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ON THE ASSESSMENT OF REGULATORS' EFFICIENCY. AN APPLICATION TO EUROPEAN TELECOMMUNICATIONS

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On the Assessment of Regulators' Efficiency. An Application to European Telecommunications*

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Abstract

This paper offers a methodology to assess the internal productive efficiency of National Regulatory Authorities (NRAs) based on the performances of regulated markets, measured in terms of the degree of market efficiency (either static or dynamic). The estimation procedure is based on a Data Envelopment Analysis (DEA), along with a smoothed bootstrap method and it is applied to telecommunications sector across 18 European countries, 5 of which are new accession countries, in 2005. After the discussion of several desirable outcomes for a telecom regulator, we construct an ad hoc database containing information about NRAs regulatory inputs and outputs. We run three bootstrapped DEAs in order to rank NRAs according to their efficiency in carrying out their regulatory activities. We find the NRAs in 2004 accession countries are more efficient in pursuing dynamic efficiency goals than the more experienced NRAs, while they perform generally worse when the regulatory outcomes are measured in terms of retail efficiency.

Keywords: regulators efficiency, Data Envelopment analysis, bootstrapping, telecommunications.

JEL classification: L86, L96.

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1 Introduction

During the second half of 20^{th} century, public utilites across industrialised countries have been characterised by a shift from public to private regulated management. Influential authors have pointed out that rather than less regulation, this liberalisation process has been requiring a different approach to regulation (Vogel, 1996; Newbery, 2000). This new way to intend the role of regulation opens many interesting issues; one of these issues is related to the evaluation of regulators' efficiency.

Despite sector specific regulatory authorities often operate within an extremely harmonized environment, as for example in the European Union, still they generate very different impacts on regulated markets: in many cases, the same form of regulation, characterized by the same regulatory instruments and objectives, does not have the same effects on market outcomes. These differences may have many explanations; the one we concentrate on in this paper points to the possible differences in the internal efficiency of national regulators.

In fact, regulation of public utilities can be both *effective* and *efficient*; effective in the sense of achieving its planned goals and objectives, and efficient in terms of achieving these goals at the least cost. The literature that deals with regulation of public utilities grew rapidly during the last twenty years; the vast majority of the contributions has been focusing essentially on the evaluation of regulatory effectiveness, either theoretically or empirically. Influential authors have been studying the role of informational constraints on regulatory activities (Baron and Myerson, 1982; Laffont and Tirole, 1986), while other authors have been focusing on comparisons between different regulatory regimes (Beesley and Littlechild, 1989; Resende, 2000). Quite surprisingly, the issues of how to evaluate regulators' productive efficiency and which are its determinants have been almost completely neglected in the literature. With this paper we start to fill this gap; our aim is in fact to provide a new and simple approach to the empirical evaluation of the internal efficiency of National Regulatory Authorities (NRAs hereafter) based on regulated market outcomes.

The provision of a methodology to assess NRAs internal efficiency is not only *per se* an interesting goal, but it is also useful to get a better understanding of the efficacy of different regulatory measures. In fact, once a measure of the productive (internal) efficiency of a regulatory body has been obtained, is then possible to embed this information in a more general analysis aimed at disentangling the efficacy of the regulatory measure from the ability (efficiency) of the NRA in putting it into force.

In order to illustrate our approach, we apply the proposed methodology to the telecommunications sector.We have decided to focus on this industrial sector due to a series of reasons; primarily because the telecom industry has the longer history of regulation among the various regulated sectors. Furthermore, telecommunications probably represent the most interesting sector where to conduct our research in view of its strong dynamics and complexities. In the ever changing environment that characterizes the telecom industry, the practice of regulation may be particularly complex: perhaps more then in other regulated sectors, in telecommunications regulators must find a balance between often diverging interests and need to keep pace with a highly dynamic environment. We have decided to restrict the analysis to European NRAs since they are subject to the common European Regulatory Framework stated by the European Commission.[1]

To the best of our knowledge, the only paper that deals with the NRAs productive efficiency is Afonso and Scaglioni (2006). The aim of the authors is to assess the efficiency of telecommunications NRAs across 16 European member states. For this purpose Afonso and Scaglioni build up a Composite Regulatory Performance Indicator by elaborating on two different sources, namely the Scorecard Report published by the European Competitive Telecommunications Association (ECTA) and the European Regulatory Institution Database (EURI) developed by the Regulation Initiative Research Group at London Business School. Nonetheless, their analysis shows many limitations and shortcomings due mainly to their output measures of NRAs activity which tend to identify the extent of the regulation rather than its effectiveness.[2] Unlike Afonso and Scaglioni (2006), our aim is to relate the NRAs

[1]The new EC regulatory framework was implemented on 25 July 2003. The framework provides the overall structure for the new regulatory regime and sets out the policy objectives and regulatory principles that NRAs must follow.

[2]ECTA Scorecards have been extensively criticized; for a critique of the use of the ECTA Scorecard as a

activity directly to the performances of the regulated markets, and therefore to measure the output of each NRA in terms of market outcomes. Output measures, must then be coupled with the amount of inputs employed in the regulatory activity in order to determine NRAs productive efficiency.

In this paper, we measure NRAs efficiency using Data Envelopment Analysis (DEA), a well known nonparametric estimation method of the production frontier. A bootstrap procedure is applied both to carry out proper inferential conclusions reducing the efficiency estimators bias and to evaluate their sample variability.

The paper is organized as follows. In the next section we describe our methodological strategy and present the data used for study. In Section 3 we present and discuss the results of the analysis. In the last section we provide some final remarks.

2 Methodological strategy

The central point of our empirical strategy is the estimation of the production frontier of the regulatory authorities; this can be done either through a parametric estimation of a stochastic production frontier or through a more general non parametric technique. The latter methodology is often preferred; reasons include: *i*) small sample size making parametric inference assumption unreliable, and *ii*) absence of an *a-priori* theoretical knowledge of the functional form of the production frontier.

Since both the above arguments apply to our problem, we have opted for a non parametric estimation; more specifically, in this paper we will estimate the non-parametric stochastic efficiency frontiers of the NRAs of eighteen European countries (Belgium, Czech Republic, Denmark, Germany, Spain, France, Ireland, Italy, Hungary, Netherlands, Austria, Poland,

tool to measure NRAs performance see Weeks and Williamson (2006). According to these authors, ECTA Scorecard rewards those NRAs that regulate more, rather than those NRAs that regulate better. Similar critiques can be addressed to EURI indicators: unlike ECTA Scorecard, EURI rewards NRAs also according to their administrative efficiency (e.g. how much rapidly they are able to take a decision). Yet it does not link the activity of each NRA to the efficiency of the regulated market.

Portugal, Slovenia, Slovak Republic, Finland, Sweden and UK) by applying the well known technique of Data Envelopment Analysis. Note that 5 out of 18 countries of the sample (namely Czech Republic, Hungary, Poland, Slovenia and Slovak Republic) have joined the European Union in 2004; this implies that these "new accession" countries have endorsed the common regulatory framework for telecommunications only in 2004. At the time of our data set, which refers to 2005, these NRAs had accumulated very little experience in the practice of regulation compared to the remaining 13 NRAs of our sample, at least in relation with the regulatory instruments implied by the EU regulatory framework; this fact will play a crucial role in the interpretation of our results.

Before proceeding with estimation, we first need to define the production process of a NRA, namely to identify correctly the inputs and the outputs of the production process; by using the jargon from the efficiency analysis, we treat each NRA as a "Decision Making Unit" that employs a certain set of inputs to produce other outputs.

The next subsection is devoted to the identification of the inputs and outputs of a representative NRA; this is not an immediate task and it requires a brief discussion. Once the inputs and the outputs have been defined, we are able to proceed with estimation.

2.1 NRAs as decision making units

A NRA can be thought of as an organization using resources to regulate the market; broadly speaking, a regulator should promote market efficiency, both in static and dynamic terms, through the regulation of retail/wholesale prices, and in a way to guarantee enough incentives for firms to invest and to stay actively in the business.

We treat each NRA as a decision making unit (DMU hereafter); the underlying assumption of our empircal exercise is that each DMU acts in order to minimize the amount of resources (inputs) employed to obtain the highest possible level of regulatory outcomes (outputs). We are aware of the fact that often public instituitions may have other objectives; nonetheless, we believe that this is a reasonable assumption in the case of NRAs which statutorily pursue market efficiency given the resources they are endowed with.

In order to proceed with the efficiency analysis of an authority production process, we need to identify clearly the inputs that a NRA employs to perform its activity and how to measure its regulatory outputs. To this end, a more precise description of what we mean by NRA "production process" may be helpful.

As already mentioned, we interpret a regulator as an organization exerting a certain amount of effort to regulate the market and to improve its efficiency; the relationship between market efficiency (Y^i) and the regulatory effort (e^i) exerted by the i^{th} NRA can be described by a standard production function, formally by $Y^i = f^i(e^i)$. Market efficiency is the output of a NRA activity and it can be measured either in static or dynamic terms by means of appropriate variables that we will discuss in sections 2.3 and 2.4. The exact amount of regulatory effort e^i is, to a large extent, not observable and it must be proxied by the amount of inputs employed; in our analysis we approximate the regulatory effort with two inputs: *i*) the staff employed in the NRA (L^i) and *ii*) the amount of financial resources spent by the same authority (B^i). Clearly, it is reasonable to assume a positive relationship between the amount of inputs employed by the NRA and the amount of regulatory effort; formally, we assume that $e^i = e(L^i, B^i)$, with $e_L \geq 0$, $e_B \geq 0$ and $e(0,0) = 0$.

Therefore, the impact of a change in the use of the two inputs on the degree of market efficiency can be derived by differentiating the NRA production function with respect to L and to B:

$$dY^i = \frac{\partial f^i}{\partial e^i}\left(e_L dL^i + e_B dB^i\right).$$

This expression highlights two kinds of efficiencies; the term $(e_L dL^i + e_B dB^i)$ represents the authority internal efficiency, that is how much a larger use of inputs translates into more regulatory effort.

Conversely, the term $\frac{\partial f^i}{\partial e^i}$ measures a sort of external efficiency, i.e. to what extent a larger effort effectively translates into higher market efficiency. We call this term "external" since it measures something that is actually out of the control of the NRA. For example, take the degree of up-take of new technologies as a measure of dynamic efficiency. The country i could show a low level of technology up-take either because the authority is really putting little regulatory effort, or, for example, because the attitude of the population towards the adoption of new technologies is so low that the regulatory effort is completely overwhelmed. A NRA can appear to be inefficient either because it is unable to translate higher inputs into higher effort, or because the environmental conditions in which it operates make it more difficult to translate its regulatory effort into market efficiency.

The external efficiency is hard to estimate. In our analysis we implicitly assume that the external contribution, for a given level of effort e, is the same across NRAs, that is $\frac{\partial f^i}{\partial e} = \frac{\partial f^j}{\partial e}$, $\forall i \neq j$. The legitimacy of such an assumption depends to a large extent on the measures of market efficiency used in estimation. In order to make the assumption less problematic, whenever possible we use measures of efficiency that are neutral with respect to the possible influence of external factors. As it will be clear, the measures that we use to account for static efficiency (i.e. retail prices) are often more directly under the control of the regulator, therefore external/environmental factors should not play a too important role. Things can be rather different with respect to the measures of dynamic efficiency; as explained in the example of the up-take, the diffusion of new technologies across the population can be deeply affected by external factors such as education and demographic structure. In this case, our results must be taken more cautiously.

With respect to the technical characteristics of the NRAs production process, we take the less restrictive approach by allowing for Variable Return to Scale (VRS) technology.

2.2 DEA bootstrap

In order to estimate the relative efficiency of each authority, we use the well known Data Envelopment Analysis technique; DEA is a linear programming approach able to accommodate multiple outputs and inputs. It is convenient to complement DEA with a bootstrap procedure in order to correct for bias in estimation and to evaluate estimates precision.

Let $x \in \mathbb{R}^p_+$ and $y \in \mathbb{R}^q_+$ denote the vectors of inputs and outputs that characterize the production process of a generic NRA. Interest is addressed to admissible pairs (x, y) belonging to the production set $\Psi = \{(x, y) \text{ such that } f(x) \leq y\}$, where $f(x)$ represents the DMU's production function. Equivalently, Ψ can be described in terms of the input requirement set $\mathcal{X}(y) = \{x \text{ such that } (x, y) \in \Psi\}$.

Following an input oriented approach, perfect production efficiency is described by the boundary of $\mathcal{X}(y)$ denoted by $\partial\mathcal{X}(y) = \{x \text{ s.t. } (x, y) \in \Psi \text{ and } (\delta x, y) \notin \Psi, \text{ for each } \delta < 1\}$. Since Farrell (1957), technical efficiency is measured through the distance of data pair (x, y) from $\partial\mathcal{X}(y)$,

$$\theta(x, y) = \inf_{\delta>0}\{(\delta x, y) \in \Psi\}.$$

The unknown statistics $\theta(x, y)$ assume values in the interval $(0, 1)$ for any point $(x, y) \in \mathbb{R}_+^{p+q}$, with value one corresponding to perfect efficiency. In situations with little *a priori* knowledge of the data generation mechanism, the method of DEA provides convenient nonparametric estimation of the unknown $\theta(x, y)$ based on n observed pairs (x_i, y_i), $i = 1, \ldots, n$. Let $Y = (y_1, \ldots, y_n)'$ and $X = (x_1, \ldots, x_n)'$ denote the $n \times p$ and $n \times q$ matrices of observed outputs and inputs, respectively, then, the DEA estimator is:

$$\hat{\theta}(x, y) = \min_{\delta>0}\left\{y \leq Ya, \delta x \geq Xa, \sum_{i=1}^{n} a_i = 1, a \in \mathbb{R}_+^n\right\}, \tag{1}$$

where $a = (a_1, \ldots, a_n)'$ is an unknown vector of intensities.

As for any other empirical estimator, $\hat{\theta}(x, y)$ is subject to sample variability. Thus, point estimates $\hat{\theta}(x, y)$ must be complemented by suitable measures of uncertainty. Unfortunately, except for simpler cases, it is not possible to derive the distribution of DEA estimators, see Kneip et al. (2008). However, quantification of estimation bias and precision is possible via bootstrap as proposed by Simar and Wilson (1998) and further discussed in Simar and Wilson (2000a,b). Bootstrap replicates $\{\hat{\theta}^{(1)}(x, y), \ldots, \hat{\theta}^{(B)}(x, y)\}$ of the DEA estimator can be conveniently computed with the R Development Core Team (2008) package `FEAR` developed by P.W. Wilson.[3] Accordingly, the bootstrap bias corrected DEA estimator is

$$\hat{\theta}(x, y)_c = 2\hat{\theta}(x, y) - \frac{1}{B}\sum_{b=1}^{B} \hat{\theta}^{(b)}(x, y).$$

[3]The R package `FEAR` is freely available at Wilson's homepage located at the following URL address `http://www.clemson.edu/economics/faculty/wilson`.

Through this bootstrap procedure, it is possible to reduce the bias of the estimated efficiency scores, to estimate their standard errors and to compute confidence intervals.[4] Asymptotic properties of the proposed bias-corrected bootstrap estimators are examined in detail by Kneip et al. (2008).

2.3 Inputs and outputs

Although our analysis covers a wide set of European countries (all the biggest European countries plus five of the most relevant 2004 accession countries), the sample size is relatively small, making the results of a multiple inputs and outputs analysis less statistically appropriate (Kneip et al., 2008). For this reason and since the DEA is a technique particularly aimed at analysing multiple output production processes, we have chosen to run 1 input/2 outputs DEAs, using as input an aggregation of the two input measures (number of staff units and reported budgeted cost) based on a Principal Component Analysis (PCA), conducted after having normalized the NRAs total budgeted cost by using the Purchasing Power Parities (PPP). We use only the first principal component which is an extremely good synthetic measure of the two original inputs as it accounts for more than 70% of the whole variability of the data-set. Table A1 in the appendix shows the inputs values of the various NRAs and the associated PCA. Since DEA needs positive input measures, we have translated all the loadings of the PCA in order to make them positive.[5]

The definition of the outputs is by far more articulated. The activity of a NRA is aimed at promoting market efficiency. Efficiency can take different forms; in our paper we focus on static and dynamic efficiency. The former occurs when production costs are minimized (production efficiency) and/or when the price that consumers are charged for a good or

[4]For details on how to compute confidence intervals that incorporate bias correction for each subject efficiency with the modified percentile method, see Efron and Tibshirani (1993).

[5]The idea behind the PCA is to map set of possibly correlated variable into a smaller set of uncorrelated variables called *principal components*. The aim of this technique is to build up a small number of variables able to account for as much of the variability in the data as possible. For further details see Mardia et al. (1979).

service equals the marginal cost of the resources used in production (allocative efficiency); the latter relates to demand creation and innovation.

Usually, industry regulators face a trade-off as they attempt to maximize static social welfare through price regulation, while providing firms with sufficient incentives to innovate at the same time.[6]

It is often difficult to disentangle between regulatory interventions aimed at improving static efficiency from those that instead are intended to stimulate investments and this is particulary true in telecommunications, probably the most dynamic industry among those subject to sector specific regulation. Here, the tension between static and dynamic efficiency is so crucial that the issue is explicitly mentioned in the new European regulatory framework for electronic communications services where it is clearly stated that the scope of regulation is to promote competition in the provision of electronic communications networks, electronic communications services and associated facilities and to encourage efficient investment in infrastructures and to promote innovation (Framework Directive, Article 8.2.).

An obvious indicator for static efficiency is given by the level of retail prices charged by the incumbent. However, it could be the case that a NRA may opt to regulate less tightly retail charges in the hope of fostering infrastructure investments by the incumbent, thus confirming the negative relationship between static and dynamic efficiency.

Market efficiency can be also pursued by enhancing competition; a more competitive market at the retail level induces lower retail prices and it may also have an impact on the degree of innovation undertaken both by incumbents and by entrant operators. In telecommunications, NRAs may heavily affect the dynamics of entry through the control that they exert on wholesale (interconnection) charges; wholesale regulation may have an impact both retail charges, but also on operators' profits and consequently, in a more dynamic perspective, on their incentives to invest in innovative activities (Bourreau and Dogan, 2001). It is worth noting that in order to reconcile static with dynamic efficiency, European countries

[6] A comprehensive overview of the main issues in the economics of regulation is in Laffont and Tirole (1993). For specific aspects regarding the telecommunications sector, see Laffont and Tirole (2000)

have implemented a set of common regulations based on the key regulatory instrument of local loop unbundling (LLU). LLU is the regulatory process in which incumbent operators lease, wholly or in part, at a regulated price the local segment of their telecommunications network, usually pairs of copper wire, to competitors in order to allow also less infrastructured operators to provide voice and broadband services.[7]

From this brief discussion it clearly emerges the difficulty to find synthetic measures of the degree of market efficiency in telecommunications, an industrial sector characterized by extremely complex interactions. We have then decided to measure static and dynamic efficiency according to the following indicators:

1. *static efficiency*, measured in terms of *i*) price levels and *ii*) degree of competition, both at the retail level;

2. *dynamic efficiency*, measured in terms of up-take of broadband technologies and in terms of amount of operators' investments.

2.4 Data

We construct an *ad-hoc* database drawing data and information from several sources. When not differently specified, variables are referred to year 2005. All monetary variables are expressed in PPP 2005.[8]

With reference to production inputs, staff and reported budgeted cost have been obtained from NRAs annual reports. This information has been treated in order to determine the actual amount of inputs employed to regulate the telecommunications sector; in fact, in many European countries the regulatory authority has various responsibilities, ranging from regulation of telecommunications, to spectrum allocation (as in the majority of the cases). In

[7]The relationship between LLU, static and dynamic efficiency in telecommunications is an extremely debated and disputed issue; for a discussion, see the recent contributions by Distaso et al. (2009), Friederiszick et al. (2008) and Waverman et al. (2007).

[8]PPP rates are taken from Eurostat.

few cases, the authority exerts its control also on other markets different from telecommunications or it is in charge of a bundle of different activities that go beyond telecommunications regulation.[9] For each NRA, we have taken into account of its specific tasks and organizational structure, and we have then appropriately adjusted the observed number of employers in order to obtain a reliable measure about the staff actually in charge of telecoms regulation.[10] This has also allowed us to derive an adjusted measure of the reported budgeted cost imputable to telecoms regulation.[11]

The definition of the outputs of a NRA is more articulated. As we have discussed above, the activity of a telecom NRA is aimed at promoting static and dynamic efficiency; therefore the “amount” of efficiency can be seen as the output of a NRA. We have selected a set of variables that we believe are the best indicators of market efficiency; in particular, at the retail level we use the following indicators:

- local calls tariffs, summarized by the average incumbent's price per-minute of a local call, measured as an average between the price of a 3 and of a 10 minutes local call ($FPRICE$);[12]

- competition in fixed voice telephony, measured as the market share of the alternative operators in the provision of voice access services through different technologies

[9]For example, BNetzA, the German Federal Network Agency, regulates non only telecommunications, but it also exerts its control on various network industries such as Electricity, Gas, Post, Railway; in the UK, Ofcom, is the regulator of the communications industries - television, radio, telecommunications and wireless communications services - and it has also the role of competition authority in these sectors.

[10]Where necessary, these information have been complemented with additional details gathered through personal surveys.

[11]Adjusted budgeted cost has been estimated multiplying the per-employee total budget by the number of employees in charge of telecoms regulation.

[12]Data about local call prices in 2005 are availabe from the 11^{th} *Report of the European Electronic Communications Regultion and Markets*. Since higher output must be associated to higher efficiency and higher efficiency is associated to lower prices, in our estimantions we have used the inverse of the average price per-minute of a local call. Formally, by indicating with p_3 and p_{10} the incumbent price of a 3 and 10 minutes local call respectively, $FPRICE$ has been computed as the inverse of $\frac{1}{2}\left(\frac{p_3}{3}+\frac{p_{10}}{10}\right)$.

$(COMPV)$.[13]

We focus on fixed telephony because it is certainly the segment that it is more under the scrutiny of regulators.

We measure dynamic efficiency in terms of amount of investments in telecommunications and of up-take of broadband technologies. As far as investments are concerned, we use the ratio between the average amount of investment in fixed telecommunications between 2004 and 2005, and the average amount of total investment in the economy (namely, the gross fixed capital formation) for the same years. We call this variable INV. Time horizon has been expanded to two years because investment is a long run decision and by restricting the observation to a single year only may lead to inaccurate evaluations of the overall intensity of investments in telecommunications.

With respect to broadband technologies, in order to capture both the level and the variation of broadband penetration within a given country, we measure the diffusion of broadband access with the variable BBUPTAKE, computed as the product between the level of penetration of broadband access in 2005, obtained by dividing the total amount of retail broadband access paths by the population, and its increment with respect to 2004:

$$BBUPTAKE = 2005\ Broadband\ penetration \times \Delta(Broadband\ penetration).$$

We use this composite index since the level of broadband penetration is a highly autocorrelated variable; in fact, the amount of broadband penetration reached in 2005 in a certain country, strictly depends on the level in 2004. This implies that those countries that have reached a high level of penetration in 2004 may appear to perform very well in 2005 even though during this period they have not experienced a significant increase in broadband penetration. At the same time, in a country where, for example, broadband access represents a more recent phenomenon, we might observe a significant increase in broadband penetration

[13] We have derived this measure by dividing the sum of fully unbundled lines, other operators' number of cable and fiber optic lines by the sum of total voice access path activated in the market. Source: *Broadband in the EU* Report, Communication Committee, July 2008.

in the current year but we may end up considering its market (and its NRA as well) less efficient than the previous one simply because, in absolute terms, the amount of broadband penetration is still low. Our variable BBUPTAKE partially avoids these problems of possible inaccurate evaluation.

Note that broadband penetration represents a measure of dynamic efficiency since, in order to provide broadband access to customers, telecom operators need to invest in infrastructures; although, the type and the amount of investments required to provide broadband services heavily depends on the type of access platform used, i.e. DSL versus cable access, yet the amount of broadband access lines sold to final customers is a good proxy for the amount of investment undertaken by the operators. Table A2 in the appendix provides the full dataset used in the elaborations.

Before proceeding, it is useful to stress an important difference between our measures of static and dynamic efficiency; in fact, while the indicators, that we use to account for static efficiency are both under a more direct control of telecom regulators, this cannot be said with respect to the measures of dynamic efficiency. Take, for instance, the incumbent's price for local calls: this tariff is almost everywhere set by the regulator through a price cap or a cost plus regulatory scheme. Similarly, the degree of competition in the fixed telephony is heavily affected by the terms of wholesale access to the incumbent's local network, which according to the European regulatory framework are under the direct scrutiny of NRAs. From this observation, it follows that the more experienced authorities, for example those that have acquired more experience in the practice of regulatory accounting and in determination of the cost of services, should regulate both retail and wholesale prices more effectively.

On the other hand, the amount of investment undertaken by telecom operators and the degree of broadband access technologies, namely the two measures for dynamic efficiency, are only partially under the control of the regulatory authorities; in these cases, the best a NRA can do is to promote the more favorable conditions to stimulate investments.

3 Results and discussion

We are now ready to present and discuss the results of our efficiency analysis. Tables 1, 2 and 3 show the efficiency scores obtained by each NRA in each of the three DEAs that we have carried out; as discussed above, all our analyses use as input the first principal component derived from a PCA of units of staff and budget given in Table A1.

Table 1: $Static-oriented$ DEA (Outputs: $FPRICE$, $COMPV$)

Country	**uncorrected eff. scores**	**bias corrected eff. scores**	c.i. lower	c.i. upper
Germany	0.912	0.819	0.722	0.903
Denmark	0.968	0.816	0.64	0.96
Italy	0.933	0.814	0.664	0.929
Finland	0.929	0.78	0.651	0.915
Czech Repub.	1	0.745	0.54	0.981
Sweden	1	0.742	0.506	0.986
Netherlands	1	0.739	0.506	0.983
Spain	0.773	0.69	0.585	0.769
Austria	0.828	0.687	0.538	0.82
Belgium	0.777	0.671	0.539	0.77
France	0.675	0.624	0.55	0.671
UK	0.679	0.611	0.537	0.672
Poland	0.589	0.55	0.495	0.584
Slovenia	0.603	0.53	0.465	0.595
Ireland	0.511	0.479	0.429	0.508
Portugal	0.4	0.371	0.333	0.397
Hungary	0.155	0.136	0.106	0.153
Slovak Rep.	0.024	0.02	0.015	0.023

With a slight abuse of jargon, we can refer to Table 1 as the results of a “static oriented” DEA, where we have used as outputs the level of retail voice tariffs and the degree of competition in the voice telephony, while Table 2 shows the outcome of a “dynamic oriented” DEA that employs the level of investments and the up-take of broadband access as measures of output. In both cases, for countries listed in the first column, the tables display DEA point estimates (uncorrected DEA), bootstrap bias corrected estimates and 95% confidence interval. New accession countries are displayed in italics. NRAs are ranked according to their bias-corrected efficiency score.

Unfortunately, the point estimates' confidence intervals are generally wide; in particular, they often overlap thus making it often not possible to disentangle NRAs according to their efficiency score. As we have already discussed in the paper, this is due to small sample size. Nevertheless, despite this limitation, we can still draw some interesting conclusions from the two DEAs.

Consider Table 1 about NRAs ability to obtain static efficiency; by looking at the confidence intervals, it clearly emerges that the authorities in Germany, Denmark, Italy and Finland are the most efficient ones, while the less efficient are those operating in Poland, Slovenia, Ireland Portugal, Hungary and Slovak Republic.[14] This means that, with the notable exception of Czeck Republic, all the NRAs of the new accession countries are characterized by a poor performance in terms of efficiency in promoting static efficiency.

This regularity may be interpreted in light of what we have already discussed when introducing our output measures: the two indicators that we use to measure static efficiency, the price of a minute local call and the degree of competition at the retail level, are both under a more direct control of the telecom regulator and, for this reason, it is not surprising that the less efficient NRAs are those that have less experience in the regulatory activity. In order to set the price of the local segment or the wholesale tariffs charged to competitors, an authority usually needs to determine the exact cost of the service through the practice of cost accounting; in the ever changing environment of the telecom industry, characterized by the launch of new technologies and by an always evolving competitive scenario, this practice is extremely complex and demanding. In this sense, the more experienced authorities are those that have learned how to proceed into the practice of cost accounting and how to regulate accurately the various telephony services that are under their scrutiny. Opposite arguments hold for dynamic efficiency measures; from Table 2, it emerges that in this case the accession countries lie in the top half of the ranking list, with Poland at the very top and

[14]For the sake of readiness, in the tables we emphasize the new accession countries.

Table 2: $Dynamic - oriented$ DEA (Outputs: INV, $BBUPTAKE$)

Country	**uncorrected eff. scores**	**bias corrected eff. scores**	c.i. lower	c.i. upper
Poland	1	0.703	0.577	0.917
Finland	0.978	0.662	0.524	0.935
Czech Rep.	1	0.624	0.525	0.939
Slovak Rep.	1	0.618	0.505	0.935
Denmark	1	0.618	0.505	0.931
UK	1	0.616	0.505	0.929
Hungary	0.775	0.556	0.452	0.746
Sweden	0.637	0.45	0.366	0.595
Slovenia	0.354	0.254	0.213	0.325
Italy	0.343	0.248	0.209	0.323
France	0.334	0.246	0.201	0.314
Belgium	0.301	0.228	0.185	0.287
Germany	0.277	0.21	0.173	0.263
Portugal	0.253	0.185	0.155	0.237
Austria	0.193	0.149	0.122	0.184
Spain	0.104	0.073	0.061	0.096
Netherlands	0.023	0.016	0.013	0.022
Ireland	0.022	0.015	0.012	0.021

Czeck Republic, Slovak Republic, Hungary and Slovenia slightly below; although we cannot fully disentangle between NRAs estimated efficiency, due to overlapping confidence intervals, we can reasonably affirm that, with the exception of Slovenia, the new accession countries are not within the less efficient NRAs in this "dynamic oriented" DEA. Quite interestingly, the more dynamically inefficient NRAs appear to be all very experienced NRAs (i.e. the NRA in France, Austria or Spain).

To interpret this result we can use an argument that is in some sense specular to the previous one: the measures that we use to account for dynamic efficiency, the amount of investment in telecommunications infrastructures and the degree of diffusion of broadband technologies, are less under the control of the NRA; in this sense, the experience that each authority has accumulated through the years, is less relevant to achieve dynamic efficiency than it is for static efficiency. On the other hand, the new accession countries are those for which, in relative terms, telecommunications are less developed; in this situation, is somehow "easier" for a NRA to stimulate investments and to improve upon the existing amount of infrastructures. This might help explaining the good performance of the NRAs of the new accession countries with respect their task of achieving dynamic efficiency.

Table 3: *Mixed* DEA (Outputs: $FPRICE$, INV)

Country	**uncorrected eff. scores**	**bias corrected eff. scores**	c.i. lower	c.i. upper
Germany	0.912	0.858	0.781	0.908
Denmark	0.974	0.84	0.669	0.966
Poland	1	0.822	0.689	0.988
Czech Rep.	1	0.781	0.582	0.985
Slovak Rep.	1	0.78	0.583	0.987
Sweden	1	0.779	0.58	0.985
Italy	1	0.778	0.582	0.991
UK	1	0.778	0.581	0.986
Finland	0.833	0.769	0.683	0.829
Spain	0.773	0.703	0.613	0.767
Hungary	0.775	0.668	0.564	0.769
France	0.675	0.629	0.568	0.671
Slovenia	0.697	0.62	0.533	0.69
Netherlands	0.658	0.619	0.561	0.656
Ireland	0.511	0.483	0.44	0.509
Portugal	0.466	0.425	0.38	0.461
Austria	0.379	0.358	0.328	0.376
Belgium	0.274	0.256	0.234	0.272

Finally, in order to make a synthesis of the above analyses, in Table 3 we provide the results of a third DEA based on a mix of outputs: one output, the average price of a one-minute local call, is representative of static efficiency, while the other one, the investments' intensity in fixed telephony, is representative of dynamic efficiency. The results are simply a combination of the previous two DEAs and are generally more difficult to interpret; as expected, new accession countries are now more dispersed across the ranking, with Poland and Czech Republic that still rank at the top and with Hungary and Slovenia in the second half. Within the experienced countries, Germany and Denmark appears to be the best performers.

4 Conclusions

Despite the growing body of theoretical and empirical literature that deals with regulation and its impact on regulated markets, the issues of how to evaluate regulators productive efficiency and which are its determinants have been almost completely neglected. With this paper we start to fill this gap by offering a new and simple approach to the empirical evaluation of the internal efficiency of National Regulatory Authorities based on regulated market outcomes.

The novelty of our approach is, in fact, to measure NRAs outputs in terms of the degree of market efficiency (either static or dynamic) that the local authority has been able to entice via its regulatory effort; the estimation procedure is based on a Data Envelopment Analysis, a well known programming approach useful to accommodate multiple outputs and inputs. Being DEA techniques extremely sensitive to variable selection and errors, we than use bootstrapping procedures to obtain the estimation bias and to improve estimates precision.

We apply the proposed methodology to the telecommunication sector across 18 European countries, five of which are new accession countries, and we base our estimations on year 2005. After having discussed several desirable outcomes for a telecom regulator, we construct an ad hoc database containing information about NRAs regulatory inputs and outputs.

Outputs can be grouped according the their static (retail) or dynamic nature; we run several bootstrapped DEAs in order to rank NRAs according to their efficiency in carrying out their regulatory activities. We find that the NRAs in new accession countries are more efficient in pursuing dynamic efficiency goals than the more experienced NRAs, while the same NRAs perform generally worse when the regulatory outcomes are measured in terms of retail efficiency. This result points to the role played by lower experience in applying regulatory instruments that NRAs in new accession countries have accumulated.

This paper suggests other interesting patterns of future research; the first, and probably, the most obvious one is to apply our methodology also to other regulated public utilities. More interestingly, and independently on the sector it is applied to, we believe that our methodology is also instrumental to get a better understanding of the efficacy of different regulatory measure; indeed once a measure of the productive (internal) efficiency of a regulatory body has been obtained, it will then be possible to embed this information in a more general analysis aimed at disentangling the effectiveness of the regulatory measure from the ability (efficiency) of the NRA in putting it into force. In this sense, our analysis can be seen as a first step towards a full assessment of the true cost of an effective regulation.

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Table A1: Principal Component Analysis

	1^{st} Component	2^{nd} Component	1^{st} Component translated
Belgium	0.325806	0.03366	4.3258055
Czech Rep.	-3.89216	-1.88801	0.1078427
Denmark	0.183902	0.170095	4.1839017
Germany	-0.72749	1.167309	3.2725076
Spain	0.813678	-0.50236	4.8136778
France	0.691809	-0.24648	4.691809
Ireland	0.97709	-0.53776	4.9770899
Italy	0.296892	-0.0549	4.2968921
Hungary	-1.06352	0.741819	2.9364833
Netherlands	0.752395	-0.30518	4.7523947
Austria	1.11581	-0.60779	5.1158103
Poland	-1.61053	1.904605	2.389475
Portugal	0.103999	0.120015	4.1039993
Slovenia	1.137651	-0.61577	5.137651
Slovak Rep.	0.5747	-0.03555	4.5747002
Finland	0.238222	0.144891	4.2382224
Sweden	0.132526	0.238008	4.1325262
UK	-0.05079	0.273387	3.9492111
Std. dev.	1.184386	0.772807	
% of Variance	0.701385	0.298615	

Table A2: the Dataset

COUNTRY	INPUTS		OUTPUTS			
	STAFF (a)	BUDGET (1) (a)	COMPV % (b)	PRICE (1) (2) (c)	INV % (d)	BBUPTAKE (b)
Belgium	230	28,577,688	15.1	6.027	1.553	0.00700
Czech Rep.	461	827,732,814	4.6	9.509	1.769	0.00299
Danmark	258	29,289,547	7.8	3.055	2.049	0.01669
Germany	450	18,118,945	8.9	3.741	1.586	0.00568
Spain	127	34,844,294	7.2	3.238	1.858	0.00405
France	165	17,401,392	3.4	3.604	1.797	0.00789
Ireland	107	18,181,970	1.9	4.124	1.337	0.00218
Italy	224	43,868,105	5.8	3.076	2.414	0.00436
Hungary	441	117,240,247	4.8	8.018	2.970	0.00007
Netherlands	153	17,156,255	19.6	3.631	1.377	0.00229
Austria	86	9,241,474	17.9	4.802	0.766	0.00595
Poland	613	37,088,499	2.6	5.606	3.033	0.00033
Portugal	261	46,208,547	5.4	5.218	2.210	0.00389
Slovenia	83	7,437,476	10.0	3.672	2.604	0.00403
Slovak Rep.	198	5,188,890	1.7	11.287	3.873	0.00041
Finland	250	25,499,721	13.1	3.355	1.781	0.01655
Sweden	270	27,137,029	11.7	3.012	2.018	0.01117
United Kingdom	292	46,392,834	8.6	3.995	3.462	0.01012
Mean	**259**	**75,366,985**	**8.3**	**4.943**	**2.136**	**0.00587**

Sources:
(a) NRAs annual reports;
(b) “Broadband in the EU” Report, Communication Committee, July 2008;
(c) 11^th Report of the European Electronic, Communications, Regulation and Market;
(d) OECD 2007 Telecommunications Outlook.