The empirics of regulatory reforms proxied by categorical variables: recent findings and methodological issues

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Abstract: Some regulatory reforms do not change just a specific signal that can be represented by a quantitative continuous variable, such as a tax rate, a price cap, or an emission threshold. The standard theory of reform in applied welfare economics (going back to contributions by e.g. Ramsey, Samuelson and Guesnerie) asks the question: What is the marginal effect on social welfare of changing a policy signal? However, reforms such as privatization, unbundling or liberalization of network industries are often described by 'packages' shifting a policy framework. It is increasingly frequent in the empirical evaluation of such reforms to use categorical variables, often in polytomous form, for instance describing unbundling steps (vertical integration, accounting, functional, legal, ownership separation) on a discrete numerical scale, such as those proposed by the OECD and other international bodies. We review recent econometric literature evaluating regulatory reforms using such variables (40 papers) and we discuss some methodological issues arising in this context.

Keywords: econometrics; policy evaluation; network industries; reforms.

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1. Introduction

Regulatory policy is often seen as one of the lever that policy makers can use to influence the welfare of a country (OECD, 2010). The evaluation of regulatory reforms may seem straightforward: governments should adopt only those that bring about social welfare improvements. This implies that desirable reforms must yield economic and social benefits that outweigh their costs (Coglianese, 2012). This seemingly simple description of the assessment of policy reforms is backed-up by a vast and well-established literature in public economics (e.g. Ramsey, 1927; Samuelson, 1986; Guesnerie, 1977; Diamond and Mirrlees, 1971; Drèze and Stern, 1990). See Boadway (2012) for a survey.

Although theoretical models in this strand of the literature, or those developed for the Cost Benefit Analysis (CBA) of policies, are often mathematically and informationally complex, their conceptual structure is quite simple (Guesnerie, 1998 and Florio, 2014). In models belonging to the "Ramsey-Samuelson-Guesnerie" tradition (RSG, henceforth), a reform can be though as a change to a vector of "signals", defined as variables affecting the behavior and welfare of individuals and firms, such as prices, rations, taxes, transfers and shareholding rights (Drèze and Stern, 1990).

In this framework one needs to model the functional relations linking government objectives, signals, constraints and private agents' reactions. The aim is to approximate how the social welfare function changes in response to a marginal change in the vector of signals controlled by the government.

Unfortunately, from the standpoint of an applied economist wishing to provide an empirical evaluation of reforms, the RSG modeling approach is not without problems. Its main shortcoming is that "a marginal change in the vector of signals" is frequently an inaccurate way of describing actual policy reforms. In fact, reforms do not necessarily involve an immediate change of signals, such as tax rates or regulated prices, nor an instantaneous variation in the social welfare function.

On the contrary, regulatory reforms are typically implemented with legislative packages that encompass a variety of instruments such as: primary laws, secondary regulations, subordinate rules,

standards, administrative guidance and circulars (OECD, 2010). For instance, in the case of the European Union (EU), regulation of network services involves the adoption of both legislative and non-legislative acts, the so-called soft law (Maresca, 2013),[1] with complex implementation mechanisms (Goldberg, 1976). Moreover, the aim of such tools and procedures is often not to induce an immediate change in a signal, but rather to provide mechanisms that, under certain circumstances, should pave the way for such a change.

A case in point is the regulation of segments of the telecom industry. For instance, "local loop unbundling" in European member states gives the right to entrants to use the incumbent telecom operator's local broadband network to offer their services directly to customers.[2] Clearly, the implementation of such a legislation cannot be described as a change in the vector of signals (Guthrie, 2006 and Nardotto et al., 2015). Rather, local loop unbundling can be interpreted as a modification of the regulatory policy framework that is expected to create the conditions for a change in signals and is thus not well approximated as a problem belonging to the RSG tradition.

We discuss the empirical assessment of "packages" or reforms of policy framework (PFR) and focus on network industries, given the pervasiveness of the economic services they provide (e.g. energy, water, telecommunications, transport). The aim is to provide a consistent analytical scheme to help researchers and policy makers avoiding methodological pitfalls and interpretational errors that might bias the evaluation of reforms when the RSG approach is neither applicable, nor appropriate. We show that, notwithstanding the analysis of PFR cannot rely on well-established theoretical foundations, such as the RSG approach, empirical analyses are feasible and necessary, albeit interpretation of results and therefore design of policy recommendations requires caution.

[1] Legislative acts (secondary law) comprise directives, regulations and decisions. Non-legislative acts include communications, green papers, and white papers. These so-called "soft laws" provide a correct interpretation of the primary and secondary laws. See Maresca (2013) and references therein.

[2] See Regulation (EC) No 2887/2000 of the European Parliament and of the Council of 18 December 2000 on unbundled access to the local loop.

The rest of the paper is organized as follows. Section 2 sets the conceptual framework, definitions and mentions examples of policy categorical variables issued by the OECD (the ETCR database) and by the Quality of Government Institute (a websiteportal collecting a large number of indexes for many countries and years). Section 3 after proposing a prototype econometric model, reviews some recent econometric literature using polytomous or binary regulatory reform variables (40 papers). Section 4 discusses potential pitfalls and methodological issues in the above literature. Section 5 concludes.

2. Conceptual framework

2.1 What are PFR in practice?

Although within the RSG tradition reforms are described as the marginal change of a vector of signals and evaluated by assessing their impact on the social welfare function, they can take a rather different shape. Let us consider the case of a government that approves a privatization bill as a broad framework to progressively give up control of several State-Owned Enterprises (SOEs) to private investors.

To properly analyze these events, one should focus not only on microeconomic facts, such as the transfer of shares' ownership of some SOEs, nor search for ultimate macroeconomic changes. In fact, privatization of SOEs, unbundling of network services, or access regulation are definitions of sets of policies aimed at inducing a change in the current economic environment and possibly affecting private agent's utility. Hence, these measures are better described as "*mesoeconomic*" changes (see Ng, 1992): they aim at changing the institutional setting and hence to induce a variety of economy-wide effects in a certain direction.

In some cases, PFR are accompanied by an even more comprehensive change: a policy paradigm shift, defined as a complete modification of the usual and accepted way of doing or thinking about something, such as the theory supporting the government's policy action. Since paradigm shifts are hard to be quantitatively assessed and are best suited for interdisciplinary

analyses involving history and political science, they will not be discussed in what follows. On the contrary, we focus on *mesoeconomic* changes induced by PFR showing that they can be the topic of empirical analyses, albeit with due caution.

Up to now, we have defined PFR mostly relying on exclusion criteria. In fact, we have used the term PFR to identify legislative or regulatory packages that are not necessarily translated into a change in the vector of signals, that do not automatically and directly affect private agents' utility function and that cannot be analyzed within the RSG analytical framework. In the economic literature, such reforms are often associated with the list of measures included in the Washington Consensus (Williamson, 1994). However, the ten policy desiderata of Williamson (1994) do not exhaustively represent a range of measures that can be put under the PFR header. Acemoglu et al. (2008) list several measures that can be defined as PFR such as: opening to trade, financial liberalization, judicial reform, privatization of state enterprises, reduction of entry barriers, tax reform, removal of targeted industrial subsidies, and central bank independence.

Since providing a complete list of policies that represent PFR is neither feasible, nor particularly informative, in this paper we equate PFR with the OECD's (2012, p. 5) definition of regulatory policy, namely: *"regulatory policy is about achieving government's objectives through the use of regulations, laws, and other instruments to deliver better economic and social outcomes and thus enhance the life of citizens and business."*[3] This definition is similar to the RSG framework, but departs from it as it assumes a certain degree of complexity that cannot be captured by a unique signal.

2.2 How are policy framework reforms measured?

When interpreting reforms within the RSG framework, empirical analyses require identifying a change of signal, such as a tax-rate, a price, an interest-rate or an exchange-rate. In these cases,

[3] See: http://www.oecd.org/gov/regulatory-policy/ (last accessed: January 2017).

since most of the proxies of signals have natural unit of measurement, the main issue for the analyst is to search for the appropriate variable.

On the contrary, to quantitatively assess the effects of PFR one needs to create or, resort to existing artificial indicator variables that have no natural units of measurement. Two leading examples of the PFR proxies are:

1. The OECD indicators of Energy, Transport and Communications Regulation (ETCR).
2. Indices of the quality of institutions (see e.g.: http://qog.pol.gu.se/).

The ETCR database. The ETCR dataset provides information about regulatory structures and policies for OECD and some non-OECD countries. Information is collected with a questionnaire sent to the government of each country and complemented with publicly available data to create annual time series starting in the mid-1970s. Questionnaires are made of closed questions that can either be answered with numerical values (e.g. what is the market share of the largest company in the sector?), or by selecting from a set of pre-specified answers (e.g. a question that can be answered with "yes" or "no", such as: "is unbundling of the local loop required?"). Qualitative information is coded into quantitative measures and then all answers are normalized in a range from zero to six, where values near zero indicate fewer restrictions to competition.[4] See Koske et al. (2015).

As shown in Figure 1 the ETCR index aggregates with equal weights indices for seven network sectors: telecom, electricity, gas post, air transport, rail transport, and road transport. For each sector, there are up to four sub-indices that cover different dimensions of the reforms: entry regulation, public ownership, vertical integration and market regulation. One of the strength of the ETCR database is that indicators are available for a very long time span, making it suitable for

[4] Consider the question: "What is the market share of the largest company in the sector?" The methodology assigns a score of zero if the share is smaller than 50%, three if it is between 50% and 90% and six if it is greater than 90%.

panel data analysis, see Figure 2. The ETCR indices have been used as proxies of PFR by several authors. See Tables 1-3.

Quality of institutions. The Quality of Government Institute maintains a dataset aimed at measuring the trustworthiness, reliability, impartiality and the level of corruption of the public administration and the judicial system in the United Nations member states. There are many categories, including: quality of government (i.e. measures of impartiality, bureaucratic quality, corruption), judicial and labor market indicators, indices of the freedom of the media, and economic indicators measuring the involvement of the government in the economy. This kind of data are used in PFR literature (see e.g. Borghi et al. 2016, Polemis and Stengos 2017), as well as in political economy studies (see e.g. Obinger et al. 2016).

This list of empirical PFR proxies is clearly not exhaustive, but it is representative of the approach often used in applied welfare economics.[5] In fact, most of the PFR proxies have two features in common: they are compiled by transforming quantitative and qualitative information into normalized scores and are aggregated with a bottom-up approach. If score assignment and aggregation is meaningful and consistent through time and space (e.g. across countries), one could track the effects and intensity of reforms as illustrated in Figure 2. However, building such scoring systems and aggregating them with bottom-up approaches involves several methodological and interpretational issues that are the core topics of the following sections.

[5] Other indicators with similar characteristics include: the set of Global Competitiveness indices compiled by the World Economic Forum (2015) and many other used, or directly compiled, by scholars for their analyses (see e.g Erdogdu, 2011a; Prati et al., 2013; Koo et al., 2013; Grajek and Röller, 2012; Howard and Mazaheri, 2009). See also Tables 1-3.

3. The econometrics of policy framework reforms

Empirical analyses can be divided into two distinct groups, depending on whether the PFR proxy enters the econometric specification as dependent or as explanatory variable.[6] The first class of models, with PFR as dependent variable, is representative of the political economy literature on the historical determinants, success and failure of reforms surveyed by Obinger et al. (2016).

On the contrary, here we focus on models where the PFR proxies enter as explanatory variables. In these analyses, the outcome variable approximates the welfare change, that indirectly reveals the belief of the analyst about the social welfare function. Oft-used dependent variables include consumer or producer prices, productivity, quantity and quality of a service. Relying on such variables is sensible, if the assumptions linking the selected dependent variable with the latent "welfare change" are discussed before policy recommendations are formulated.

Consumer prices are the most straightforward and important signal for a welfare analysis (Price and Hancock, 1998 and Florio, 2013). Although less orthodox, an alternative approach is to rely on consumers' satisfaction surveys to measure perceived welfare changes (see Clifton et al., 2014 and Fiorio and Florio, 2011 among others). However, as shown in Table 2, many alternative outcome variables that proxy the quality of the services have also been used.

3.1 A prototypical econometric model for PFR evaluation

Variables that are typically used as regressors in the evaluation of PFR can be denoted as: $\mathbf{x}_{i,t} = [\mathbf{x}_{(1)i,t}, \mathbf{x}_{(1)i,t-j}, y_{i,t-k}]$, where $\mathbf{x}_{(1)i,t} \equiv [\mathbf{PFR}_{i,t}, \mathbf{D}_{i,t}, \mathbf{S}_{i,t}, \mathbf{Z}_{i,t,}]$ for $j, k > 0$. $\mathbf{PFR}_{i,t}$ is a set of proxies for the

[6] Here we focus on standard reduced-form regression models. An alternative, is to rely the so-called potential outcome model (Cameron and Trivedi, 2005). In this setting, the focus is on the average change that a treatment (i.e. a PFR) induces on a given outcome variable. Since the "change" is computed by comparing the outcome for treated and non-treated statistical units, the empirical analysis has to rely on counterfactuals (i.e. how the outcome of an average untreated unit would change if it were to receive the treatment). See Imbens and Wooldridge (2009) for a review of the econometrics of program evaluation.

PFR, $\mathbf{D}_{i,t}$ are demand-side controls, $\mathbf{S}_{i,t}$ are supply-side controls, and $\mathbf{Z}_{i,t}$ includes deterministic regressors (e.g. time trend, individual and time effects) and additional controls (e.g. firm characteristics). Notice that $\mathbf{x}_{(1)i,t}$ might also include polynomial transformations and interaction terms. From now on, for ease of notation, we drop the subscripts that index statistical units and time, but we recall that GLM can be applied to cross-sectional, time-series or panel data. [7]

Demand-side controls (**D**) directly impact on most outcome variables. When *y* is the price of a good or service, natural candidates are the prices of its substitutes and per-capita income. Supply-side drivers (**S**) proxy the change in unit costs, that in turn are correlated with input prices (e.g. in the case of electricity production, natural gas, coal, nuclear, hydro, solar, wind), and in the longer-run also with technological shifts. Thus the choice of the elements in **S** hinges on the analyst's knowledge of the technological features of the market under scrutiny.

Lastly, **Z** collects all the remaining controls, including deterministic regressors (time and individual fixed effects, seasonal dummies, linear and polynomial trend terms) and other observable characteristics (e.g. gender, location, being a listed company).

We can cast many of the empirical specifications used in the literature of PFR evaluation in the class of generalized linear models (GLM):

$$g(E(y \mid \mathbf{x})) = \mathbf{x}'\boldsymbol{\beta} \qquad y \sim LEF \tag{1}$$

where *y* is the outcome of interest, that can be a cross-sectional, time-series or panel variable, **x** denotes the set of explanatory variables that includes also the PFR proxy, $\boldsymbol{\beta}$ is the vector of unknown parameters, $g(.)$ is called link function and *LEF* indicates a density belonging to linear

[7] We point out that the notation is somehow simplistic; in fact, we use $\mathbf{x}_{(1)i,t-j}$ to indicate that the model can include lags (not necessarily in the same number and order) of all or only some of the variables in $\mathbf{x}_{(1)i,t}$. Moreover, notice that subscripts and the variables entering the set of regressors should be adjusted according to the nature of the dataset and depending on the empirical specification. For instance, a static panel model would exclude $y_{i,t-k}$.

exponential family. Examples of *LEF* densities are the Bernoulli for binary data, the Poisson and negative binomial for count data, and the Normal for continuous data (Gourieroux et al., 1984).

Combining different link functions and *LEF* densities yields a wide array of models (McCullagh and Nelder, 1989). For illustrative purposes, let $\mu \equiv E(y \mid \mathbf{x})$ and $\eta \equiv g(\mu)$. The role of the link function $g(.)$ is to map $E(y \mid \mathbf{x})$ to $\eta = \mathbf{x}'\boldsymbol{\beta}$. When $g(.)$ is the identity function $\eta = \mu$; moreover, if y is a continuous normally distributed variable, such as (the log of) the electricity price, we get the linear regression model: $E(y \mid \mathbf{x}) = \mathbf{x}'\boldsymbol{\beta}$. If y is a binary variable with Bernoulli distribution, such as consumers' satisfaction (e.g. $y = 1$ corresponds to "satisfied", $y = 0$ means "not satisfied"), we can obtain both the Probit and the Logit models.[8] Therefore, as it can be seen from Tables 1-3, the GLM approach encompasses all the specifications commonly used in the econometric literature of PFR evaluation in network industries.

3.2 PFR in network industries: a short review

We briefly discuss some of the contributions that have dealt with the empirical assessment of PFR in network industries. Most of the selected studies relies on panel data, while a minority focuses only on the time series (Bacchiocchi et al. 2005, 2008) or cross-section dimension (Fiorio et al. 2013 and Nardotto 2015). A summary is shown in Tables 1-3.

Two classes of models have been used. Linear models, when the dependent variable is continuous, such as log-prices, log-productivity and GDP growth (e.g. Hyland 2016; Borghi et al. 2016, Prati et al. 2013). Models for limited dependent variables, when the outcome variable is a dummy, such as consumers' satisfaction or energy deprivation (Fiorio and Florio 2011, Fiorio et al.

[8] Both the Probit and Logit models are conditional probability models of the form, $\Pr(y_{it} = 1 \mid \mathbf{x}_{it}) = h(\mathbf{x}_{it}'\boldsymbol{\beta})$, where $h(.)$ is a function that ensures that the Pr(.) is a well-defined probability. The Logit model is obtained when $g(.)$ is the logit function, such that $\eta = \ln[\mu / (1 - \mu)]$ and $E(y \mid \mathbf{x}) = \exp(\mathbf{x}'\boldsymbol{\beta}) / [1+ \exp(\mathbf{x}'\boldsymbol{\beta})]$. The Probit model is obtained when $g(.)$ is the inverse of the standard Normal cumulative distribution function (cdf). Then $\eta = \Phi^{-1}(\mu)$ and $E(y \mid \mathbf{x}) = \Phi(\mathbf{x}'\boldsymbol{\beta})$, where Φ is the standard Normal cdf.

2013, Florio and Poggi, 2010). Although the GLM framework subsumes both approaches and can be applied to any data structure, for the sake of brevity, here we focus on panel data and discuss only linear models. Some assumptions and results used in the analysis of linear specifications are easily extended to models for limited dependent variables. See Cameron and Trivedi (2005) for details. Moreover, we notice that implementation of both linear and limited depended variables models requires the analyst to make two choices: first, how to model the heterogeneity of statistical units and, second, between static or dynamic specifications.

Using Equation (1) under the assumption that the link function $g(.)$ is the identity function and that the outcome variable is normally distributed, we get a linear one-way error component model for panel data:

$$y_{it} = \alpha + \mathbf{x}_{it}'\boldsymbol{\beta} + u_{it} \qquad \text{for } i = 1,\ldots, N;\ t = 1,\ldots,T \qquad (2)$$

$$u_{it} = \mu_i + \upsilon_{it} \qquad (3)$$

where, u_{it} is the error term, μ_i is the unobservable individual-specific effect that accounts for the heterogeneity among statistical units, υ_{it} is the remainder disturbance.

The model in (2) and (3) encompasses most of the linear panel data specifications in the analyses shown in Tables 1-3. Either fixed or random effects are used to account for the heterogeneity among statistical units. Unobservable individual-specific effects, μ_i, are assumed to be fixed parameters to be estimated in the fixed effects (FE) model. The FE model is appropriate when the aim is to focus on a specific set of statistical units, say N countries, and inferences are conditional on those N units. The FE model is thus a conditional analysis: it delivers consistent estimates of the effects of PFR on the outcome variable conditional on the individual-fixed effects μ_i and makes prediction feasible only for the N units in the sample.

In the random effects (RE) model unobservable individual-specific effects, μ_i, are assumed to be a stochastic variable. The RE model is appropriate when N statistical units have been randomly drawn from a large population and those N units are a representative sample of the

underlying population. A case in point is the analysis of household survey data. The RE specification is an example of marginal or population-weighted analysis: inferences pertain to the population from which the sample has been drawn and prediction is also feasible for units outside the sample.

In the FE model the individual-effects, μ_i, are potentially correlated with the observed regressors $\mathbf{x}_{it}$. On the contrary, the consistency of estimates in the RE model depends on the assumption that μ_i are distributed independently from $\mathbf{x}_{it}$. We can see that Tables 1-3 display more FE than RE models: in fact, this stronger condition is often untenable in the evaluation of PFR.

We now turn to the choice between static and dynamic specifications. Since most economic relations are not static in nature, dynamic specifications are often a natural choice and are implemented in 20 out of 40 surveyed studies. In panel data models there are two sources of correlation over time. The first, due to unobserved heterogeneity, arises because of the observation of the same individual over multiple time periods. The second, true state dependence, occurs when correlation over time is due to the causal mechanism explaining the fact that y_{it} is determined by y_{it-j} for $j > 0$. The unobserved heterogeneity explanation implies that the correlation over time is constant. This is clearly restrictive when an unobserved shock this period will affect the behavioural relationship for some periods and whose effect is not constant over time. An example are models describing prices or investment decisions (e.g. Brau et al. 2005, Alesina et al. 2005).

In such cases, some dynamics can be introduced using a distributed lag structure for the explanatory variables of interest, including the lagged dependent variable among the regressors (e.g. Fiorio and Florio, 2013), or capturing serial correlation assuming an autoregressive process for the error term of the model, υ_{it}, (e.g. Howard and Mazaheri, 2009). Neglecting the effect of lagged dependent variables or, more generally the presence of serial correlation, may distort inferences and lead to overestimation of the effect of all variables, including PFR proxies.

Prices. Having discussed the methodology, we now organize the discussion around the nature of the outcome variable. Being the most important signal for welfare analysis the main strand of the literature focuses either on end-users or on wholesale prices. Empirical evidence on the impact of reforms on prices is mixed, largely depending on the characteristics of the countries where they are implemented. See Table 1.

As far as the electricity sector is concerned, Bacchiocchi et al. (2015) show that liberalizations are associated with lower electricity prices for the EU15 countries, but with higher prices in New Member States. However, according to Hyland (2016), after controlling for the possible endogeneity of reforms, that arises because prices might be a push factor for reforms, market restructuring does not impact on wholesale electricity prices in EU27. Focusing on developing countries, Nagayama (2007, 2009) shows that, contrarily to expectations, liberalizations are associated with industrial and residential electricity prices increases (Nagayama, 2009). Moreover, while single regulatory reforms are not associated with significant price changes, the coexistence of an independent regulator and unbundling tends to correlate with lower prices, but it is not possible to identify a common pattern across countries (Nagayama, 2007). Similarly, the analysis carried out by Erdogdu (2011*b*) on a sample of 62 countries suggests that the sign and magnitude of the association between different reform steps and electricity price-cost margin varies greatly across countries. Fiorio and Florio (2013) focus specifically on changes in corporate ownership implementing a variety of static and dynamic panel data model. They show that while the impact of liberalisation on prices is small and uncertain, public ownership is associated with lower residential electricity prices in EU15 countries.

The impact of regulatory reforms on prices has also been assessed in other network industries, reporting heterogeneous findings but pointing out to a limited, if not detrimental, role of privatizations per se. Brau et al. (2010) highlight that EU gas industry privatizations do not lead to benefits for consumers, but that some price lowering effects can be imputed to the softening of the entry legislation. Growitsch and Stronzik (2014) show that in the EU legal ownership unbundling of

natural gas transmission networks is associated with lower end-user prices while privatizations lead to a price increase. Finally, Bacchiocchi et al. (2011), focusing on EU telecommunications, report that regulation is associated with price reductions, while privatizations seems to play no significant role in explaining the price of international, national, local calls, and connection charges.

Productivity, investment and other performance variables. As shown in Table 2, a second and very diffuse strand of the literature deals with the evaluation of the impact of reforms on productivity, investment decisions and various measures of the quality of the service provided.

A first subset of studies focused on the impact of reforms on different macroeconomic aggregates. Prati et al. (2013) analyse the impact of trade, agriculture, network, and financial reforms on GDP growth for a sample of over ninety developing and developed countries. While reforms are positively correlated with growth, the association between liberalization in network industries (telecom and electricity) and growth is not statistically distinguishable from zero. Bacchiocchi et al. (2005, 2008), relying on time-series techniques, show that while UK privatizations had no long-run impact on output, public expenditure has been sustained by their proceeds, that have also temporarily boosted investments. A positive effect on investment was found also by Alesina et al. (2015), who show that entry liberalization and privatization in OECD countries had positive long-run effects on investment in the electricity, gas, water, communications, post, transport and storage sectors. On the other hand, Gugler et al. (2013) analyze the impact of regulations on aggregate investments in generation, distribution and transmission assets in 16 European countries, providing a mixed evidence. Their results indicate that the establishment of a wholesale market or free choice of supplier boosts investment, while unbundling tends to decrease aggregate investment spending by adversely affecting the incumbent company. Consistently, Nardi (2012) shows that the correlation between ownership unbundling and investment in the electricity network is statistically indistinguishable from zero, once the lagged value of the dependent variable is included in the model. Grajek and Röller (2012), focusing on the telecommunications industry,

analyse the impact of entry regulation on investment decisions of over 70 fixed-line operators in 20 European countries. They highlight that entry regulation discourages investment by both incumbents and entrants. Cambini and Rondi (2010) focus on the investment decisions of 23 energy utilities in five EU countries. They show that investment rate is lower under rate of return regulation than under incentive regulation.

Concerning R&D expenditure, research analysed suggests a negative impact of liberalization reforms. Kim et al. (2012) analyse a panel of 70 electricity-generating firms located in 15 OECD countries and show that entry liberalization is negatively associated with their level of R&D expenditure. Erdogdu (2013), focusing on a panel of 27 developed countries shows that reforms are negatively associated with government spending in energy R&D activities.

Looking at environmental outcomes, two recent studies by Asane-Otoo (2016) and Clò et al. (2017) analyse the impact of reforms on greenhouse gas emissions and intensity. Asane-Otoo (2016) studies the relationship between restructuring policies and greenhouse gas emissions from the electricity sector in OECD countries and shows that emission intensity is negatively correlated with the degree of competition. In the case of 27 European countries, Clò et al. (2017) find that an increase in public ownership is associated with an improvement of environmental performance both before and after the introduction of the Emissions Trading System.

Productivity issues are debated by Pompei (2013), who shows that, for a panel of 19 EU countries, the increased stringency of entry regulation is negatively associated with total factor productivity (TFP) growth in the electricity sector. Borghi et al. (2016), focusing on a panel dataset of electricity distribution firms operating in 16 European countries, show that in countries with poor quality of institutions, public ownership is associated with lower TFP, while where the quality of government is higher public ownership and TFP are positively correlated. Bottasso and Conti (2010) analyse the impact of motorway networks on output for a panel of twenty-one manufacturing and service sectors of eleven EU countries. They show that the elasticity of output with respect to motorway is lower in countries where the degree of entry barriers is higher.

As far as the quality of service is concerned, empirical evidence tends to confirm that reforms aiming to foster competition usually have beneficial effects, while a simple shift from public to private ownership did not lead to substantial gains. This is what emerges from the work of Zhang et al. (2008) which, using a panel of 36 developing countries, demonstrate that privatization and regulation do not lead to higher electricity generation and installed generation capacity, but competition is associated with performance improvements. Similar conclusions are drawn by Koo et al. (2013), which analyse the effect of private participation in the power service sector on the electric power transmission and distribution losses in 35 developing countries. They show that the efficiency of the power service is negatively correlated with private participation. Polemis (2016), focusing on 30 OECD countries, shows that the association between privatisation and electricity performance (labour productivity and installed capacity) is either negative or statistically indistinguishable from zero. Erdogdu (2011*a*), relying on a panel dataset of 92 developed and developing countries, shows that the efficiency boosting impact of reforms in the power sector is limited at best. Among the studies supporting a positive impact of reforms on service quality we include Zhang et al. (2005), which provide evidence that in developing countries electricity generation and installed generation capacity increase in the presence of an independent regulatory authority. Moreover, they show that the sequence of reforms matters: the introduction of competition before privatization leads to greater gains in terms of electricity generation and installed generation capacity. Polemis and Stengos (2017) focus on the electricity performance, as measured by capacity, generation, and productivity for 30 OECD countries. Using a static panel threshold fixed effect model, they split countries into two groups: liberalized and non-liberalized. For the latter group, they find that electricity performance is positively influenced by structural reforms. Nepal et al. (2010) study the association between ownership unbundling and quality of service for 29 electricity distribution networks in New Zealand, finding that duration and frequency of supply interruptions in electricity distribution network is negatively associated with ownership unbundling.

Focusing on the telecommunication industry, Howard and Mazaheri (2009) show that neither privatizing, nor liberalizing the market spur the diffusion of information and communication technologies (ITCs). However, increasing the 'de jure' independence of the regulatory authority has beneficial effects for the diffusion of ITCs. Briglauer (2014) shows that for a panel of EU27 countries the adoption of fiber-based broadband services is negatively correlated with the effectiveness of previous regulation. In a subsequent work the author shows that this negative correlation is explained by the fact that mandatory access regimes have a negative impact on investments and hence, indirectly, on fiber-based broadband adoption (Briglauer, 2015). Nardotto et al. (2015) show that in the UK local loop unbundling has increased the quality of service, as measured by the download speed of broadband internet connection. Belloc et al. (2013) analyse a panel of 22 European countries and show that liberalizations in the telecommunication industry are positively associated with the year-on-year change of market share of entrants, especially in the presence of an independent regulatory authority.

Customer satisfaction. While the previous analyses focus on what can be thought to be the determinants of the quality of services, an alternative approach is to use consumers' satisfaction surveys to directly measure perceived welfare changes (see e.g. Clifton et al., 2014). See Table 3. Florio and Poggi (2010) analyse how electricity and natural gas market reforms affect the probability of EU households struggling to pay bills. The authors show that while the probability of deprivation is positively affected by privatization, the effect of liberalization is not statistically distinguishable from zero. Fiorio and Florio (2011) show that consumers' satisfaction is higher in countries where the market is liberalized and characterized by large public ownership of the electricity industry. Fiorio et al. (2013) show that local public transport users' satisfaction is higher in cities where local transportation is managed by a monopolistic, integrated service organization. Ferrari et al. (2011) analyse the 2002 wave of the Eurobarometer survey with a multilevel random

effect model and show that customers' satisfaction is negatively associated with privatization and liberalization in the telecommunication, energy and transport.

4. Potential pitfalls and suggestions for the empirics of PFR

Studies in Tables 1-3 rely on several PFR proxies. The process of building such variables is prone to several types of errors that can be grouped into three main categories:

i. Conceptual errors;

ii. Discretization, definition of orderings and metrics.

iii. Aggregation errors.

These three issues cause a broader class of empirical problems that goes under the header of *measurement error*. Moreover, given the nature of PFR proxies, interpretation of results requires some caution. This section discusses issues (i-iii), measurement error and provides suggestions for the interpretation of results in empirical analyses of PFR.

Conceptual errors. When researchers look for variables that can approximate PFR, the risk of introducing conceptual errors is high. Although PFR proxies might not represent the analogous of signals in the RSG context, appropriate measures can be defined. Unbundling, for instance, can be thought as a categorical variable with an ordering going from full vertical integration, to complete unbundling. This is a relatively simplistic but consistent way of identifying the sequence of legislative acts that trigger the unbundling process. The proxy in fact identifies a new state of the economy, with accounting, legal and functional unbundling of a given industry.

Interpretational and identification problems arise when the variable designed as a PFR indicator might also be the outcome of some macroeconomic shock. A case in point, is the Herfindahl-Hirschman index of concentration, or more simply reliance on the market share of the largest service provider in a country.

While these variables are in principle legitimate PFR proxies, their interpretation largely depends on the ingenuity of the researcher. The market share of, say, the largest electricity generator, is part of the policy and can be used as a PFR proxy when the regulator forces the incumbent to divest generation capacity. On the contrary, if the market share has changed in response to an exogenous technological shock that altered the optimal production plan not only for the incumbent, but for any firm in a sector, the validity of the PFR proxy is questionable. In this case, the technological shock is a confounding factor that causes an omitted variable bias and hence ultimately affects the evidence in favor or against the reform.

Thus, if available, control variables should mitigate the omitted variable problem. These problems can also be addressed with a set of robustness checks, where alternative PFR proxies are used.

Discretization, definition of orderings and metrics. Discretization is the process of converting a continuous variable into a discrete one. In the definition of any scoring system, criteria for building indicators starting from raw information are needed. When the underlying data are continuous, discretization may or may not have alternatives. In practice, most PFR variables, such as those in the ETCR or in the GCI databases, rely on a multidimensional, often discrete, scale.

The reason for relying on discretized variables is due to the complexity of finding a unit of measure for PFR proxies. While discretization might apparently make the analysis easier, it has many drawbacks (Rucker et al., 2015). First, potentially useful variability is discarded; second, when the PFR is used as an explanatory variable, this loss of variability reduces the precision of in-sample and out-of-sample predictions. In the extreme case of summarizing PFR with a dichotomic variable, there might be a substantial reduction in statistical power, that increases the chance of both type-I (i.e. false positive) and type-II error (i.e. false negative). Moreover, Lien and Balakrishnan (2005) show that dichotomization of the independent variable reduces goodness-of-fit and may increase or decrease the regression slope. Dichotomization leads also to interpretational issues. In

fact, using a dummy variable within a panel regression to measure, say an anti-monopoly policy, implies that competition increases by the same magnitude in all countries. Lastly, discretization is often arbitrary. In fact, original data often do not provide guidance for the design of intervals to be used for the definition of the scoring system. In such cases, collapsing scores into a dichotomic variable, or aggregating them in very wide brackets might be a viable strategy. Overall, there is a clear trade-off between statistical variability and discretization error. As it can be seen in Tables 1-3, several studies have pursued this approach, recoding the discrete PFR proxy into a dichotomic variable. See Bacchiocchi et al. (2015), Growitsch and Stronik (2014) and Nagayama (2007) among others.

Discretization might also lead to issues in the definition of orderings and metrics. The first difficulty arises when there are several viable PFR, but according to an ideal path that goes from "less ambitious or advanced" to the "most ambitious or advanced" none of them represents a win-win option. Coding such information is a very complicated task. A further issue arises when a categorical variable implies considering ordinal data as cardinal. In these cases, it may even be preferable to shrink the information into a dichotomic variable, dramatically reducing the error, but also losing information and variability. Alternatively, as suggested by Fiorio and Florio (2011), one might check whether results critically depend on the cardinalisation adopted.

Aggregation. There are usually no valid economic criteria to guide the aggregation of different PFR indicators using bottom-up approaches. For this reason, equal weights are often assigned to different aspects of PFR and upper-level indices are simple averages or sums of the lower-level variables. See Figure 1. This might bias estimates, affect inference and influence the evaluation of PFR; in fact, aggregate reform scores depend on arbitrarily selected equal weights.

The problem can be either attenuated, by relying on data-reduction techniques, or completely avoided, by using only lower-level indicators. In this case, one PFR proxy will be interpreted as the variable of interest and the remaining as controls. Data-reduction techniques, such

as Principal Component Analysis, have been successfully used to calculate weights and synthetic PFR proxies in many settings (see e.g. Ferrari and Manzi, 2014; Florio and Poggi, 2010). However, if on the one hand they easily lead to a weighing scheme, on the other hand they are a-theoretical, leave no control to the analyst and are severely affected by the presence of outlying observations. A further alternative is to check the robustness of results to different weighting schemes with a random weights analysis (Koske et al., 2015).

Besides problems related to the weighting scheme, the use of aggregate PFR measures in place of sub-indices lead to a loss of information, since it does not allow to identify the effects resulting from distinct aspects of the regulation.

Measurement error, ME. Measurement error (ME) identifies any deviation from the true value of variable that arises in the definitional or measurement stage (Asher, 1974) and therefore subsumes all the issues discussed so far. Mismeasurement is likely to be particularly severe in the case of PFR proxies since they rely on several non-standard data sources such as media coverage, legal and non-legal acts and expert surveys.

Misreporting by subjects, coding and other errors, such as those discussed above, are likely to inflate ME.[9] As Blackwell et al. (2015) point out, also missing data are a limiting special case of mismeasurement that arises when there is no prior information about the true unobserved values of the variable of interest. Moreover, even in the presence of correctly measured variables, what we called "*conceptual errors*" are another source of ME. In fact, observed data often do not correspond to the exact concept the analyst is interested in (e.g. the use of years of schooling as a proxy for human capital).

ME can be purely random or have both a casual and a nonrandom component. Nonrandom ME arises when the deviation from the true value of variable is systematically influenced by some

[9] See the surveys in Angrist and Krueger (1999), Bound et al. (2001), Cameron and Trivedi (2005), and Hausman (2001).

factors that introduce an upward or downward bias in the observations. Examples include the fact that data are often more accurate for some countries than for others (Albouy, 2012), or that long time series are more precisely measured in the present than in the past.[10] A purely random white noise ME, is less worrisome than the nonrandom case for at least two reasons. First, econometric techniques for estimating its effects are better developed (see e.g. Asher, 1974; Cameron and Trivedi, 2005). Second, contrarily to the nonrandom error case, it tends to average out in aggregate data, such as macroeconomic variables. This also explains why the literature on "error-in-variables" has developed in parallel with the increasing availability of micro-level cross-sectional and panel databases (Angrist and Krueger, 1999).

There are many factors that determine the magnitude and the sign of the effect of ME on inferences, including: its nature (classical or non-classical, random or nonrandom), whether mismeasurement affects the dependent and/or the one, or more, independent variables, whether the variable is continuous or not, the nature of the model (bivariate or multivariate, linear or nonlinear), the nature of the dataset (cross-sectional or panel data).

A benchmark case involves a continuous cross-sectional variable subject to classical ME of additive form. In this setting, instead of observing the true variable of interest, we observe a proxy that is the sum of the latent variable and a white noise error term that is independent of both the correctly measured variable and the regression error.[11]

Depending on the aim of the analysis a given PFR proxy can be used either as the dependent or as an independent variable in a linear regression. Classical ME in the dependent variable leads to less precise least squares estimates, but does not introduce any bias (Angrist and Krueger, 1999). On the contrary, when there is a single regressor subject to classical ME, least squares estimates

[10] Gallop and Weschle (2017) provide a thorough discussion of the topic and develop a sensitivity analysis approach that can be used to conduct robustness analysis of inferences in the presence of nonrandom measurement error.

[11] More formally, suppose that we are interested in $y_i = \beta x_i^* + u_i$, but instead of observing the correctly measured variable x_i^*, we only have data on $x_i = x_i^* + \xi_i$, where $\xi_i \sim (0 , v_\xi)$, and $\text{cov}(x_i^*, \xi_i) = \text{cov}(u_i, \xi_i) = 0$.

will be downward biased and inconsistent. While adding more controls not contaminated by measurement issues, will decrease the magnitude of the *attenuation bias* (i.e. the bias toward zero coefficient of the mismeasured variable), the inconsistency problem remains and extends also to the coefficients of the other regressors, but for them the sign of the bias is not predictable. Similarly, if there is more than one explanatory variable measured with error, estimates are still inconsistent but the sign of the bias is not known a priori (Cameron and Trivedi, 2005). Lastly, going back to the case of a single mismeasured regressor, it can be shown that the inclusion of polynomial terms will generally inflate the size of the attenuation bias (Griliches and Ringstad, 1970). This case is relevant since researchers often include quadratic terms to capture nonlinearities relating PFR proxies with the outcome of interest (Alesina et al., 2005; Erdogdu, 2011).

Given the prevalence of panel data analyses in the literature on the empirical evaluation of PFR it is legitimate to ask what happens if the reform proxy is contaminated by classical ME. Griliches and Hausman (1986) show that, since panel variables are typically positively correlated over time, the attenuation bias in the fixed effect model is larger than in the cross-sectional case. Moreover, they show that relying on first-differenced data to remove fixed effects yields a larger attenuation bias than when running the regression on the level of variables.

Classical ME is a useful benchmark, but the underlying assumptions are often not met by most widely used PFR proxies. For instance, variables in the ETCR database represent scores in a finite interval and are often transformed into a 0-1 dummy (see Tables 1-3). Clearly, neither scores, nor dummy variables are consistent with the classical ME assumptions. In fact, when the mismeasured variable is binary, ME cannot be independent of the correctly measured values of the variables. A dummy, can only be misclassified in one of two directions: a true "zero" classified as "one" or a true "one" classified as "zero". The sign of the error depends on the true unobserved variable. Similarly, in the case of a score that can take on only some values in an interval. In a bivariate linear regression setting, a mismeasured dummy variable still leads to an attenuation bias, but generalizations of these results to other settings are not possible (Card, 1996).

In general, when moving from linear to non-linear models with classical or nonclassical ME (such as probit or Poisson specifications) characterization of its effects becomes much harder. Moreover, while instrumental variable estimation often provides a solution to the problem in linear models, it does not deliver consistent estimates in a nonlinear regression framework. In this setting, neither the linear, nor the nonlinear form of two-stage least squares estimator leads to consistent estimates of coefficients. See Bound et al. (2001), Hausman (2001) and Schennach (2016) for a survey of ME in nonlinear models.

While there is no *panacea* for ME, visual inspection of data may sometimes help spotting outliers. In such cases, trimming (i.e. dropping observations with outlying values) and winsorizing (i.e. capping outlying data points) can be used to deal with outliers and various form of measurement error (Angrist and Krueger, 1999).[12] Alternatively, if one is willing to make some simplifying assumptions both classical and non-classical ME can be addressed with ad-hoc estimators.[13]

Lastly, let us consider the ideal case when both the outcome variable and the PFR proxy are correctly measured. Should we omit other relevant variables because they might be measured with error? No, because we would simply substitute the bias due to ME with an "omitted variable bias". Moreover, McCallum (1972) has shown that using a proxy of a latent variable will induce a smaller asymptotic bias than simply dropping the variable from the model.

Interpretation of results. Within the GLM framework the interpretation of estimated coefficients, from a purely statistical point of view, is relatively straightforward. In fact, a key feature of GLM is that the conditional mean is of the single-index form, meaning that it is a nonlinear function of a linear combination of regressors and parameters, $\mathbf{x}'\boldsymbol{\beta}$. When it is also a monotonic function,

[12] Lien and Balakrishnan (2005) discuss the relative merits of trimming and winsorizing for in-sample inference.

[13] Since the literature on the topic is very diffuse, it cannot be surveyed here. The interested reader is referred to Bound et al. (2001), Hyslop and Imbens (2001), Schennach (2016) and references therein.

interpretation of regression results is further facilitated, even if the conditional mean is non-linear, as in the case of Logit and Probit models. More precisely, it can be shown that the ratio of coefficients for two different regressors equals the ratio of the marginal effects and that the sign of the coefficient gives the sign of the marginal effect (Cameron and Trivedi, 2005).

However, economic interpretation requires more caution. First, since any empirical specification omits some relevant, but possibly unavailable explanatory variable, the error term will pick-up the influence of such omissions; for this reason, estimates should not be given a causal reading. Rather, the estimate of coefficient associated with the PFR proxy represents the conditional correlation (or association) between the reform and the outcome variable of interest.

In some cases, interpretational issues might arise even if there is an observable signal that allows the researcher to cast his analysis of PFR within the RSG theoretical framework. Assume that the PFR can be measured with a continuous time-series variable representing privatization proceeds for the Treasury. If the aim of the government is to reduce the country's indebtedness by selling SOEs, then a positive estimated coefficient, showing that per-capita GDP increases for each additional euro of privatization proceeds, represents evidence in favour of the reform (see e.g. Bacchiocchi et al. 2005, 2008). Alternatively, suppose that the government aims at privatizing because private ownership is assumed to improve the efficiency of a strategic sector of the economy. In this case, since governments might even want to under-price SOEs, cash proceeds would not be an appropriate signal. An indicator variable might thus be a better PFR proxy (e.g. a dummy equal to one in the case of full public ownership, and zero otherwise). While reliance on discontinuous scores induces a loss of variability, it is nevertheless the best available information that the analyst can use, given the aim of the government. In this case the coefficient associated with the PFR variable should be read as an estimate of a structural break induced by the reform.

It is useful to point out that the use of dummy variables is potentially subject to other issues. First, care should be taken when interpreting results when the dependent variable is log-transformed. The coefficients of dummy variables cannot be given the interpretation of elasticities,

as in the case of continuous regressors. Second, in the case of a semi-logarithmic model, the percentage change in Y due to a discrete change in D from 0 to 1 is in fact given by $p = 100 \times (\exp\{c\} - 1)$; however, using the Ordinary Least Squares (OLS) estimate of c, denoted as $\hat{c}$, yields a biased estimator for p. A better solution is to rely on $\hat{p} = 100 \times [exp\{\hat{c} - 0.5\ \hat{V}(\hat{c})\}$ -1], where $\hat{V}(\hat{c})$ is the OLS estimate of the variance of $\hat{c}$ (Kennedy, 1981). Among the surveyed study only Nepal et al. (2016) have addressed this issue as suggested.

5. Concluding remarks

This paper has reviewed the econometrics of policy framework reforms starting from the distinction between the theory of reform *à la* RSG and the problem of evaluating PFR when these cannot be read as a marginal change to a specific economic signal.

This distinction clearly matters when carrying out empirical analyses of reforms in network industries, given that we have highlighted that PFR assessment is particularly prone to both methodological and interpretational errors. Moreover, the interpretation of estimated coefficients differs, because usually it is not meaningful to express them as marginal changes of the variable of interest, but rather as a transition from a policy regime to another.

The punchline of our analysis is that even if going from the theory to empirics of PFR might be challenging, their empirical evaluation is an essential task for supporting policy making activities. In fact, the quantitative measurement of how social welfare responds to a change of circumstances, such as those implied by a PFR, is a not only at the core of applied welfare economics, but also a necessity, in that "*evaluation of regulatory outcomes informs policy makers of successes, failures and the need for change or adjustment to regulation so that it continues to offer effective support for public policy goals*" (OECD, 2010, p. 9). This point is stressed also by Parker and Kirkpatrick (2012) who highlight that "*evidence on the outcomes of regulatory policies should help policymakers design regulatory measures that work better*". Further research is therefore needed to understand how to address the methodological issues discussed in this paper.

We have suggested how to avoid some potential pitfalls and reviewed some findings based on proxy variables of regulatory reforms.

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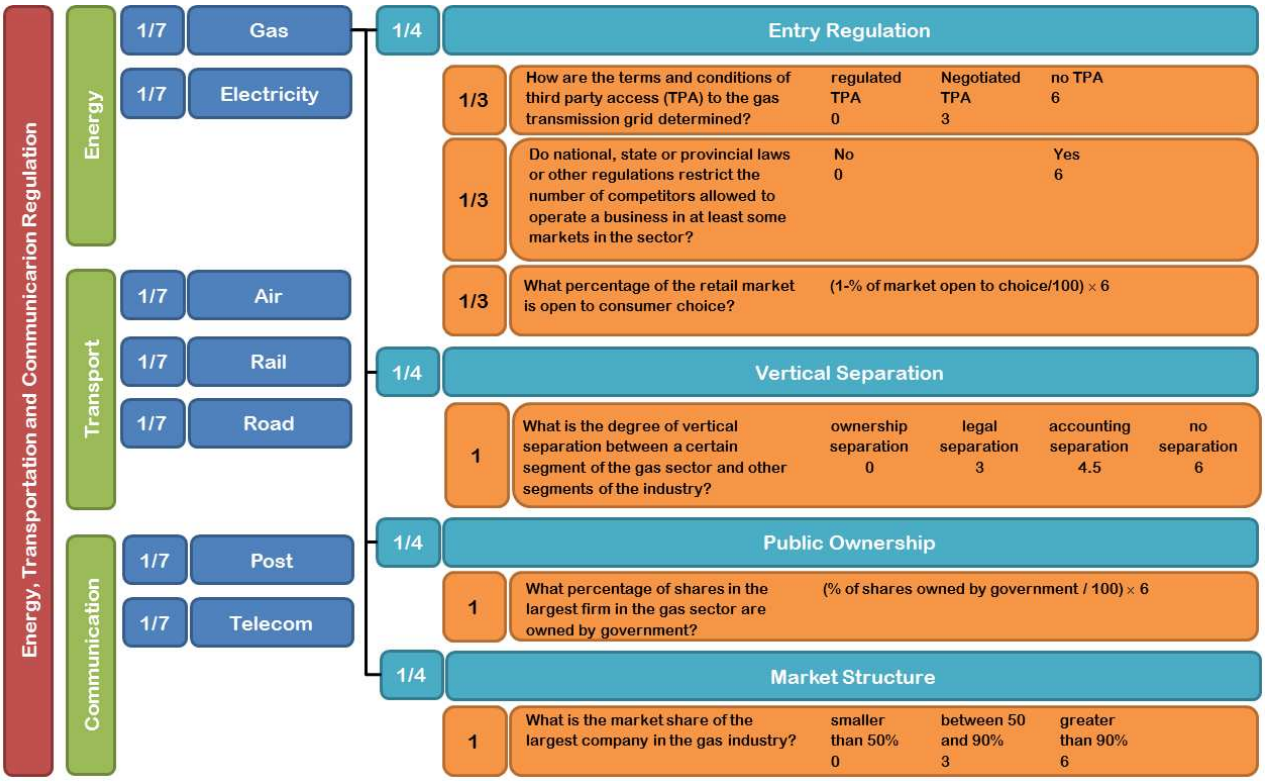
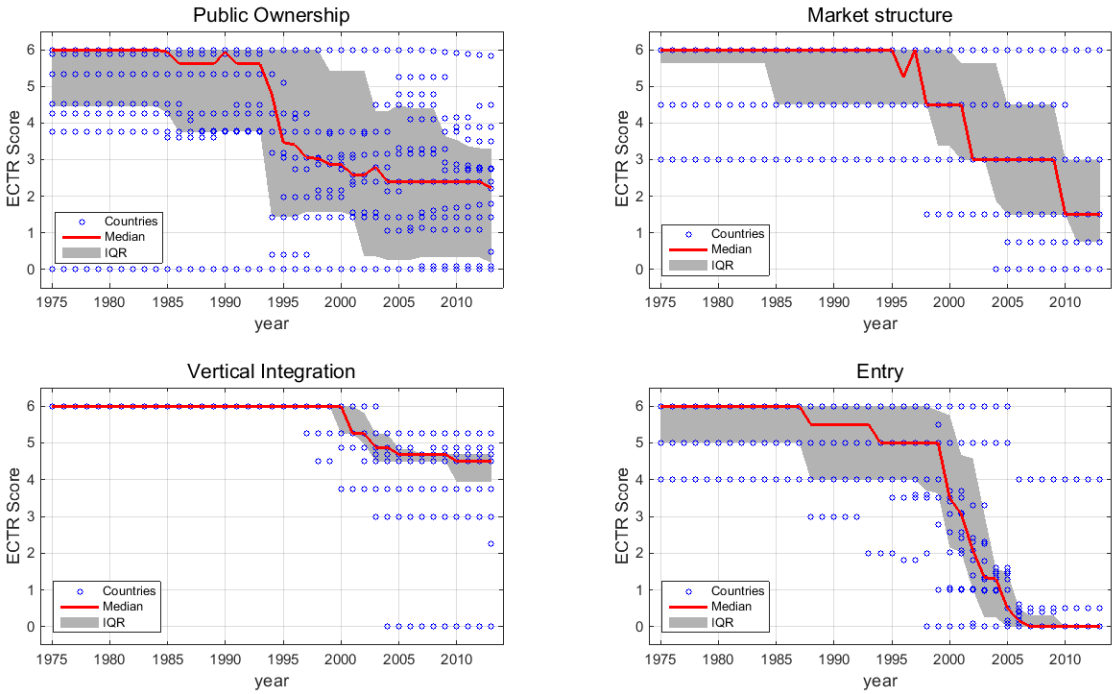
Figure 1. Structure of the OECD's Energy, Transport and Communications Regulation (ETCR) database.



Notes: The ETCR index aggregates with equal weights indices for seven network sectors: telecom, electricity, gas, post, air transport, rail transport, and road transport. For each sector, there are up to four sub-indices that cover different dimensions of the reforms: entry regulation, public ownership, vertical integration and market regulation. We show the underlying questionnaire for the gas sector. Numbers are sector, topic and question weights used for aggregation purposes.

Source: authors' elaboration using data in Koske et al. (2015).

Figure 2. Trends of ECTR reform indicators in EU-15 countries for the natural gas industry, 1975 – 2013.



Notes: each panel shows one of the Indicators of Energy, Transport and Communications Regulation (ETCR), for individual EU15 countries (dots), the median value of the indicator (line) and the interquartile range, (IQR, shaded area). ECTR reform indicators score from 0 to 6.

Source: authors' calculation on data sourced from the ETCR database maintained by the OECD (Koske et al., 2015).

Table 1. Summary of empirical analyses of the effect of PFR in network industries: prices as dependent variable.

	Sample				Model		PFR proxy			
Reference	**Countries**	**Period**	**Industry**	**Dependent variable**	**Estimator**	**Dynamic**	**Description**	**Transf.**	**Source**	**Results**
Bacchiocchi et al. (2011)	EU15	1997-03	T	loc., int., nat. P, and connection charges	IV FE	No	PO, MS, ARI	log	OECD-ETCR	Mixed evidence: regulation reduces P, but technological and demand-side factors have more explanatory power.
Bacchiocchi et al. (2015)	EU27	1990-11	E	P households	FE	No	ER, VI, PO, ARI	Dummy, log	OECD-ETCR	Liberalization associated with lower P for the EU15 countries, but higher P for the NMS.
Brau et al. (2010)	EU15	1991-07	E	P households	GMM	Yes	VI, ER, PO, MS	-	OECD-ETCR	Loosening entry regulation reduces P
Erdogdu (2011*b*)	62 countries	1982-09	E	Electricity end use - fuel cost margin; Cross subsidy levels	FE, RE	No	Composite reform score	-	various	No uniform pattern; impact of different reform steps varies greatly across countries.
Fiorio and Florio (2012)	EU15	1978-07	E	P households	FE, GMM	Yes	ER, VI, PO and a combination of those indices	dummy	OECD-ETCR	Public ownership associated with lower residential electricity prices
Growitsch and Stronzik (2014)	18 EU countries	1989-07	G	P households	FE, GMM	Yes	VI, ER, PO, legal and ownership unbundling	Dummy, continuous	OECD-ETCR and other sources	Ownership [legal] unbundling (Privatization) associated with no change in [lower] (higher) P.
Hyland (2016)	EU27 + Norway	2001-11	E	P industrial users	FE, GMM	Yes	Unbundling	-	various	Correlation between prices and restructuring is statistically nil
Nagayama (2007)	83 developing countries	1985-02	E	industrial and residential prices	OLS, FE, RE	No	various regulatory reform indices	dummy; interactions	various	Coexistence of an independent regulator and unbundling associated with lower prices, but results vary greatly across countries.
Nagayama (2009)	78 developing countries	1985-03	E	industrial and residential prices	FE, RE, IV	No	liberalization	score	various	Liberalizations associated with price increases

Notes: Industry: E = electricity; G = gas; W = water; T = telecommunications; Tr = transportation; various = more than one industry (jointly). Estimator: FE = Fixed effects; RE = random effects; GMM = generalized method of moments; AR(1) = Autoregressive model of order 1; LSDV = least-squares dummy variables; VECM = Vector error correction model. Dynamic: "yes" if lags of the dependent variable or autoregressive error terms are included. PFR proxy description: ARI = aggregate regulatory index (typically the sample average of underlying PFR proxies); PO = public ownership; ER = Entry regulation; VI = vertical integration; MS = market share.

Table 2. Summary of empirical analyses of the effect of PFR in network industries: Productivity, Investment and other performance variables

	Sample				Model		PFR proxy			
Reference	Countries	Period	Industry	Dependent variable	Estimator	Dynamic	Description	Transf.	Source	Results
Alesina et al. (2005)	OECD	1975-98	E, G, W, T, P, Tr	Investment/capital stock	FE, GMM	Yes	ARI, ER, PO	-	OECD-ETCR	Deregulation, entry liberalization and privatization have a positive long-run effect on investment.
Asane-Otoo (2016)	OECD	1990-12	E	CO_2, NOx, SOx intensity	FE, correlated RE	No	ER, VI, PO	Dummy	OECD-ETCR	Emission intensity is negatively correlated with the degree of competition
Bacchiocchi and Florio (2008)	UK	1979-98	various industries	various macroeconomic variables	VECM	Yes	privatization proceeds	-	Various	Privatizations have no long-run impact on output; transitory impact on investment and the public expenditures
Bacchiocchi et al. (2005)	UK	1979-99	various industries	various macroeconomic variables	VECM	Yes	privatization proceeds	-	Various	Privatizations have no long-run impact on output
Belloc et al. (2013)	22 European countries	1975-00	T	Market share of new entrants	FE	No	Privatization, Liberalization,		OECD-ETCR and other sources.	Liberalizations positively associated with year-on-year change of market share, especially in the presence of a regulatory authority.
Borghi et al. (2016)	16 European countries	2002-09	E	total factor productivity	FE	No	PO	Dummy	OECD-ETCR	Association between PO and productivity depends on the quality of government (QoG). Lower [higher] productivity with poor [high] QoG and PO
Bottasso and Conti (2010).	11 EU countries	1980-03	Tr	Production	GMM	Yes	ER	-	OECD - ETCR	Elasticity of output with respect to motorway is found to be lower for countries with high degree of entry barriers
Briglauer (2014)	EU27	2005-11	T	Next-generation fiber based adoption	FE	Yes	lines used by service-based competitors as a share of total regulated wholesale broadband lines	-	various	Adoption of fiber-based broadband services negatively correlated with the effectiveness of previous regulation
Briglauer (2015)	EU27	2004-12	T	Next-generation fiber based investment	FE	Yes	lines used by service-based competitors as a share of total regulated wholesale broadband lines	-	various	Broadband access regulation negatively correlates with investment in new fiber infrastructure
Cambini and Rondi (2010)	23 firms in 5 EU countries	1997-07	E, G	Investment rate	OLS, FE, GMM	Yes	Incentive, rate of return regulation and PO	dummy	various	Investment rate is lower under rate of return regulation than under

										incentive regulation
Clò et al. (2017)	27 EU member states, Norway, Turkey	1990-12	E	CO_2 emissions and intensity.	FE, RE	No	PO, Market structure	-	OECD ETCR	Increase in public ownership associated with a reduction of both emissions and carbon intensity.
Erdogdu (2011*a*)	92 countries	1982-08	E	Performance of electricity industry	FE, RE	No	Composite reform score	squared	various	Reforms have a limited impact on the efficiency of the market.
Erdogdu (2013)	27 IEA member countries	1974-08	E	government spending in energy R&D	FE, RE	No	Composite reform score	-	various	Reforms negatively associated with government R&D spending
Grajek and Röller (2012)	20 EU countries	1997-06	T	Tangible fixed assets as proxy for investment	system OLS and IV with FE	Yes	ARI	-	Plaut Economics	Entry regulation discourages investment by incumbents and entrants
Gugler et al. (2013)	16 European countries	1998-08	E	Aggregate investments in generation, distribution and transmission assets	Panel cointegration, FE, GMM	Yes	ER, PO, VI, other	scores and dummies	OECD and other sources	Establishment of a wholesale market or free choice of supplier boosts investment; unbundling decreases investment
Howard and Mazaheri (2009)	154 countries	1990-07	T	Tech. Distribution indices for internet use and mobile phone adoption	FE + lagged dep. Var or AR(1) error term	Yes	Privatization, liberalization, regulatory separation and de-politicization	Dummy	World Information Access project	Privatization and liberalization do not spur the diffusion information and communication technologies (ITCs). Regulatory separation is beneficial for diffusion of ITCs
Kim et al. (2012)	70 firms across15 OECD countries	1990-08	E	R&D expenditure	FE Tobit	No	ER	-	OECD-ETCR and other sources	Entry liberalization associated with lower R&D
Koo et al. (2013)	35 developing countries	1990-01	E	power service efficiency (power transmission and distribution losses)	FE, RE, GEE	No	Private participation	log	World Bank's PPI database.	Private participation negatively correlated with efficiency.
Nardi (2012)	14 European countries	2001-10	E	Quality of transmission network	corrected LSDV	Yes	Unbundling	scores	various	Association between ownership unbundling and grid investments is not statistically significant.
Nardotto et al. (2015)	UK	2009	T	Speed of connection	OLS	No	Dummy = 1 if line served by LLU entrant	-	OfCom	Local loop unbundling (LLU) has increased average broadband speed.
Nepal et al. (2016)	29 electricity distribution networks, New Zealand	1996-09	E	quality of service	FE, RE	No	ownership unbundling	dummy	various	Duration and frequency of supply interruptions in electricity distribution negatively associated with ownership unbundling
Polemis (2016)	30 OECD countries	1975-11	E	indicators of electricity performance (capacity, generation, productivity)	FE, GMM	Yes	ARI and others		OECD-ETCR	Association between privatisation and electricity performance (labour productivity and installed capacity) is either negative or statistically indistinguishable from zero
Polemis and Stengos	30 OECD countries	1975-13	E	indicators of electricity performance (capacity,	panel threshold	no	ARI	-	OECD-ETCR	Reforms positively correlated with electricity performance in non-

(2017)				generation, productivity)						liberalized countries
Pompei (2013)	19 EU countries	1995-07	E	TFP growth	GMM	Yes	ARI, ER, VI, PO	-	OECD-ETCR	Increased stringency of entry regulation negatively impacts on productivity
Prati et al. (2013)	over 90 developed and developing countries	1973-06	E, T	GDP growth	FE, GMM	Yes	ARI	-	legislation and official documents	Association between liberalization and growth is statistically indistinguishable from zero
Zhang et al. (2005)	25 developing countries	1985-01	E	per-capita electricity generation and installed generation capacity	FE	No	Regulation; Competition; Privatization; Sequencing dummy variables	dummies	Various	Generation and generation capacity positively associated with the presence of an independent regulatory authority and by the introduction of competition before privatization
Zhang et al. (2008)	36 developing countries	1985-03	E	per-capita electricity generation and installed generation capacity	FE	No	Composite regulatory index; competition; public ownership	dummies and score	Various	Privatization and regulation do not lead to higher electricity generation and installed generation capacity; competition associated with performance improvements

Notes: Industry: E = electricity; G = gas; W = water; T = telecommunications; Tr = transportation; various = more than one industry (jointly). Estimator: FE = Fixed effects; RE = random effects; GMM = generalized method of moments; AR(1) = Autoregressive model of order 1; LSDV = least-squares dummy variables; VECM = Vector error correction model. Dynamic: "yes" if lags of the dependent variable or autoregressive error terms are included. PFR proxy description: ARI = aggregate regulatory index (typically the sample average of underlying PFR proxies); PO = public ownership; ER = Entry regulation; VI = vertical integration; MS = market share.

Table 3. Summary of empirical analyses of the effect of PFR in network industries: customers' satisfaction as dependent variable

	Sample				Model		PFR proxy			
Reference	**Countries**	**Period**	**Industry**	**Dependent variable**	**Estimator**	**Dynamic**	**Description**	**Transf.**	**Source**	**Results**
Ferrari et al. (2011)	over 16000 citizens in EU countries	2002	T, E, P, Tr	Consumers' satisfaction	RE	No	ARI	-	OECD - ETCR	Customers' satisfaction is negatively associated with the privatization and liberalization
Fiorio and Florio (2011)	EU15	2000, 2002, 2004	E	Consumers' satisfaction	Probit	Yes, lagged ETCR data	ER, PO and a combination of those indices	dummy	OECD-ETCR	Satisfaction for the price paid is higher when there are bot PO and liberalization
Fiorio et al. (2013)	over 14000 citizens in 33 European cities	2009	Tr	Consumers' satisfaction	Probit	No	PO, Deregulation	categorical	various	Satisfaction higher in cities where local transportation is managed by a monopolistic, integrated service organization
Florio and Poggi (2010)	7 / 10 EU countries	1994-05 / 2004-05	E, G	Energy deprivation	Static and dynamic Probit	Yes	ER, VI, PO and a combination of those indices	-	OECD-ETCR	Probability of deprivation is positively affected by privatization; the effect of liberalization is not statistically distinguishable from zero

Notes: Industry: E = electricity; G = gas; W = water; T = telecommunications; Tr = transportation; various = more than one industry (jointly). Estimator: FE = Fixed effects; RE = random effects; GMM = generalized method of moments; AR(1) = Autoregressive model of order 1; LSDV = least-squares dummy variables; VECM = Vector error correction model. Dynamic: "yes" if lags of the dependent variable or autoregressive error terms are included. PFR proxy description: ARI = aggregate regulatory index (typically the sample average of underlying PFR proxies); PO = public ownership; ER = Entry regulation; VI = vertical integration; MS = market share.