**[Accelerate energy transition with smarter regulation for faster grid digitalization]**

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## Overview

The energy transition is already under way and will have consequences in all activities of the sector's value chain. Changes in the electricity network will be critical to allow a greater integration of renewable energy production, more energy efficiency and a more active participation of consumers (Irena, 2019). This movement requires a transformation in the activities of the electrical networks, particularly stimulated by the investment in new Smart Grids’ (SG) technologies in the distribution networks. Yet, the power utilities in Western countries have not stood out positively in relation to other sectors, in terms of the evolution of innovation and productivity (Mac Kinsey, 2017; OECD, 2020; Jamasb, 2005; IEA, 2020). This is true despite the general regulatory contexts of the network ativities of the electricity sectors that provide relatively high and stable returns, compared to other sectors (BCG, 2020, CEER, 2020).

Regulation has an important role in the implementation of innovations in the electricity networks (Lind et al., 2019; Galus, 2017; Faerber et al., 2018). Several authors argue that the path for promoting innovation in networks can be sustained on the direct financing of innovation through tariffs or own funds (Damian et al., 2008; Jamasb and Pollit, 2015). Others suggest mixed approaches, based on incentive-based regulation that emulate a competitive context, in which investment returns are not fully guaranteed and may require greater funds allocation in innovation to “survive” (Jenkins and Arriaga, 2017; Cambini, et al., 2016). But these analysis overlook the specificities of several network innovations, whose intangibility and spillovers alter the profile of costs and returns over time. Regulation should consider the specificities of the new needs required to the networks and differentiate according to the results of the new technologies (Tuballa, 2016; Galus, 2017; Grubler et al., 2018). In the few studies that analyse the implications of different regulatory approaches in the promotion of cost saving technologies like SGs, it is shown that investment benefits more from an incentive based regulation than a “cost plus”, even if the former is typically associated with overinvestment (Marques et al., 2014; Brown & Sappington , 2018). Still, it has not been shown the effect of dynamic impact of the savings in capital costs. For example, investments in SG technologies that allow reduction of planning and network management costs may have a distinctive regulatory treatment than those with positive externalities, whose effects go beyond the network activity. Those investments may have an impact on the entire energy system and on the whole economy and even in the society, such as theft reduction, energy efficiency, fewer power interruptions, air quality improvement, improved security of supply, that should be taken into account in the regulatory process. Therefore, it is reasonable to assume that these gains should receive a different regulatory treatment.

The main objective of this paper is to improve the understanding about the most appropriate regulatory approaches to modernize the distribution networks and enable the energy transition. It will focus on the expecteted gains and functionalities of the invesments that will namely enable the development of new services, reinforce efficiency and resilience, while preserving the social and economic affordability.

## Methods

We develop a decision model that assesses the changes in the firms’ incentives to invest in new technologies like SG under different regulatory schemes. The model assumes that companies maximize their expected gains by allocating their resources to Operational Expenditures (OPEX), Capital Expenditures (CAPEX) or Innovation, under different regulatory contexts. We compare two representative regulatory settings: TOTEX; and hybrid regulatory schemes. The former considers the total amount of expenditures, irrespectively of their origin; the hybrid schemes refer to a combination of instruments often used in the practice: rate of return for CAPEX and price cap for OPEX; pure cost plus with dedicate innovative funds. In a both static and dynamic manner, the models account for the relations between the cost structure of the network companies and the different types of SG investments. This includes the positive externalities that go beyond the operation and planning of the network infrastructure. The model also tests for the effect of different assumptions concerning the sharing of gains between consumers and companies.

The base equations of the decisions models are the following:

$-I\_{SG}+\sum\_{t=1}^{T}\frac{DC}{\left(1+r\right)^{t}}+\sum\_{t=1}^{T}\frac{DI\_{C}}{\left(1+r\right)^{t}}+\sum\_{t=T+1}^{\infty }\frac{rγ\left(I\_{SG}-DI\_{C}\right)+\left(1-α\right)DC}{\left(1+r\right)^{t}}+\sum\_{t=1}^{\infty }\frac{ξG}{\left(1+r\right)^{t}}\geq 0 $ (1)

$-I\_{TotexSG}+\sum\_{t=1}^{T}\frac{DTOTEX}{\left(1+r\right)^{t}}+\sum\_{t=T+1}^{\infty }\frac{\left(1-δ\right)DTOTEX}{\left(1+r\right)^{t}}+\sum\_{t=1}^{\infty }\frac{ξG\_{Totex}}{\left(1+r\right)^{t}}\geq 0$ (2)

where *T* is the next time review period, $α$ is the proportion of the cost savings that is transferred to consumers after *T*, $γ$ is the proportion of the investment expenditure that is accrued on the ﬁrm’s regulatory asset base after *T*. *DC* is the cost decrease, *r* is the ﬁrm’s cost of capital. $I\_{SG}$is the amount invested in SG technology, *DIC* is the reduction of conventional investment due to the SG investment, $ξG$ is the proportion of external benefits due to SG that is retained by the company, $I\_{TotexSG}$ is the amount invested in SG technology in a TOTEX regulatory scheme, $DTOTEX$ is the costs decrease in a TOTEX regulatory scheme, $ξG\_{Totex}$ is the proportion of external benefits due to SG that is retained by the company in a TOTEX regulatory scheme. The first equation applies to a hybrid regulatory scheme, while the second one applies to a TOTEX regulatory scheme.

## Results

A TOTEX regulatory scheme, that fully emulate a competitive situation, may have the potential to more effectively promote innovative investments or processes that brings benefits in reducing total network costs (CAPEX+OPEX) than cost plus or other regulatory schemes. That result is still valid if the innovative technology lead to an increase in OPEX (due to new types of digital innovations that need more software resources, for instance), provided that total costs decrease. However, there is a large set of technologies that have positive externalities, which go beyond the network activities, such as technologies related to advanced metering infrastructure/wide area measurement systems (smart metering and communication), selfcomsumption and demand active management. On such circumstances, the results show that there is no a one size fit all regulatory scheme and a case-by-case approach should be preferred.

## Conclusions

In the energy transition context, when regulatory concerns embraces many targets, regulatories schemes must be adequately adapted to the specificities and advantages of each type of innovative investment or process. The presented models allow to analyze the advantages of a TOTEX regulatory approach to promote innovation which reduces the future needs of investment in the network, comparing with traditional schemes (hybrid or cost plus). These models also allow for adjusting regulatory schemes to innovation, whether it leads in cost savings in network activities or to progresses beyond these activities, such as ensuring the emergence of prosumers. These results advance over previous works (Marques et al., 2014; Costa et al., 2017), helping to incentivize regulated industries like electricity network companies to innovate more, to a level more comparable to the best performing industries.

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