in their business plans aiming at innovative projects of which costs would occur immediately but benefits would only occur within a longer time frame.

Provision for technological progress – Besides a separate CAPEX treatment both regulatory regimes provide for technological progress to differing extents. The UK approach includes different instruments to promote technological progress. The RIIO price control review process will facilitate the inclusion of technical and commercial innovation related to capital expenditures with the instrument 'secondary deliverables'. Moreover, the explicit and time-limited innovation stimulus will especially provide for asset innovation in order to adapt the British energy sector to the decarbonization and sustainability targets. Both instruments leave the decision for a certain technology to the network operator. In contrast to this, the Italian regulator explicitly incentivizes investments featuring a specific technology with a higher rate of return. This may involve demarcation problems. Moreover, it includes a *regulatory presumption on a certain technology* as the supported investment categories are highly specified. This may result in a distorted roll-out of certain technologies ignoring the actual network requirements.

Long-term perspective (dynamic efficiency) – The RIIO approach explicitly assumes a long-term value for money perspective and adjusts CAPEX-related regulatory instruments accordingly. This statement allows for short-term static inefficiencies in favor of more efficient electricity networks in the long run due to technological progress. This enables a *transformation of overarching policy targets* (long-term horizon) in regulatory functionalities. In Italy, the regulatory sensitivity for a dynamic efficient resource allocation of CAPEX is expressed less explicitly than in the United Kingdom. However, the regulator starts assessing specific investments with the individual benefit they bring to the system.

Output oriented vs. input oriented regulation – The Italian approach to leave the investment activity mainly to the network operator (apart from the abovementioned efficiency appraisal of specific investments) and the elaborated quality regulation imply a strong focus on outputs. If the quality level deteriorates, the company receives a penalty but, apart from that, the Italian regulator does not apply an in-depth control of inputs. The Ofgem, in contrast, pursues a mixture of input and output oriented regulation. That is, the regulator does not only control the investment activity ('menu-of-sliding-scales' approach, business plan review) but also controls if related pre-defined output measures are reached. This involves a high *level of regulatory complexity* and a high *level of regulatory scrutiny* in the United Kingdom whilst both categories can be ranked as rather low to medium in Italy.

Regulatory commitment – Last but not least, the level of regulatory commitment can be ranked as quite acceptable in both countries. The Ofgem extends regulatory predictability to 8 years with the implementation of RIIO, albeit keeping the option open to intervene with a 'mid-term review'. The AEEG sticks to regulatory periods of four years but grants the extra allowance for specific investments for up to 12 years.

In summary, the analysis shows that the approaches in the United Kingdom and Italy are characterized by quite antagonistic regulatory features. The emerging RIIO model puts investment to promote technological progress in a long-term context, designs regulatory functionalities for overarching sustainability and decarbonization targets and adjusts related regulatory instruments accordingly to facilitate a long-term value for money consideration. These can be considered as essential regulatory measures to solve the abovementioned regulatory dilemma. However, the enhancements of the regulatory regime simultaneously risks to be rather 'heavy handed' due to the high level of complexity and regulatory scrutiny. The yet due practical regulatory implementation of RIIO has to prove if the new functionalities actually deliver a dynamic efficient outcome. Notwithstanding these caveats, Ofgem can be considered as the pioneer in pursuing new regulatory design options. In contrast, the Italian approach can be considered as pragmatic. Italy does not pursue such a holistic interpretation of dynamic efficiency as the United Kingdom. The light-handed incentive regulation scheme was enhanced on a continuous basis to better provide for required investments and technological progress in a changing energy market. However, this involves technology preferences given by the regulator and may imply demarcation problems.

5. CONCLUSION

This paper addressed the question of whether incentive regulation is still fit for purpose to provide dynamic efficient investment stimuli to enable the paradigm shift towards technological progress in electricity networks. In accordance with economic literature, the main issue lies in the fact that incentive regulation mainly incentivizes productive efficiency (OPEX). Dynamic efficient investments, however, are not sufficiently promoted. *Vis-à-vis* the new requirements on electricity networks, due to the transformation of the energy system, a regulatory dilemma emerges.

Searching for practical examples to solve this dilemma, this paper presents two case studies of regulatory regimes and investigates to what extent the United Kingdom and Italy implement enhanced regulatory measures towards technological progress and dynamic efficiency. The United Kingdom can be considered as a pioneer in pursuing this path by changing the priorities from a regulatory focus on cost-efficiency to a holistic innovation-oriented approach with a forward-looking, long-term value for money perspective in terms of CAPEX. All this happens in order to facilitate a technological adaptation of the networks to the overarching decarbonization and sustainability targets. Hence, the prospective RIIO model in the United Kingdom suggests that, theoretically, a regulatory stimulation of dynamic efficient investments and a transformation of climate targets into regulatory functionalities are indeed possible. The United Kingdom example features the new regulatory awareness to undertake a long-term perspective with respect to regulatory incentives instead of focusing solely on short-term efficiency targets. The downside, however, is a very planning intense regulatory scheme and a high level of regulatory scrutiny. Italy's approach implies a less holistic but rather straightforward solution to promote technological progress where the regulator may increase the rate of return for specific investments and investigates their efficiency. This may involve demarcation problems and technology preferences given by the regulator.

Overall, the albeit antagonistic approaches taken in the UK and Italy are inspiring steps towards a more sensitive regulatory approach to stimulate technological progress and dynamic efficiency notwithstanding the formulated caveats. In order to tackle the overarching climate targets and to facilitate the paradigm shift towards technologically enhanced network infrastructure integrating a high share of RES, it is crucial that other countries become alert, initiate the regulatory debate and follow their examples.

In doing so, decision makers should critically reflect upon the 'fit for purpose' of regulatory incentives on a regular basis. However, especially emerging incentive regulation schemes should not be changed substantially in order to allow the desired effects in terms of productive efficiency to unfold. This should provide a more robust basis for further evaluation. Nevertheless, regulatory reflection should take into account a gradual, anticipative 'smartening' of regulatory incentives for technological progress and dynamic efficiency.

To conclude, the most challenging issue is transferring environmental policy targets and their implications on networks into adequate regulatory functionalities. Reconfigured incentives aiming at dynamic efficient investments should strike a good balance between the right timing of implementation, pragmatism avoiding a too ambitious level of regulatory involvement, and overly targeted incentives which might imply regulatory presumption on the right technology.

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