Regulatory and ownership determinants of unbundling regime choice for European electricity transmission utilities

Alexis Meletioua,b,*, Carlo Cambinib,c, Marcelo Masera
d

a Joint Research Centre (JRC), Directorate for Energy, Transport and Climate, Via Fermi 2749, 21027 Ispra, Italy
b Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Torino, Italy
c IEFE, Bocconi University, Milan, Italy
d Joint Research Centre (JRC), Directorate for Energy, Transport and Climate, Westerdijkweg 3, 1755 LE Petten, The Netherlands

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ABSTRACT

One of the fundamental provisions of the European electricity directives is the so-called unbundling of structures and functions. Vertical disintegration with Full Unbundling (ownership unbundling or independent system operation) is considered an important step toward electricity market restructuring. While Full Unbundling (FU) models appear to be the most prevalent, several European countries adhered solely to less stringent forms of unbundling. Using a dataset of the 35 major electricity transmission utilities in Europe, this study provides an econometric analysis to understand the individual effect of regulation and ownership structure on the decision to adopt more stringent unbundling regimes. The overall results show that incentive-based or hybrid regulatory schemes and private ownership, are associated with a higher probability that a country will opt for FU.

1. Introduction

In the late 1980s, policymakers and academic experts largely agreed that the energy generation should be provided through organized and competitive markets, losing its monopoly status (Fox-Penner, 2010). However, the distribution and transmission segments of the industry remained as “natural” monopolies. This form of industry restructuring was known as “liberalization” or “deregulation.”

In Europe, the liberalization and restructuring of the electricity markets started mainly with the introduction of the European Union’s first Electricity Directive (notably Directive 96/92/EC) on February 19, 1996. This first legislation package was followed by a second in 2003 (Directive 2003/54/EC) and a third in 2009 (Directive 2009/72/EC). The overriding goal of the three directives was to design an efficient, competitive, and sustainable energy market across the European Union (EU). One of the fundamental provisions of the three directives is the so-called “unbundling”: the separation of the market functions traditionally provided by vertically integrated undertakings (VIU), into functionally independent parts (Tanrisever et al., 2015). Various forms and degrees of unbundling are possible (Nillesen and Pollitt, 2011). The least stringent form is accounting unbundling while ownership unbundling is the most extreme. In between these two forms is legal unbundling; these are described in detail in the next section.

Since the first steps toward market liberalization in 1996, there has been debate over the “right” degree of vertical network unbundling to secure a level playing field (Brunkreft, 2015). Initially, the first electricity directive involved accounting unbundling. Going beyond the provisions of the first directive, the second introduced a reinforced unbundling regime where Transmission System Operators (TSO2) had to be operated through separate legal entities when they were part of a VIU (legal unbundling). While the unbundling provisions of the first and second directives were accepted in their positive impact, European Commission (EC) proposed the third Electricity Directive3 imposing...
minimum obligations on TSOs with regards to structural unbundling. Structural unbundling allows utilities choosing between two principal options: a Full Unbundling (FU) model or an Independent Transmission Operator (ITO) model. FU provides for two conceivable options: ownership unbundling (OU) or an independent system operator (ISO).

Since the implementation of the first and second directives, a small number of countries have gone beyond the requirements of accounting and legal unbundling (LU) by implementing a FU model. At the same time, many countries have opposed stringent forms of unbundling in favor of legal unbundling (Van Koten and Ortmann, 2008). In the course of the third electricity directive, the countries were required to tighten the previous unbundling rules for transmission, choosing between the two principal options: a FU model or ITO model. Remarkably, some countries refrained from choosing FU models, although it was one of the legal alternatives; they opted instead for an ITO model, which amounts to a stricter enforcement of the legal unbundling provisions that were already mandatory (Lindemann, 2015).

Motivated by the fact that some countries have chosen FU models while others an ITO or LU, we hypothesize that variation in the choice of structural regime can be explained in part by a set of diverse factors. This study is particularly concerned with the effect of the regulatory scheme and the ownership structure of the utility. Our analysis also controls for several other potential influences, including overall government effectiveness, socioeconomic conditions, and network and market characteristics.

Many studies focus on the choice of the ideal regulatory scheme following vertical disintegration of monopolies. Pollitt (2008) argues that ownership separation under specific models may require stronger regulation than under vertical integration or a legally unbundled TSO with significant government ownership of electricity assets. In this analysis, we treat “regulation” as a primary control variable. Russo (1992) demonstrates how regulation in the electric utility sector can influence the choice of governance structure, such as the level of vertical integration. More recently, Lindemann (2015), based on a theoretical analysis, argues that the decision to either implement OU or adhere to ITO model depends on the objective the regulatory authority determining the level of vertical separation. In a more general context, Green et al. (2006) and Pollitt (2009) note a strong correlation between the strength of the regulatory intervention and the progress with electricity reform in a given country. This study attempts to answer the question, “which regulatory scheme (e.g., cost-based vs. incentive-based) can create the most favorable conditions for the adoption of FU?”

Privatization and unbundling are usually closely interlinked (Hofbauer, 2009). Some privatization of electricity network assets has already taken place in Europe, but there is still relatively limited evidence regarding effects on unbundling decisions. The first European experience, in the UK, showed an apparent relationship between the privatization of state-owned electricity networks and ownership unbundling. On the contrary, the experience of Nordic countries showed that the full state ownership of electricity transmission networks might also facilitate ownership unbundling. In general, privatization changes the characteristics of owners and corporate governance, and affects responses to external factors, including capital markets (Jamasb and Pollitt, 2008). Heddenhausen (2007) qualitatively described the interdependence between liberalization and the privatization of formerly state-owned utilities in four European countries.

Several empirical studies have assessed the impact of unbundling on consumer prices and investments, including those by Gugler et al. (2013), Nardi (2012) and Fiorio and Florio (2009). However, empirical analysis of the determinants of unbundling regime preference is scant. To the best of our knowledge, only Van Koten and Ortmann (2008) studied the effect of various control variables, primarily the corruption perception index, on the choice of structural regimes for the electricity transmission sector in Europe. Our paper adds to this literature in three ways. First, in contrast to earlier work, we use panel data from 1995 to 2016, which captures a longer and more recent period than previous studies. Second, we introduce key variables of interest, namely regulatory and ownership factors. Third, we use a large sample of 35 utilities, from 28 European countries: 25 European Union member states (EU-25), Albania, Switzerland, and Norway.7

The paper is structured as follows. Section 2 discusses the different unbundling regimes and presents a review of the regimes implemented by European countries. Section 3 elaborates on the factors used in the quantitative analysis. Section 4 develops our main hypotheses and provides the data sources. Section 5 presents the steps of the analysis and discusses the results. Finally, Section 6 sets out the conclusions.

2. Transmission unbundling in the European electricity sector

2.1. Early unbundling: accounting, administrative and legal models

Toward the policy goal of market liberalization, the first step under the 1996 directive involved accounting separation. Accounting unbundling, which is the least stringent form of unbundling, requires electricity undertakings to keep separate internal accounts for each of their transmission and distribution activities, to prevent cross-subsidization. The internal accounts must include a balance sheet and a profit-and-loss statement for each activity. Although it was never officially recognized by EC energy legislation, a mixed form, “administrative unbundling” (AU), can also be distinguished. AU implies only accounting and/or organizational separation of generation and transmission activities. Organizational separation refers to separating operational and management activities for transmission and generation activities.

The second and more deliberate step towards market liberalization was legal unbundling under the 2003 directive. Legal unbundling (LU) requires transmission systems to be operated through separate legal entities when a VIU exists. In principle, legal unbundling means that the essential input must be controlled by a legally independent entity but a firm that is active in the downstream market is still allowed to own this entity. Ownership under legal unbundling entities the downstream firm to receive the entity’s profits, but interference in the entity’s operations is forbidden (Höfﬄer and Kranz, 2011).

2.2. Structural unbundling regimes

Although second directive provisions have raised the unbundling of network operators to a new level, in its sector inquiry of 2007, the EC argued that the development of competition in European energy

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7 Our dataset includes the major European TSOs and transmission asset owners, of each EU-28 member state, Albania, Switzerland, and Norway, which are also members of ENTSO-E. Our analysis excludes regional TSOs as well as the electricity utility from Malta. According to the Maltese regulatory authority, in Malta there are no transmission systems or TSOs; there is only an electricity distribution system covering the whole country (forms part of a VIU) (MRA, 2015).

8 Albania, Switzerland, and Norway are three Western Europe states that are not members of the European Union (EU). Some studies suggest that the influence from the EU is evident, particularly in electricity policy and reforms, but parallels with EU member states indicate that non-membership of the EU, though influential, is not decisive (Bartle, 2006). The introduction of electricity reforms in the periods of second and third electricity directives in Norway and Switzerland respectively, also supports this conjecture.
markets was too slow (EC, 2007a). As a result, EC put the issue of ownership unbundling at the center of the third energy package, which was presented to the public in 2007 (Brunekreeft, 2015; Heddenhausen, 2007). In principle, the third directive allows utilities to choose among three alternative unbundling regimes: a) ownership unbundling (OU), b) independent transmission operator (ITO), or c) independent system operator (ISO). At the utility level, the models are mutually exclusive while at the country level, when the transmission system is operated by more than one utility, different unbundling models may be adopted. Additionally, under special conditions, the directive allows for derogation from the unbundling provision when the member states can demonstrate that there would be substantial problems for the operation of their small isolated electricity systems (EC, 2009). Fig. 2a and b shows that the most prevalent unbundling regime implemented is OU followed by the ITO and ISO models. Overall, twenty counties opted for OU, seven for ITO, and three for ISO. The UK and Germany apply a mix of different models. Out of the 35 utilities, twenty-one have OU, nine have ITOs and five have ISOs.

Each of the unbundling regimes is designed to remove the incentive for VIUs to discriminate against competitors with regard to access to the network and commercially relevant information, as well as to provide incentives to invest in infrastructure (EC, 2010). Despite the expectation of the EC for the models to be equally effective, the ITO model has frequently been criticized for providing an insufficient degree of structural separation between network operation and production or supply activities. A considerable number of studies classify the ITO model as a strict form of legal unbundling rather than as a full unbundling regime (such as Geldhof and Vandendriessche, 2008; Höffler and Kranz, 2011; Meyer, 2012; Brunekreeft et al., 2014; Brunekreeft, 2015; Lindemann, 2015). Additionally, Nardi (2012) describes ITO as a “softer” form of unbundling. Brunekreeft (2015) states that the ITO model requires strong administrative rules, but does not require network divestiture; as such, ownership structures are left intact. Both the OU and ISO models are considered more stringent unbundling forms when compared to the ITO model. OU implies a strict ownership separation of the TSO from the commercial business, while the ISO model splits the transmission ownership from the system operation. Under the ISO model, the operator has no direct interest in the financial performance of any of the assets that incorporate or utilize the transmission network. For these reasons, we grouped the OU and ISO models under the category of FU and examined the adoption of FU against the alternative of an ISO.

2.2.1. Preliminary full-unbundling

Since the implementation of the first and second directives, fourteen countries have gone beyond the requirements of accounting and legal unbundling by implementing a preliminary form of full unbundling (PFU), which includes germainal forms of the OU and ISO models. The UK and Sweden implemented ownership unbundling policies shortly before the introduction of the first directive in 1996 (EC, 2007b). In the UK, the Electricity Act of 1989 initially introduced legal unbundling of the transmission network, which was followed by ownership unbundling in 1995 (Heddenhausen, 2007). In Sweden, ownership unbundling was initiated in 1996, before the EU directive came into effect (IEA, 1996).

2.2.2. Full-unbundling

2.2.2.1. The OU model. Under ownership unbundling (OU), commercial (generation and supply) and transmission activities must be controlled or owned by independent entities with these entities not allowed to hold controlling interest in both activities. Moe specifically, under Article 9(1) (b) of the third directive, the same entity is not entitled to exercise control over an undertaking performing any of the functions of production or supply, and to exercise control10 or exercise any right over a TSO or transmission system. The same rule applies for the alternative situation.11 The provision does not exclude the case of the same person exercising rights in both transmission and generation or supply sectors as long as these rights are significantly limited.

2.2.2.2. The ISO model. Conceptually, a transmission network consists of two parts: the transmission owner (TO), who owns the assets, and the system operator (SO), who operates the network (Brunekreeft, 2015). Under the ISO model, both the TO and SO are ownership unbundled from the rest of the system, with the SO being asset-light and the TO having no system operation function (Pollitt, 2008). However, the ISO model also allows for the remaining of the transmission assets within VIU when, for instance, it is difficult12 to proceed with separating generation and transmission assets ownership (Nardi, 2012).

Although only officially appearing in the EU legislation in the provisions of the third directive, a germinal form of ISO model was introduced and applied in a few European countries much earlier. Italy was the first country that applied this model in 1999 was, followed by Greece (2002), Hungary (2004), and the UK and Ireland (2005). Today, the ISO model is only applied in a few countries, namely, the UK, Ireland, and most recently, Latvia, where in 2013 the government appointed an SO. In the UK, National Grid acts as a TSO for the English and Welsh ownership unbundled network, while it is the ISO of the Scottish network that is still owned by two VIUs (Moselle, 2008).

Some of the countries that adopted ISO have since abandoned the model. Specifically, the utilities in Greece, Italy, and Hungary abandoned the ISO model after a few years of implementation experience. We do not consider the experience in Greece and Italy as full-unbundling and we do not classify these endeavours as “the first time of full unbundling.” In 2002 Greece implemented a hybrid ISO model that in practice was a combination of organizational and legal unbundling rather than full unbundling. We classify the Greek utility as structural unbundled, adopting an ITO model in 2012, during the course of the third directive. In 2002 and 2003, Italy implemented a combination of legal and ownership unbundling, where the SO coexisted with several TOS. We classify the Italian utility as ownership unbundled in 2004. In Hungary, only two years after the 2004 adoption of the ISO model, unbundling became less stringent, switching back to a form of legal unbundling in 2006. We classified the Hungarian utility fully unbundled in 2004, adopting the ISO model and opting for the ITO model in 2012, during the course of the third electricity directive.

2.2.2.3. The ITO model

The ITO model was based on a proposal made by Germany, France, and six other member states at the end of January 2008. The proposal was the result of a political compromise among member states, after a long period of negotiations. Substantially, it reflected the member states’ controversy about an “optimal” vertical structure and the notion that there may not be a “one-size-fits-all” approach (Brunekreeft, 2015). Out of the eight member states that have initially opposed OU, five of them have applied an ITO model while the rest have opted for other.

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10 Control is constituted by rights, contracts or any other means which, either separately or in combination and having regard to the considerations of fact or law involved, confer the possibility of exercising decisive influence on an undertaking.

11 The alternative situation is that of a person exercising control over a TSO, and exercising control or any right over a firm performing any of the functions of production/supply. The rights may include the power to exercise voting rights, the power to appoint members of the supervisory board, the administrative board or bodies legally representing the undertaking, and the holding of a majority share.

12 When there is no previous implementation of accounting unbundling.

13 Austria, Bulgaria, Slovakia, Greece, Luxembourg, and Latvia.

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9 The fourteen, ownership unbundled utilities come from the following countries: Czech Republic, Denmark, Italy, the Netherlands, Norway, Portugal, Poland, Slovakia, Slovenia, Spain, Hungary, Finland, Ireland, and the UK.
alternatives. Latvia implemented an ISO model, Slovakia implemented OU, and Luxembourg has maintained legal unbundling. Germany and Austria, who formed the main opposition, has adopted an OU model with ITO. Croatia and Switzerland also apply an ITO model. Switzerland, although not a part of the EU, is fully compliant with the provisions of the third directive, implementing an unbundling regime that is closer to the ITO than the FU.

In compliance with the rules of the third directive, an ITO model may be adopted when, on the date of entry into force of the directive (3 September 2009), the transmission system belonged to a VIU. Under the ITO model, the ownership structures are left intact, as the TSO remains part of a VIU. Three individual yet independent organizations are in charge of ensuring the compliance of the VIU as long as required administrative rules are in place: a supervisory body, a national regulatory authority, and EC compliance.

2.3. Variation in unbundling regimes during the course of the three directives

The subsequent analysis is predominantly based on two comprehensive sets of data that cover (1) the adopted structural regime, and (2) a compiled list of explanatory factors and controls. The data cover 35 major electricity transmission network utilities, from 28 European countries: EU-25, Albania, Switzerland, and Norway.

In the course of the three directives, we consider a parameter (t) as the time of change of the structural model, affecting an individual utility (i), from country (j), toward a more stringent one. We consider (t) the year in which the utilities have implemented structural unbundling, irrespective of which electricity directive was implemented at that time. For some utilities that have not implemented structural unbundling in the course of the first and second directives, we consider t instead as the year of legal unbundling.

For the scope of our analysis, we collected data on structural regimes at time (t) as well as one-year prior to the adoption of a more stringent unbundling regime. On the contrary, over the course of the third directive, LU is not an option; utilities are obliged to opt for the FU or ITO model only.

To account for the different options and conditions prior to and after the implementation of the third directive, we split our analysis into two observation periods: Period A for t ≤ 2009 and Period B for t > 2009. As such, Period A includes the utilities that have followed structural unbundling for the first time in their corporate history, in the course of the first and second electricity directives (see Fig. 1). We also include the utilities for which full unbundling was rejected in favor of legal unbundling. For these utilities, we consider t the time that they were legally unbundled for the first time in their corporate history. Period B includes the utilities that followed different structural unbundling regimes during the course of the third electricity directive.

3. Regulatory scheme and ownership structure of the European utilities

The values for the variables representing the regulatory scheme and the ownership structure concern the period of one year (t-1) and two years (t-2) before the adoption of a more stringent unbundling regime at time t, from an individual utility i. The variable “regulatory scheme” remains relatively steady in different observation periods, while the “ownership structure” variable changes between t-1 and t-2, in periods A and B respectively.

3.1. Regulatory scheme

TSOs incur expenditures for operation and maintenance (OPEX) and capital investment (CAPEX) in order to provide transmission under service quality standards (Friaset al., 2007). Regulation is provided to remunerate OPEX and CAPEX after defining which costs are eligible to enter the pricing scheme.

Different criteria can be used to classify European countries according to regulatory schemes. For the scope of current analysis, following Cambini et al. (2016), we consider whether regulatory schemes induce cost efficiency or productivity by providing relevant incentives to TSOs. Economic regulation takes the form of: a) cost-based models, b) incentive-based models, and c) hybrid models. Out of the 35 utilities in our sample, 54% were subject to incentive-based schemes, 26% to hybrid schemes, and the remaining 20% to cost-based schemes. Fig. 2a shows the applicable regulatory scheme at the country level.

The cost-based approach sets prices that cover the capital and operating costs of production and enable the utility to earn authorized rates of return. Rate-of-return regulation (Blank and Mayo, 2009) may provide relatively weak incentives for cost efficiency (Cambini et al., 2016). Traditional rate-of-return regulation encourages capital investments if the rate of return exceeds the cost of capital, and favours capital over operating expenses (Avery-Johnson effect), and may not promote cost efficiency (Tahvanainen et al., 2012). In our sample, seven countries (Belgium, Bulgaria, Croatia, Finland, Greece, Switzerland, and Sweden) implemented cost-based regulatory schemes prior to structural unbundling. In Croatia, rate-of-return regulation is implemented but without accounting guidelines for treatment of CAPEX (ERRA, 2009).

Fig. 2a shows that the incentive-based regulation was widely used in European countries prior to structural unbundling. Price-cap regulation (RPI-X regulation) is the earliest and most well known incentive-based scheme that incorporates an adjustment for anticipated productivity.

14 At this level, we also consider unified (vertically integrated) ownership. Unified ownership requires no unbundling; both network and generation activities continue to be owned and managed by the same company.

15 We call baseline conditions the unbundling regimes implemented before the adoption of a more stringent one.

16 The sample contains, a considerable number of utilities (46%), which were already structural unbundled before the introduction of the third directive, which made structural unbundling mandatory.

17 Avery-Johnson(AJ) effect may be mischaracterized as empirical evidence of the AJ effect are disputed; see Law (2014).

18 Although, Kihm et al. (2017), argue that the traditional cost-based regulation can employ a variety of incentive-oriented tools to approximate the forces that would shape performance in a competitive market. These tools may include regulatory lag, prudence reviews, and incentive returns.
Variations include revenue caps, revenue or profit sharing, performance measurement (yardstick) regulation, and menus (Joskow, 2008). Norway was among the first to implement market-oriented reforms in the electricity sector, and switched from rate-of-return to incentive-based regulation in 1997. Today, Norway is applying a form of quality-adjusted revenue-caps. Similar to Norway, Germany switched from cost-based regulation to an incentive-based scheme in 2009 (Frontier-Economics, 2012).

Many European regulators have developed and implemented hybrid models that combine rate-of-return and incentive-based regulation (Blank and Mayo, 2009). In Portugal, for example, the allowed returns are based on CAPEX and only OPEX is affected by the efficiency measures (Crispim et al., 2014). In Italy, TSOs are incentivized to trim OPEX costs by a factor of X year-on-year, but the invested capital is remunerated at a rate that is fixed in periods of four years (Cambini and Rondi, 2010; Crispim et al., 2014; Schiavo et al., 2013). In Hungary, the regulatory approach used by the regulator is a price-cap mechanism even though some items are subject to rate-of-return regulation (ERRA, 2009).

Over the last few years, apart from incentives for cost efficiency, regulators have introduced incentives related to service quality and innovation. Quality-of-service regulation has become a topical issue, particularly in the context of large-scale disturbances and adverse weather phenomena (Tahvanainen et al., 2012). National Energy Regulators (NERs) have also developed dedicated incentive mechanisms to stimulate innovation in the transmission sector. Often targeted at different technologies or commercial arrangements, these mechanisms are
designed to support innovation that TSOs are unlikely to undertake in the absence of incentives.

Our study accounts only for the cost-efficiency parameter of regulation, leaving aside other features such as quality of service and innovation incentives, as it is a central aspect of regulation. Regulatory judgment about allowances for future CAPEX are a prominent issue for regulators, even more so as reliability considerations have greater political importance, and infrastructure in the 1950s and 1960s approaches the end of its useful life and component failures increase (Brandstätt et al., 2011; Joskow, 2006). The decision to exclude quality of service and innovation incentives was underpinned by two more considerations. First, the effect of cost efficiency and quality incentives may be contradictory. In theory, price-cap regulation suggests an inclination to quality deterioration (Ajodhia and Hakvoort, 2005; Giannakis et al., 2005). Companies might respond to cost-saving incentives by reducing service quality, rather than by pursuing efficiency improvements. Hence, the calculation of a single index to capture the efficiency improvement is challenging. A second issue is that a very limited number of European countries apply innovation-stimulus mechanisms. In most European countries, research, development, and demonstration expenses are treated like any other cost; that is, there is no specific compensation for the risks involved in testing new technologies and processes.

3.2. Ownership structure

The variables presented in this section concern the ownership structure of electricity transmission utilities one year before the first-time implementation of structural unbundling.

3.2.1. Control and cash-flow rights

In principle, the definition of corporate ownership relies on both voting rights (VRs) and cash-flow rights (CFRs). VR is the right to participate in corporate governance by way of shareholder voting, while CFR is the right to receive capital gains, dividends, and other distributions from the firm. In this study, the definition of corporate ownership refers predominantly to VRs rather CFRs. We identify the ultimate shareholders as those who control an absolute majority (i.e., more than 50%) of the VRs or hold enough VRs to have de facto control (Faccio and Lang, 2002; LaPorta et al., 1999).

Out of the 35 utilities in our sample, only two are widely held, while the rest have at least one ultimate shareholder. Both cases of widely held companies are in the UK. Of the utilities with ultimate owners, only 18% have more than one ultimate shareholder; the rest have a single ultimate shareholder. Overall, 54% of the utilities are subsidiaries of holding companies while the remaining 46% are distinct legal entities. Where the utility is a subsidiary, we consider the ultimate shareholders of the parent company.

The separation between ownership of equity and control is a useful way to understand the degree to which VRs are proportional to the CFRs. Our sample includes two utilities where the principle of proportionality is not satisfied and shareholders reduce their CFR below their VR by using either voting caps or shares with superior VRs as control-enhancing mechanisms. A voting cap is a restriction prohibiting shareholders from voting above a certain threshold irrespective of the number of voting shares they hold. In Spain, legal limitations regarding shareholding in the TSO (REE) have been established; no individual or voting rights (VRs) and cash-flow rights (CFRs). VR is the right to participate in corporate governance by way of shareholder voting, while CFR is the right to receive capital gains, dividends, and other distributions from the firm. In this study, the definition of corporate ownership refers predominantly to VRs rather CFRs. We identify the ultimate shareholders as those who control an absolute majority (i.e., more than 50%) of the VRs or hold enough VRs to have de facto control (Faccio and Lang, 2002; LaPorta et al., 1999).

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company may hold more than 3% of REE’s VR or CFR, except for the State holding company (SEPI) that can not hold less than 10% of the capital stock (REE, 2003). Shares with superior VR assign more VR to one class of stock than an other; thus, two classes of shares, usually denoted as class A and class B shares (class A are superior to class B shares) are issued. This is the case for the Finish TSO (Fingrid), where class A shares confer three to ten votes each; while class B shares confer one vote each (Fingrid, 2016).

The utility sample exhibits a complex web of cross-ownership patterns among utilities, where the State holds both direct and indirect control rights. Cross-shareholdings refers to a situation where company X holds a stake in company Y, which, in turn, holds a stake in company X (ESGI, 2007). In few cases, we used a “weakest link” approach to measure the State’s ultimate control rights (UCR). According to this approach, the UCR of a given investor is simply equal to the minimum ownership stake along a chain (i.e., the weakest link). For instance, in the German TSO, Amprion, the State controls 30% of the utility through a cross-shareholding structure: the State holds 15% of VR in the two major shareholders respectively.

3.2.2. Public vs. private ownership

We utilize two broad categories of ultimate shareholders: (1) the State and (2) the private investors. Our definition of the State includes both central and local (municipal) governments (e.g., including state assets funds. Private investors include widely owned corporations, financial institutions, insurance companies, mutual funds, and pension funds.

Because our definition of ownership relies predominantly on control rather than equity, we developed a categorization reflecting the extent to which VR are held by the State or by private investors. Table 2 summarizes the relevant categories. Among the 35 utilities in our sample, 51% are fully state-owned and 23% mostly state-owned as shown in Fig. 2b. Only a small number of utilities have been privatized; 17% are fully privately owned and 9% are mostly privately owned.

The sample includes a few cases where ownership structures transformed before the ownership unbundling. In 2010, Tenet became the owner of the German TSO, E.ON Transpower, after a sell-off deal with Germany’s largest energy group, E.ON. Following in the footsteps of E.ON, Electrabel agreed to sell its majority stake (64% in 2004) in the Belgian TSO, Elia. Starting in 2005, Electrabel gradually reduced its stake and eventually withdrew from the company in 2010. Similarly, on 19 May 2010, Belgian system operator Elia and the Australian infrastructure IFM Investors became the new shareholders of the former Vattenfall transmission system operator, now called 50Hertz. Finally, in July 2011, RWE AG reached an agreement on the sale of a 74.9% share in TSO Amprion. In light of the very high levels of investment that were required for the expansion of the network (i.e., €3 billion until 2021), a consortium of mainly German institutional investors became the new ultimate shareholder.

4. Data description and hypotheses

4.1. Dependent variable

As noted in Section 2, the dependent variable values concern the unbundling regime at (t) as well as one-year prior the change of the unbundling regime at (t-1). The time of unbundling (t) and the baseline conditions at (t-1) are critical parameters in our analysis; thus extra caution was required to ensure that data were collected consistently across miscellaneous data sources. First, we collected official data on structural regimes from European Commission reports (2016, 2014, 2007b, 2003, 2002, 2001). Then, all the collected data were cross-referenced by analysing the annual reports of European NERs as well as recently published articles (such as Gugler et al., 2013; Van Koten and Ortmann, 2008). Where discrepancies were found, we relied on the official data derived from EC reports as our primary source.

4.2. Independent variables

We ran an econometric model with the transmission unbundling regime as the dependent variable and regulatory scheme (REG) and ownership structure (OS) as the variables of main interest. Summary statistics of independent variables for period A and B are shown in Table 3.

4.2.1. Regulatory scheme

To map structural regimes for transmission utilities in Europe, we gathered information from a broad range of sources, including institutional and consulting reports as well as academic research. Initially, we sourced data from Eurelectric and ERRA reports (Eurelectric, 2014, 2013; ERRA, 2006, 2009). Additional data were collected from annual reports of NERs as well as recently published papers (e.g., Cambini et al., 2016). Where discrepancies were found, we relied on the data derived from the NERs’ reports as our primary source.

Following the literature on economic regulation of utilities, we formulated our hypotheses as follows:

- **Hypothesis 1**: the presence of incentive-based regulation, or a hybrid approach, will increase the probability of a country adopting a more stringent unbundling regime like PU.

- **Hypothesis 2**: the presence of cost-based regulation will increase the probability of a country adopting less stringent unbundling regime, such as LU or ITO.

To formulate our hypotheses, we considered three aspects:

First, a key concern in the European policy debate on vertical industry structures is the adequacy of investment incentives and the assurance of non-discrimination of VIUs with regard to accessing to the transmission network. FU and forced access to the incumbent transmission grid enables competition in the generation sector but come at the cost of lost vertical economies (Gugler et al., 2013). In countries with cost-based regulation and the prevailing business model for the VIU is adding new infrastructure to increase revenues, may be less need for investment incentives as the investments are fairly high (Fuentes-Bracamontes, 2016; Höfler and Kranz, 2011). Assuming the greater effectiveness of FU against ITO model in terms of investment incentives, a FU model may be a less desirable option in this context.

Second, combining less stringent forms of unbundling with rate-of-return regulation may allow higher profits for VIUs. A rate-of-return regulated monopolist can enhance profits through vertical integration (Führ, 1990). Van Koten and Ortmann (2008) argue that with high transmission fees, rate-of-return regulated VIUs may be able to cross-subsidize their generation activities. In this context, we conjecture that in countries where there is cost-based regulation, unbundling regimes such as ITO or LU that allow vertical integration may be a more desirable option.

Third, in countries implementing an incentive-based or a hybrid form of regulation, there would be a high probability of opting for a FU model as part of an evolutionary process. A recent paper from Fuentes-Bracamontes (2016) discusses the dynamics of new utility business
models based on technological innovation and regulatory adaptation, including restructuring. In this context, endeavours to move regulation beyond cost efficiency and toward innovation may require full ownership and/or operation separation.

4.2.2. Ownership structure

The data concerning the OS variable are predominantly based on publicly available information concerning corporate ownership in the European electricity transmission sector. Primarily, we sourced data from individual utility annual financial reports for the years 1995–2016. Whenever the corporate annual reports were unavailable or were missing data, we gathered data from miscellaneous sources such as stock market websites and NERs' reports.

The impact of state ownership on the choice of structural model is unclear. State-controlled firms may have objectives or incentives that differ from privately-controlled firms; these objectives are not purely financial (Gugler et al., 2013) and may include public policy objectives, such as the build-out of reliable, secure and sustainable electricity transmission infrastructure. Privately-controlled firms, pursuading purely financial and not consumer-oriented goals, may oppose FU in favor of LU or ITO model. Still equipped with considerable influence on the electricity sector, politicians in some countries might inhibit structural changes to state-owned utilities that would threaten the treasury's income (Lindemann, 2015).

4.2.3. Control variables

Apart from the main independent variables, we use the following control variables: the market share of the largest electricity generator (GCR), the net import of electricity relative to the total electricity consumption in a utility's control area, NetIMP, the length of the electricity transmission network, KML, government effectiveness, GE, the gross domestic product (GDP) per capita (pc) in EU-28, GDP.pc and the time trend, TT.

To define GCR, we use an indicator that shows the market share of the largest generator in the utility's control area, also known as one-firm market concentration (CR1). The CR1 values were sourced from Eurostat's website (Eurostat, 2016) as well as from miscellaneous sources. The net production of the largest generator is considered to go to market share relative to total production. We opted for CR1, against the alternative of the Herfindahl-Hirschman Index (HHI). Because the HHI was not readily available. We included the GCR variable because we believe that in countries with high concentrated electricity generation markets, where typically an incumbent VIU holds the largest market share, VIU will exploit their dominant position against a FU. On the contrary, smaller market shares of the VIU can result in financially weaker utilities being more vulnerable to a FU model.

For the NetIMP, all the relevant data were sourced from ENTSOE's online data portal. The net imports of electricity in utility's network were divided by the net electricity consumption. Positive values denote that the utility is a net importer while negative ones denote that the utility is a net exporter. Using this ratio, we directly take into consideration the net imports of the utility as well as the consumption in the utility's area. Similar to Van Koten and Ortmann (2008), we included this variable, expecting that a utility that is a net exporter gains more from owning the network. That said, a net importer might be able to hamper competing imports from abroad and thereby increase its profit.

For the length of electricity transmission network (KML), data were sourced from the annual technical and financial reports of the individual utilities. In the electricity transmission business, the substations and the high to medium voltage transmission lines are considered a primary production asset. Today, transmission-level voltages are usually 110 kV and above. For the calculation, of the values of KML variable, of an individual utility, we sum up the distance of lines (in kilometers) of different voltage levels, namely 110 kV, 150 kV, 220 kV, and 400 kV. By including the variable KML, we account for the size of the transmission network and thereby the relevant size of the utility. The more kilometres (km) of electricity lines owned by a utility, the larger the utility size and the respective business activities. Alternative proxies to reflect the size of a utility may be its revenues or customers served. Since the values of revenues are highly correlated with those of the variable of the main interest, REG, a pragmatic alternative could be the size of the utility’s customer base (CUS). We found the correlation analysis between KML and CUS found to be 74% and 79% in periods A and B respectively. We speculate that the larger the company, the more likely it is for the company to opt for a LU or ITO model.

Government effectiveness (GE) data were sourced from The World Bank's website. GE variable captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. We conjecture that countries with higher GE scores will implement more stringent unbundling regimes.

The GDP.pc data were obtained by the Eurostat's website (Eurostat, 2016). GDP.pc is an explanatory variable that varies over time, and as such, can capture the transnational dimension of the economic conditions affecting the electricity transmission sector. Considering the economic growth and the average increase of GDP per capita in EU-28, the last 20 years, we expect that the GDP.pc will have a positive effect on unbundling (more stringent unbundling).

Similar to Van Koten and Ortmann (2008), we also included a time-trend variable (TT). We expect the TT variable to have a positive effect.

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Table 3

| Variables/Statistics | Units | Period A (t ≤ 2009) | Period B (t > 2009) |
|----------------------|-------|---------------------|---------------------|
| REG                  | none  | N | Min/Max | Mean | Standard deviation | N | Min/Max | Mean | Standard deviation |
| OS                   | VR    | 70 | 0/100 | 66.05 | 40.95 | 68 | 0/100 | 66.30 | 40.21 |
| GCR                  | %     | 70 | 1/100 | 49.8 | 30.12 | 68 | 1/100 | 43.74 | 26.45 |
| GDP,pp               | €      | 70 | 23289 | 1476 | 68 | 25000/27000 | 25704 | 283 |
| NetIMP               | %     | 70 | −0.006 | 0.17 | 68 | −0.5/0.65 | 0.013 | 0.19 |
| KML                  | km    | 70 | 11183 | 16623 | 68 | 395/100000 | 12699 | 18667 |
| GE                   | percentile rank | 70 | 0.753 | 1.10 | 68 | -0.48/2.45 | 0.82 |
| TT                   | year  | 70 | 2001 | 3.09 | 68 | 2009/2016 | 2011 | 1.38 |

Note: The abbreviations ‘C,’ ‘H’ and ‘I’ stand for the terms ‘cost-based,’ ‘hybrid’ and ‘incentive-based’ models, respectively.

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23 Although innovation opportunities are limited for transmission, there is still place for TSOs to participate in pilot projects and seek for some innovative business solutions. See for example the active role of TSOs in a recent smart grid project survey (TSOs are leading 10% of the pilot projects surveyed) (Giordano et al., 2013).

24 The HHI sums the squares of the market shares in percentages of all relevant firms. The value of HHI is thus between 0 and 10,000.

25 Violation of the assumption of the absence of multicollinearity is discussed in Section 5.
because, over time, the EC has required more stringent unbundling.

5. Empirical analysis and results

5.1. Econometric model specifications

The main purpose of the econometric analysis is to examine whether the choice to adopt more stringent forms of unbundling for European transmission utilities is influenced by the regulatory scheme in place or the utilities’ ownership structure. To perform the analysis, we ran an ordered logistic regression model with the transmission unbundling regime as the dependent variable and regulatory scheme (REG), ownership structure (OS), and various control variables as regressors. All of the independent variables are lagged by one year. As noted before, t is the year of change in the unbundling regime of individual utility i in country j. The parameter s denotes time and s ∈ {t, t-1}. We perform two distinct yet alike sets of analysis and consider two regression models respectively: Model 1 for Period A and Model 2 for Period B.

Our analysis is based on the following equation:

\[ Um^* = \beta_0 + \sum_{k=2}^{3} \beta_k REG_{i,j,s-1} + \beta_2 OS_{i,j,s-1} + \beta_3 GCR_{i,j,s-1} + \beta_4 GDP_{i,j,s-1} + \beta_5 NetIMP_{i,j,s-1} + \beta_6 KM_{i,j,s-1} + \beta_7 GE_{i,j,s-1} + \beta_8 TT + \epsilon_{i,j,s} \]

Um is a latent variable that relates to three/four\(^{26}\) observable ordered unbundling types, in the typical manner:

\[ Um = \begin{cases} 1 & \text{if } Um^* < \mu_1 \\ 2 & \text{if } \mu_1 \leq Um^* < \mu_2 \\ 3 & \text{if } \mu_2 \leq Um^* < \mu_3 \\ 4 & \text{if } \mu_3 \leq Um^* \end{cases} \]

while the independent variables are defined as follows:

- Um stands for the transmission unbundling regime implemented for utility i, in country j, and can take the categorical values μ ∈ {FU, ITO, PFU, LU, AU).
- REG\(_{i,j,s-1}\) stands for the regulatory scheme implemented in the electricity transmission segment of country j.
- OS\(_{i,j,s-1}\) stands for the State’s control rights in the utility i of country j at time s-1.
- GCR\(_{i,j,s-1}\) stands for market share of the largest electricity generator in the utility’s control area at time s-1.
- GDP\(_{pp ij,s-1}\) stands for the ratio of kWh consumption to real GDP in EU-28 at time s-1.
- NetIMP\(_{ij,s-1}\) stands for the net imports of electricity relative to the total electricity consumption in utility’s control area, at time s-1 in country j.
- KM\(_{ij,s-1}\) stands for the length of the high/medium voltage transmission network of utility i, in country j, at time s-1, measured in km.
- GE\(_{ij,s-1}\) stands for the government effectiveness of country j
- TT stands for the time trend

In our model the predictor REG, is a categorical variable while the rest seven predictors (OS, GCR, GDP\(_{pp}\), NetIMP, KML, GE, TT) are numerical, continuous variables. REG\(_{i,j,s-1}\) (κ = 2, 3) are dummy variables representing hybrid and incentive-based regulation respectively, while the cost-based regulation is the omitted category. Hybrid (κ = 2) and incentive-based (κ = 3) models are the target groups, while the cost-based regulatory scheme (κ = 1) is the reference group.

We assume that the control variables are clustered by country. In the vast majority of European countries, electricity transmission system

\(^{26}\) For more details regarding the stringency of different unbundling models in periods A and B see Table 1., Section 2.

is operated by a single utility while in a small number of countries the system is operated by more than one utility (four utilities in Germany, four utilities in the UK, and two utilities in Austria). Utilities from the same country are clustered together (country-level clustering) and the observations are equally weighted.

The method of ordered logistic regression is often used to analyze longitudinal and clustered response data, particularly if responses are ordinal. It also allows the predictor variables to be a mix of continuous and categorical variables. Although logistic regression does not make many of the key assumptions of linear regression models that are based on ordinary least squares algorithms (particularly regarding linearity, normality, homoscedasticity, and measurement level) the data should still be assessed in terms of satisfying few assumptions.

First, the model should have little multicollinearity. Although multicollinearity is not an assumption of ordered logistic regression in a strict sense, it is still a necessary condition to ensure proper interpretation. To deal with multicollinearity, we relied on variance inflation factor (VIF) analysis. None of the predictors tested was correlated with the other predictors in the models and the VIF values were lower than the threshold concerned.\(^27\)

Second, a key assumption of regression analysis is that the modelled independent variables are not endogenous. Endogeneity is a typical problem that could prevent teasing out causal relationships from mere correlations. To purge our estimates of endogeneity, i.e., to eliminate the correlation between the explanatory variables and the error term, we have lagged the explanatory variables. Thus, in our model, the values of the dependent variable (at time t or t-1) are a function of the predetermined independent variable values, at time t-1 or t-2. The underlying assumption of this approach is that the actions taking place in the future cannot affect the actions that took place in the past. Lagged explanatory variables are a common strategy used in political science in response to endogeneity concerns in observational data\(^28\).

Van Koten and Ortmann (2008) argue that it takes time to decide on...
and implement an unbundling regime and, for this reason, they suggest that the unbundling regime should be regressed on the lagged explanatory variables.

5.2. Regression results

Table 4 summarizes the effects of each predictor when two different yet alike analyses are carried out, one for each of the considered observation periods; Period A and Period B. Model 1 considers t ≤ 2009 and Model 2 considers t > 2009. The meaning of ordered logistic regression coefficients, with log-link function, is not straightforward as that of linear regression; we report the odds ratios, or \( \exp(\beta) \) because is easier to interpret. Because of clustering, we use the robust Huber/White/sandwich estimator for the calculation of standard errors (SE).

Overall, it can be inferred that the differences between the results of Models 1 and 2 are minor, as the key variables’ significance levels and odds ratios values are quite similar. In Model 1, REG(2) and REG(3) variables are highly significant with p-values less than 1% while the OS variable is not significant. In Models 2, REG(3) is significant, with p-value at 10% while REG(2) is significant at 5% confidence level. Interestingly, in Model 2 the OS variable is highly significant, with p-value at 5%.

All of the estimated models show that the effect of REG(3) is highly significant and positive, suggesting that incentive-based regulation compared to cost-based regulation can be associated with a higher probability that a country will adopt a more stringent unbundling regime, with odds ranging from 5.48 to 10.29. Similarly, REG(2) is also highly significant and positive in both models considered. Specifically, when a hybrid scheme is used (instead of a cost-based one) the odds for a country to opt for more stringent unbundling regimes is higher by a factor of 8.28 or 7.11 in periods A and B, respectively. In period B REG(2) had more effect than REG(3) while in Period A this result was reversed. This finding suggests that, given policy developments, cost-based regulation may adequately influence the choice of a more stringent unbundling regime. We further discuss the regression results regarding REG, in Section 5.3 when we calculate the marginal effect of REG(2) and REG(3) on the probability of choosing PFU or FU.

The OS variable is significant at 5% level in Model 2 but insignificant in Model 1. For an additional unit of VR held by the State, the odds for a country to adopt a more stringent unbundling regime is lower by a factor of 0.988. With odds ratios slightly below the 1 (i.e., 0.988) the probability of the occurrence of lower stringent unbundling is almost equal to the probability of the occurrence of less stringent unbundling. This result indicates a negative but weak correlation between OS and Um. While the effect is significant, the OS variable does probably not exert a large influence. We further discuss these findings in Section 5.3 where we calculate the marginal effect of OS on the probability of choosing FU.

The variable GE was fairly significant in models 1 and 2. In Model 1 the p-value was equal to 8% while in Model 2 the p-value was equal to 1%. An increase in the GE with one unit (the government is more efficient) increases the odds of the average European country to opt for more stringent forms of unbundling by a factor of 1.7 and 2.8 in periods A and B, respectively. The results support our hypothesis that the probability of the occurrence of more stringent unbundling is higher by a factor ranging from 2.6 to 2.89.

The overall results suggest a non-significant effect of the GCR, KML and NetIMP variables for both models. The p-values for these variables were fairly high and higher than the standard 10% levels of significance. Regarding GCR, the analysis did not support our conjecture that in countries where VIUs possess large market shares in the generation segment will exploit their dominant position against more stringent unbundling. Similarly, regarding KML, the results suggest that more stringent unbundling is not dependent on utility size. Finally, regarding NetIMP, our results partially contradict Van Koten and Oertmann (2008), who found that the variable exerted a significant albeit small influence.

5.3. Marginal effects

We also calculated the marginal effect of the REG and OS on the choice of unbundling regime. The values at which the marginal effects are evaluated are the means of the independent variables.

The findings in Table 5 (Period A) suggest that hybrid (REG(2)) or incentive-based regulation (REG(3), increases the probability of a country to opt for PFU while decreasing the probability of a country to opt for AU and LU. More specifically, when hybrid and incentive-based regulatory schemes are applied, the probability of the average European country to choose a PFU increases by 40.5 and 44 percentage points respectively. Likewise, a hybrid and incentive-based regulation decrease the probability of a country to implement LU by 18.6 and 19.3 percentage points respectively. Table 6. (Period B) shows that hybrid regulation, REG(2), increases the probability of a country to adopt FU by 45 percentage points. Unlike the use of incentive-based regulation, REG(3), increases the probability of a country to adopt FU by 34 percentage points.

The results support our hypothesis about the positive relationship between full unbundling and incentive-based or hybrid regulation. Besides, Höfler and Kranz (2011) underline the necessity of a strong and thoroughly implemented regulation before changing the regime towards full separation. Also, if incentive-based regulation is meant to evolve to promote innovation and enable new utility business models, full separation may be required. Our results are also consistent with the literature on the rent-seeking behaviour of regulated firms because incentive-based regulation may limit opportunities in the absence of unbundling.

Concerning the OS variable, Table 6 shows that a decrease in the VR with one point (less public ownership) increases the likelihood of the average European country to choose ownership unbundling for transmission by 0.02 percentage points. The effect of OS is quite moderate as the value of the probability is less than 1. Our findings are in line with Florio and Florio (2007) and Jamash and Pollitt (2008), who argued that privatization is not a prerequisite for liberalization, restructuring, and ownership unbundling. By and far, our results seem to contradict the argument of OECD (2000), according to which the liberalization reforms have taken place against the backdrop of a broader paradigm shift from state ownership and centralized management of infrastructure industries, to one that favors decentralized structures, competition, independent regulatory oversight, and private ownership. Our results neither confirm nor contradict, Pollitt (2008)'s argument that ownership unbundling of transmission networks may occur at the same time as privatization, the restructuring of generation or

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30 It is worthwhile to mention that the variable is marginally insignificant in Model 2, with a p-value equal to 16%.

31 The true effect of OS may be even more negative than the one estimated in the analysis, given that the state ownership is very sticky and the EC pressed for structural unbundling, implying that, in the end, nearly all firms had some form of structural unbundling in place.
excluding one specific regime on the REG, OS and significant control variables while excluding one specific country. This technique is among the most well known re-sampling techniques and is particularly useful for validating of econometric models by using subsets from the data at hand.

In the first period (Model 1), the significance of REG(2) and REG (3) (p < 1%) were virtually unaffected, and the greatest weakening was caused by the exclusion of France (REG2 = 1.7%). France has not adopted stringent unbundling and uses a hybrid regulatory scheme. The regime changed from AU to LU in the course of the second directive. In the second period (Model 2), the effect of the REG(2) was virtually unaffected, while the effects of REG(3) and OS on the unbundling regime were less robust to the exclusion of countries. The significance of the OS (p < 5%) was weakened most by the exclusion of the UK (p = 14.7%). The significance of the REG(3) (p < 10%) was weakened most by the exclusion of Switzerland and Bulgaria. The exclusion of Switzerland from the regression lowered the significance of the REG(3), with p = 25.8%. The exclusion of Bulgaria lowered the significance of the REG(3) less drastically, with p = 14.7%.

### 5.4. Sensitivity analysis

We ran tests to determine the sensitivity of our results to the exclusion of specific countries. Applying a Jackknife technique\(^{*}\), we repeatedly ran ordered logistic regressions of the transmission unbundling regime on the REG, OS and significant control variables while excluding one specific country. This technique is among the most well known re-sampling techniques and is particularly useful for validating of econometric models by using subsets from the data at hand.

In the first period (Model 1), the significance of REG(2) and REG (3) (p < 1%) were virtually unaffected, and the greatest weakening was caused by the exclusion of France (REG2 = 1.7%). France has not adopted stringent unbundling and uses a hybrid regulatory scheme. The regime changed from AU to LU in the course of the second directive. In the second period (Model 2), the effect of the REG(2) was virtually unaffected, while the effects of REG(3) and OS on the unbundling regime were less robust to the exclusion of countries. The significance of the OS (p < 5%) was weakened most by the exclusion of the UK (p = 14.7%). The significance of the REG(3) (p < 10%) was weakened most by the exclusion of Switzerland and Bulgaria. The exclusion of Switzerland from the regression lowered the significance of the REG(3), with p = 25.8%. The exclusion of Bulgaria lowered the significance of the REG(3) less drastically, with p = 14.7%.

### 6. Conclusions

This paper analyses the correlation between regulatory and ownership factors, among others, and the structure of electricity transmission in Europe. We review the European regulatory status quo as well as the ownership structure of European transmission utilities, and employ an econometric model to assess their influence on the choice of unbundling regime, including ownership unbundling. In the context of the three EU electricity directives, we carried out two different analyses; one in the course of the first and second electricity directives (Model 1, period A) and one in the course of the third electricity directive (Model 2, period B).

If policymakers intend to promote more stringent unbundling regimes, then the use of an incentive-based or hybrid regulation may be better than cost-based regulation. In particular, when an incentive-based scheme is applied, the odds for a country to opt for more stringent unbundling regimes are fairly high and range from 85% to 91%. The results also imply that incentive-based regulation could be effective when policy goals include ownership separation. In this context, incentive-based or hybrid scheme may increase the likelihood that a country opts for full-unbundling, with the probabilities ranging from 34 to 45 percentage points. The use of a cost-based regulatory scheme considerably increases a country’s likelihood of adopting a less stringent form of unbundling, such as an ITO.

When the State controls the electricity transmission utilities, it is marginally less likely for a country to choose a FU model. For an additional percent of control rights held by the State, the probability of adopting FU decreases by 0.02 percentage points. This result is not straightforward and recommends that a mixed ownership structure may increase a country’s likelihood to adopt a FU.

Our analysis is confined to Europe-28 but could be extended worldwide to consider the experiences of other countries that opt for alternative structural unbundling regimes. Although our sample includes utilities from 28 European countries, the findings suggest policy recommendations for evaluating structural regimes for electricity transmission, along with regulatory and ownership options. In this regard, the results can provide useful policy directions, primarily to the European continent countries but also to countries worldwide.

### Disclaimer

The views expressed are purely those of the authors, and may not in any circumstances be regarded as stating an official position of the European Commission.

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**Table 5**

Marginal effects for the European countries in Period A.

| Country Code | Utility | Year of Unbundling | Unbundling Model |
|--------------|---------|--------------------|------------------|
| AE           | ÖST     | 2017               | OU               |
| AT           | APG     | 2012               | ITO              |
| AT           | VUN     | 2012               | OU               |
| BE           | Elia    | 2012               | OU               |
| BG           | ESO     | 2015               | ITO              |
| HR           | HOPS d.o.o. | 2015     | ITO              |
| CZ           | ČEPS    | 2005               | OU               |

Note: ***denotes significance at 1% confidence level, ** denotes significance at 5% confidence level, * denotes significance at 10%. Marginal effect values are expressed in percentage points.

**Table 6**

Marginal effects for the European countries in Period B.

| Country Code | Utility | Year of Unbundling | Unbundling Model |
|--------------|---------|--------------------|------------------|
| AL           | ÖST     | 2017               | OU               |
| AT           | APG     | 2012               | ITO              |
| AT           | VUN     | 2012               | OU               |
| BE           | Elia    | 2012               | OU               |
| BG           | ESO     | 2015               | ITO              |
| HR           | HOPS d.o.o. | 2015     | ITO              |
| CZ           | ČEPS    | 2005               | OU               |

Note: ***denotes significance at 1% confidence level, ** denotes significance at 5% confidence level, * denotes significance at 10%. Marginal effect values are expressed in percentage points.

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\(^{*}\) The Jackknife method is based on producing resamples that leave out a single sample point. This means that the number of resamples should be equivalent to the number of sample points in the initial, real samples.
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