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The European Commission has intensively discussed the mandatory separation of natural gas transmission from production and services. However, economic theory is ambiguous on the price effects of vertical separation. In this paper, we empirically analyse the effect of ownership unbundling of gas transmission networks as the strongest form of vertical separation on the level of end-user prices. Therefore, we apply different dynamic estimators as system GMM and the bias-corrected least-squares dummy variable or LSDVC estimator on an unbalanced panel out of 18 EU countries over 19 years, allowing us to avoid the endogeneity problem and to estimate the long-run effects of regulation. We introduce a set of regulatory indicators as market entry regulation, ownership structure, vertical separation and market structure and account for structural and economic country specifics. Among these different estimators, we consistently find that ownership unbundling has no impact on natural gas end-user prices, while the more modest legal unbundling reduces them significantly. Furthermore, third-party access, market structure and privatisation show significant influence with the latter leading to higher price levels.

Keywords: natural gas, networks, regulation, ownership unbundling, panel data

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1 Introduction

Ownership unbundling has been one of the most important issues in the discussions preceding the third legislative package for European energy markets. With ownership unbundling as the strictest regulatory regime of vertical disintegration the company who owns and operates the transmission assets is fully separated from the rest of the system meaning that it has no further business activities in retail or production and import[1]. On the one hand, the European Commission strongly argued in favour of ownership unbundling for gas and electricity transmission networks, preferring it to legal unbundling, which had been the minimum standard in the previous Directive. Having investigated the gas and electricity sectors, the Commission was dissatisfied with market outcomes, especially in the gas sector. The status of unbundling of transmission system operators was identified as one major obstacle to a well-functioning market environment (European Commission, 2007, 2008). On the other hand, several transmission system operators (TSOs) and countries, e.g. Germany and France, opposed these efforts of the Commission, doubting the economic benefits and raising juridical arguments against ownership unbundling. The package was adopted in summer 2009 and is entering into force in 2011 allowing now for both legal and ownership unbundling, and leaving the choice to Member States. Though a final agreement on the package has been reached, the question as to whether ownership unbundling is superior to legal unbundling remains on the political agenda. Therefore, the problem has not been solved.

From an economic point of view, ownership unbundling would be preferable if it increased net social welfare. An intuitive indicator for a positive welfare effect is if the introduction of ownership unbundling leads to lower end-user prices.[2] Economic theory gives little guidance as ambiguous results are reported (cf. e.g. Laffont and Tirole, 1993; Vickers, 1995; Buehler, 2005; Höffler and Kranz, 2011). On the one hand, it is argued that the stricter vertical separation is designed, the less incentive a network operator has to discriminate between affiliated companies and third parties. Thus, competition on down- and upstream markets will be fostered and the risk of vertical foreclosure reduced. On the other hand, ownership unbundling may lead to a loss of economies of scope and thus of operational efficiency. The net welfare effects, however, are sensitive to model assumptions and depend on, for instance, assumptions about the intensity of competition in the downstream market, on the demand function, on the role of investments or on the design of access price regulation.

Thus, the impact of vertical separation remains an empirical question. Since some countries already have established ownership unbundling (e.g. U.K.) and others have not (e.g. France), the question can be answered empirically. For that, we construct

[1] The weakest form is accounting unbundling meaning that the utility has to set up separate accounts only for different services. Legal unbundling requires that the different services have to be operated by separate companies which can still belong to the same owner.

[2] Please note that lower end-user prices are not a sufficient condition for higher social welfare as investments may be negatively affected (cf. e.g. Buehler et al., 2004, 2006). For the purpose of this paper, we concentrate on retail prices, however.

a panel out of 18 EU[3] countries spanning a time interval of 19 years. To isolate the effect of ownership unbundling, we gather data from national regulators and introduce a dummy variable which explicitly differentiates ownership unbundling from any other form of vertical integration or separation. In addition, we analyse the effect of other regulatory instruments as the degree of market opening, public or private ownership of the transmission system operator (TSO), negotiated or regulated third-party access (TPA) and whether any restrictions to market entry exist upstream. As regulatory reforms might take some time to become price effective (cf. e.g. Joskow, 2008), we also calculate the dynamic effects in terms of long run multipliers. Additionally, we control for differences among countries' economic performance, the structure of the gas sector (e.g. gas export and import) and the oil price, as in several countries gas contracts are indexed to oil prices.

To analyse the effect of ownership unbundling on retail prices[4], we face various econometric challenges, i.e. cluster correlation (I), a potential endogeneity bias (II) and a small sample bias (III). Therefore, we (I) apply a static fixed effects estimator with robust standard errors (Froot, 1989 and Williams, 2000), and the System Generalized Method of Moments estimator (system GMM, Blundell and Bond, 1998) which uses lagged variables as instruments (II). A bias-corrected least-squares dummy variable estimator (LSDVC, Bruno, 2005) allows us to compensate for the small sample bias (III) in Instrumental Variable estimation. This threefold estimation strategy ensures more robust results than a single estimator strategy.

Our paper contributes to the literature analysing the effects of reforms in energy regulation on final customer prices in three ways. First, this paper is the first that explicitly models ownership unbundling. Second, in contrast to comparable previous studies we address the potential endogeneity problem of regulatory reforms. Third, our paper is the first to identify long-run effects of reforms by calculating dynamic multipliers, addressing a natural lag between the introduction of a regulatory regime and its effect.

The remainder of the paper is organized as follows. We start with an overview of existing studies that empirically assess regulatory reforms in the energy sector. Section 4 presents the dataset and some descriptive analyses with a focus on regulatory indicators. The applied econometric approaches and the results are discussed in section 5. Finally, we conclude.

2 Related Literature

A change of the regulatory framework of an industry, such as the introduction of ownership unbundling in the gas sector, is justified if it improves social welfare. In many

[3] In an earlier version of this paper we included other OECD countries as well. By interviews of the designated regulatory authorities it turned out that none of these countries has introduced ownership unbundling for gas TSOs, but show ambiguous regulatory structures.

[4] We use the terms end-user prices for household customers and retail prices synonymously throughout the text.

countries worldwide, both energy sectors - electricity and gas - have passed through a radical liberalisation process. Countries have chosen different approaches not only with regard to implemented measures but also with regard to speed and timing. However, empirical studies on the price effect of the liberalisation process in the energy sectors are rather rare (an overview is provided in Table 1). The three studies on gas will be at the centre of the following discussion.

Copenhagen Economics (2005) has been the first investigating the determinants of natural gas end-user prices. Copenhagen Economics has developed its own indicator capturing regulatory reforms, the so-called Market Opening Index (MOI) for 14 European countries. The indicator is scaled between 0 and 1, with 1 indicating full market opening. The explanatory variables are modelled with a lag of one year and a fixed effects estimator is applied. Privatisation and competitive tariff structures tend to decrease end-user prices. However, regulation of these prices shows an increasing effect, quite the opposite of what is usually intended. The indices which cover information on the unbundling of networks are not significant. Due to the high level of aggregation, it is difficult to identify effects of a single regulatory measure like the introduction of ownership unbundling. Therefore, results remain vague. Furthermore, the construction of the indicator lacks transparency and seems to be based - at least partly - on individual judgements.

Like the majority of studies of liberalisation in developed countries (OECD or EU), a recent paper by Brau et al. (2010) relies on the OECD database, indicators of regulation in energy, transport and communications (ETCR), as it is publicly available and provides for consistency. This database covers a broad range of regulatory areas, i.e. entry regulation, public ownership, vertical integration and market structure. Each of these four main indicators consists of three sub-indicators.[5] As the weighting procedure as well as the coding provided by the OECD data is somehow arbitrary and results are sensitive to these issues, Brau et al. advocate the application of sub-indicators and the adjustment of the actual coding in light of the specific research question to be analysed while most previous studies rely on the aggregate indicators and the OECD coding.[6] The authors compare two sources for residential end-user prices in the gas sector - Eurostat and the International Energy Agency (IEA) - and find hardly any evidence of beneficial effects of regulatory measures on European end-user prices. Instead, privatisation tends to increase prices. However, Brau et al. neglect two important sub-indicators: the existence of market barriers for entrants and the regime of third party access (TPA),

[5] The OECD database provides regulatory indicators for seven network industries, i.a. electricity and gas, for 29 OECD countries. The overall structure of the indicators is the same across sectors. Concerning gas, each of the 12 sub-indicators is coded 0, 3 or 6 with the highest score of 6 indicating the most restrictive conditions regarding competition. For aggregation equal weights are used except for the indicator for vertical integration. See Conway and Nicoletti (2006) for further details.

[6] Looking at two earlier studies on the electricity sector by Steiner (2001) and Hattori and Tsutsui (2004), with the latter being more or less a re-evaluation of the former, gives some indication regarding this line of argument. While Hattori and Tsutsui define the unbundling variable to be 1 if legal unbundling has been established, Steiner already regards accounting unbundling as a form of vertical separation leading to the detection of reverse effects for unbundling and the introduction of a power exchange.

both of which are crucial for market entry conditions. Therefore, estimations may face an omitted variable problem. Furthermore, the authors rely on the three OECD sub-indicators of vertical integration which do not explicitly cover ownership unbundling of TSOs. This will be discussed in the next section.

Concerning the empirical methods applied, Table 1 shows that dynamic panel approaches like GMM or LSDVC have become popular as they are generally capable of dealing with the endogeneity problem of dynamic price processes. Reforms of the regulatory framework not only influence end-user prices or investments, they might also be driven by these variables.[7] Indeed, only Cambini and Rondi (2010) effectively model regulatory indicators as endogenous regressors in the dynamic setting.[8] Their approach is different to ours, however, as they concentrate on the influence of incentive regulation on investment behaviour using firm-level data, not controlling for ownership unbundling or focussing on end-user prices. Also, they do not report the long run effects of regulation.

To sum up, economic theory reports ambiguous effects concerning the pros and cons of ownership unbundling which calls for an empirical assessment. To date, no empirical study has isolated the effect of ownership unbundling and evaluated its long-run effect on natural gas retail prices. With this study we fill this gap by trying to support these discussions with empirical evidence and answering the question as to whether or not this action has brought about beneficial outcomes.

[7] Regarding electricity, this has been explicitly analysed by Nagayama (2009). He defines one single indicator, the so-called liberalisation model, subsuming information on various areas of regulation, such as e.g. price regulation and consumer protection. Applying an ordered probit model he shows that the selection of a certain liberalisation model by a country is influenced by electricity prices.

[8] Brau et al. (2010), for example, apply system GMM, but only lagged dependent variables are instrumented. Potential endogeneity of regulatory indicators is not tackled.

Table 1: Overview of empirical studies

Study	Countries (Time) Sector(s)	Dependent variables	Regulatory indicators	Control variables	Empirical model[1)]	Success factors[2)]
Steiner (2001)	19 OECD (1986-1996) Electricity	- End-user prices industry - Ratio of end-user prices - Sector performance (capacity utilization)	- OECD database[3)] - Power exchange - Time to privatisation - Time to liberalisation	- GDP - Share of nuclear power - Share of hydro	Factor analysis, FE, RE	Price levels - Third party access (-) - Power exchange (-) - Unbundling (-)
Hattori and Tsutsui (2004)	19 OECD (1987-1999) Electricity	- End-user prices industry - Ratio of end-user prices	- OECD database[3)] - Power exchange - Time to privatisation - Time to liberalisation	- GDP - Share of nuclear power - Share of hydro	FE, RE	Price levels - Market opening (-) - Power exchange (+) - Unbundling (+)
Alesina et al. (2005)	21 OECD (1975-1998) Utilities, communications and transport	- Investments - Capital stock	- OECD database[3)] - Lagged, squared - Interaction terms	- GDP - Interest rate	Difference GMM (Arellano-Bond 1991)	- Entry liberalisation (+) - Privatisation (+) - Increasing returns
Copen-hagen Economics (2005)	14 EU (1993-2003) Electricity and gas	- End-user prices industry	- MOM database - Lagged	- Price for heavy fuel oil (lagged)	Factor analysis, FE	- Privatisation (-) - Tariff structure (-) - Regulation of end-user prices (+)
Zhang et al. (2008)	36 developing countries (1985-2003) Electricity	- Generation per capita - Installed capacity per capita - Generation per employee - Capacity utilization	- Private ownership (generation) - Market share of three largest generators - Regulatory governance index - Interaction terms	- Country risk - GDP per capita - Urbanisation - Industrialisation - Export	FE	- Market share of three largest generators (+)
Nagayama (2009)	78 developed and developing countries (1985-2003) Electricity	Electricity price - Households - Industry	- Liberalisation model	- GDP per capita	Ordered probit, FE, RE, IV	- Power price drives liber-alisation - Liberalisation (+)

Table 1: continued

Study	Countries (Time) Sector(s)	Dependent variables	Regulatory indicators	Control variables	Empirical model[1)]	Success factors[2)]
Brau et al. (2010)	12 EU (1991-2007 Gas	End-user prices households - Eurostat - IEA	- OECD database[3)]	- GDP per capita - Gas production per capita - Gas imports per capita - Oil price (Brent) - Consumer price index	System GMM (Arellano-Bond 1991)	- Ambiguous - Privatisation (+)
Cambini and Rondi (2010)	5 EU (1997-2007) Electricity and gas (firm-level data; 23 TSOs and DSOs)	- Investment rate	- Incentive regulation - X-factor - Allowed cost of capital	- Owenership - Energy supply per GDP - Gas imports per capita - Price index - Interest rate	FE, 2SLS, Difference GMM (Arellano-Bond 1991)	- Incentive regulation (+) - X-factor (-) - WACC (+)
Sen and Jamasb (2010)	19 Indian states (1991-2007) Electricity	- Efficiency (plant load, network losses) - End-user prices industry and households	- Independent regulatory body - Unbundling of networks - Open network access - Privatisation	- Population - GDP per capita - Share of hydro	LSDVC (Bruno 2005)	- Regarding prices: open network access (-)
Nillesen and Pollitt (2011)	New Zealand (1995-2007) Electricity (firm-level data on 28 DSOs)	- Unit operational costs	- Ownership unbundling	- Connection density - Output (kWh) - Quality (SAIDI)	FE, RE	- Ownership unbundling

Source: Own compilation. [1)] Estimators: FE (fixed effects), RE (random effects), GMM (generalized method of moments), IV (instrumental variable), 2SLS (two stage least squares) and LSDVC (bias-corrected least-squares dummy variable). [2)] Main identified effects. (+) signals an increasing and (-) a decreasing effect on the dependent variable(s). [3)] OECD indicators of regulation in energy, transport and communications (ETCR).

3 Data

In order to analyse the effect of regulatory reforms on end-user prices with a special focus on ownership unbundling we construct a panel consisting of 18 EU countries encompassing 1989 through 2007. While the starting date has been chosen because no major changes in gas market regulations have occurred before 1990 in the considered countries, the country choice has been made for data availability reasons.[9]

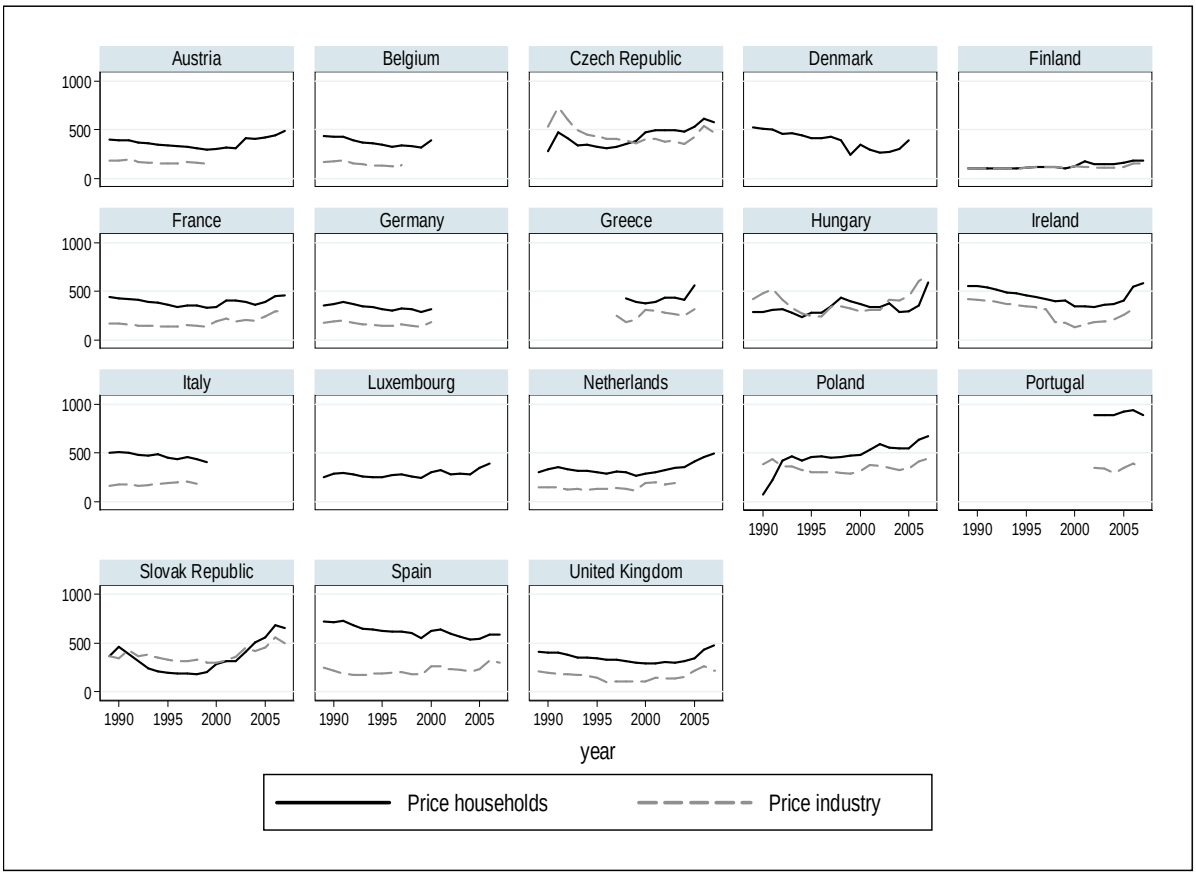

Figure 1: End-user prices [$\text{USD}_{2000}/10^7$ kcal]

As market liberalisation is a step-wise process, typically starting with opening up the segment of large industrial customers for competition and ending with residential consumers (Joskow, 2008), we focus on end-user prices for households since they indicate the effects of regulatory reforms best. We use net-of-tax natural gas prices in real terms of the database *Energy Prices & Taxes* published by the International Energy Agency (IEA) expressed in $USD_{2000}/10^7$ kcal. Figure 1 shows the price dynamics in

[9] The analysis has an EU focus and is based on the OECD database, indicators of regulation in energy, transport and communications (ETCR), that provides information for 19 EU Member States (out of a whole sample of 29 OECD countries). With no data on household gas prices available for Sweden leaves us with 18 countries.

the considered EU countries with residential end-user prices being compared to industry prices.[10]

The overall picture across countries is rather heterogeneous. Not only do price levels differ substantially, but the development over time also varies considerably. Southern European countries, i.e. Greece, Italy, Portugal and Spain, are among the ones with the highest residential end-user prices and the largest gap between households and industry, though the difference in most of them has diminished over time. While almost all Member States have higher residential end-user prices than for industry, the eastern European countries that joined the EU in 2004, reported the opposite at the beginning of the period.

To account for changes in regulatory regimes of the considered countries we rely on the OECD indicators for regulation in energy, transport and communications (ETCR) as it secures data consistency. The ETCR dataset provides yearly time series up to 2007. Following the arguments of Brau et al. (2010) we use information of the sub-indicators instead of applying the main indicators: besides the more or less arbitrarily chosen weighting structure[11], using aggregate indicators leads to a loss of information. Moreover, effects of a distinct regulatory measure cannot be identified. Since this paper analyses the effects of ownership unbundling, we concentrate in the setup of our regulatory indicators on the information provided by the basic questions underlying the overall OECD indicator and amend this data where necessary. With regard to the coding of the ETCR dataset, Brau et al. (2010) point to the problem of the arbitrary cardinalisation of often categorical variables into the 0-6 scale that may influence results. Therefore, if not otherwise mentioned, we apply discrete variables instead of the 0-6 scale. All regulatory indicators are coded in a way that higher values correspond with conditions usually being assumed to be more restrictive regarding competition. Thus, positive signs are expected in the estimations.

A first set of indicators deals with conditions of market entry. Concerning third-party access to the transmission network, the discrete variable *TPA* is introduced with 0 indicating regulated access, 1 negotiated access and 2 otherwise. In order to measure the effect of giving customers access to alternative suppliers so that they have the choice among different offers, we create the continuous variable *Liberal*. As information on the actual degree of market opening is provided, the variable is designed as 100% minus the given percentage. An increasing share of customers who can choose among several suppliers should lead to an increase of the competitive pressure in this segment resulting in lower end-user prices. Limitations on access to production or import markets are covered by the discrete variable *Barriers*.[12]

For the privatisation efforts of the various countries ETCR provides for three variables indicating the percentage of the sector owned by the government. As these indicators are highly correlated and in order to circumvent multicollinearity, the given informa-

[10] All price data will enter estimations in log-form. The absolute values in Figure 1 are just for visualisation purposes. Descriptive statistics can be found in the Appendix.

[11] See Footnote 6.

[12] In particular, it is asked if any regulations are in place that restrict the number of competitors allowed to operate a business in at least some upstream markets.

tion is condensed to one single variable *Ownership* by simple averaging and discretising thereafter. Since private entities are generally assumed to perform more efficiently, the indicator is 0 if the public share is less than 25%, 1 if the share is below 50%, 2 if it is less than 75% and 3 otherwise.[13]

The main issue of this paper - ownership unbundling of gas TSOs - is not covered by the OECD database. Therefore, we create a new dummy OU_TSO indicating whether a country has introduced ownership unbundling ($OU\_TSO = 0$) or not ($OU\_TSO = 1$). While five countries have established ownership unbundling after having legally unbundled their gas TSOs first, Poland and Portugal directly shifted from vertically integrated utilities to ownership unbundling. Therefore, to distinguish whether lower end-user prices are caused by the most rigid form of vertical separation or just by breaking up formerly vertically integrated gas utilities, we introduce a second dummy VI_TSO. This variable becomes 0 if at least legal unbundling has been implemented and 1 otherwise.[14] From the OECD indicators for vertical separation only the one for gas distribution is added to the variable list (VI_DSO).[15] Since only two characteristics are actually reported in the ETCR dataset, the variable spoils down to a dummy with 0, indicating a (not further specified) form of separation of gas distribution system operators (DSOs) and 1 otherwise.

The last set of indicators deals with market structures in the competitive parts of the value chain, i.e. production/import (MS_Prod) and supply (MS_Supp).[16] ETCR provides for ranges indicating the importance of the largest player. The corresponding two variables are coded as follows: a 0 indicates that the largest utility has a share of less than 50% in the relevant sector, 1 with a share between 50 and 90%, and 2 otherwise. We expect retail prices to increase with market concentration.

To avoid misspecifications of our model, we consider several control variables which may influence end-user prices for households, i.e. sector-specific factors like the total amount of gas supplied to customers, the indigenous gas production, natural gas imports and exports as well as macroeconomic indicators like the GDP, all expressed as per capita variables. Due to the close relation between oil and gas, the oil price is additionally taken into account. We use West Texas Intermediate (WTI) prices to map the oil price because

[13] A correlation matrix for the various indicators, including the four main indicators of the ETCR dataset, can be found in the Appendix. The created variable *Ownership* is highly collinear to each of the original three OECD sub-indicators for public ownership.

[14] The information on both dummy variables has been collected from various benchmarking reports of the European Commission and checked by personal interviews with the designated regulated authorities. Both variables show no problematic correlation. Details on both dummies are provided in the Appendix.

[15] The other two ETCR indicators covering the separation of the production and the supply segment are dropped for two reasons. First, correlations with indicators for entry regulation are rather high facing the risk of multicollinearity. Second, vertical separation is usually discussed in the sense of essential facilities with the potential of being a natural monopoly. While this is true for gas pipelines (transmission and distribution), production and supply are clearly competitive parts of the value chain. See e.g. Gordon et al. (2003).

[16] The third category of the OECD, the market structure in gas transmission, has been neglected due to the - at least - questionable relevance and data inconsistencies.

gas prices are expressed in USD and WTI has been widely applied in international comparisons (cf. e.g. Brown and Yücel, 2007).

Concerning the development of natural gas end-user prices, it can often be observed that industry prices adjust faster to these sector-specific and macroeconomic factors than residential end-user prices. Therefore, industry prices may function as a kind of transmission belt between these factors and the prices for households. An auxiliary fixed effects regression reveals that industrial prices are indeed significantly influenced by per-capita GDP, the oil price and per-capita gas production but not by residential end-user prices and per-capita natural gas import.[17] Therefore, natural gas imports as well as end-user prices for industry are chosen as control variables with the latter serving as a kind of instrument for GDP and natural gas production. Regarding the industrial gas prices, a negative (and significant) coefficient would indicate a higher demand elasticity, whereas a positive sign would just show a level effect on residential end-user prices.[18] However, as the oil price is of special importance for the gas market, it additionally enters the set of control variables. Not only are several gas contracts in Europe still indexed to oil, but oil is also a close substitute for gas in the heating market; this is of particular interest for the residential end-user market. For annual data it is quite common to use also the one-year lagged oil price as the adjustment process of gas prices is lagged by around six months (cf. e.g. Siliverstovs et al., 2005).

4 Empirical Analysis

To analyse the effect of ownership unbundling on retail prices, certain econometric problems have to be tackled. The first one is that longitudinal price data might be biased by autocorrelation or cluster-correlation. Approaches that assume independence of observations - like the traditional fixed effects and random effects estimator - generally underestimate the true variance leading to inflated t-statistics. To avoid possibly corresponding inconsistency problems we use a robust variance estimator (cf. Froot, 1989; Williams, 2000). This estimator allows for heteroscedasticity, both between and within clusters, and for serial correlation.

A second econometric challenge is that causality between the institutional change in regulation and prices might not be unique, but reciprocal. Then, explanatory variables are correlated with the error term (endogeneity problem). To address endogeneity, we apply the System Generalized Method of Moments estimator (system GMM, Blundell and Bond, 1998), which uses lagged (endogenous) variables as instruments. We model all regulatory indicators as endogenous variables.[19] Furthermore, we allow gas imports to

[17] A preceding correlation analysis shows that gas supply, production as well as exports are highly collinear. Therefore, only the production variable enters the regression. Results for both, the correlation analysis as well as the regression, are presented in the Appendix.

[18] This design also captures the effect, if industrial end-user prices gain more from regulatory reforms (higher demand elasticity) which has been shown by Steiner (2001) and Hattori and Tsutsui (2004) for electricity.

[19] Modelling the indicators strictly exogenous leads to a rejection of the Sargan test indicating that regulatory reforms - at least partly - have been driven by high end-user prices for households.

be endogenous as causality between the dependent variable and imports can be assumed to be bidirectional. Using the standard treatment for endogenous variables, lags of order two and higher for the transformed equation and lag one for the levels equation are specified (cf. Roodman, 2006, 2008). The remaining regressors are treated as strictly exogenous instrumenting themselves.

Third, our data set is rather small, as it covers only 18 countries. Nickell (1981) has shown that the conventional least-squares dummy variable (LSDV) estimator for dynamic panels is inconsistent for a finite time horizon T and a large number of cross-sectional dimensions N (Nickell, 1981). Furthermore, with only 18 countries we likely face the problem of a small sample bias. Therefore, consistent Instrumental Variable (IV) estimators like Anderson and Hsiao (1982) and Generalized Method of Moments (GMM) estimators like Arellano and Bond (1991) might be biased (Kiviet, 1995). Kiviet (1995, 1999) as well as (Bun and Kiviet, 2003) provide for techniques to approximate the small sample bias but deliver consistent results only for balanced panels. With the unbalanced nature of our panel, adopting those corrections would lead to a high loss of information as they would in fact require discarding the cross-sections or time series causing the imbalance. Therefore, we apply the corrected least-squares dummy variable (LSDVC) estimator by (Bruno, 2005) whose approach avoids the aforementioned shortcomings. The small sample bias is approximated via bootstrapping.

For our empirical analysis, we model the log end-user price for residential costumers y_{it} of country i and period t as a function the regulatory indicators R_{it} of the current and one year lagged oil price X_{it}, and other control variables Z_{it} including industry prices and market structure. η_i captures unobserved heterogeneity across countries and ϵ_{it} is the error term satisfying the usual assumptions.

A dynamic setting additionally allows for some gas price dynamics by introducing one and two years lagged end-user prices as further explanatory variables.[20]

$$y_{it} = \alpha_1 y_{it-1} + \alpha_2 y_{it-2} + R_{it}\rho + X_{it}\beta + Z_{it}\delta + \eta_i + \epsilon_{it}. \tag{1}$$

Given the lagged endogenous variables, we can calculate the long run effect of regulation on household prices in a partial adjustment model:

$$\rho^* = \frac{\rho}{1 - \alpha_1 - \alpha_2}. \tag{2}$$

The results of our three model specifications evaluating the impact of regulatory reforms, and ownership unbundling in particular, on end-user prices of residential customers are listed in Table 2. The parameter values indicate the short-run effects (impact multipliers). Overall, we obtain robust results throughout all three estimators. In none of our models does ownership unbundling (OU_TSO) seem to have any significant effect on retail prices. The same holds for vertical separation of distribution networks (VI_DSO). However, countries which at least legally unbundled transmission networks

[20] A twice lagged dependent variable is required to obtain valid results of the Arellano-Bond AR(2) test for the system GMM and LSDVC estimator to prevent autocorrelation in the error terms.

from the rest of the value chain (VI_TSO) indeed show lower retail prices. This holds especially true on the long run, where the effect approximately doubles. Apart from that, only one regulatory variable, third party-access (TPA), has the expected sign. Countries without regulated TPA have significantly higher natural gas prices than others. Again, this effect is twice as high in the long run. Neither market liberalisation (*Liberal*) nor the existence of limitations on access to production or import markets (*Barriers*) have significant price effects. Interestingly, a higher share of publicly owned companies (*Ownership*) reduces natural gas retail prices. This result corresponds to previous empirical studies (e.g. Alesina et al., 2005; Brau et al., 2010).

Looking at the control variables, the oil price is significant in all estimations. The positive sign is consistent with expectations as the oil price should control for the fact that many contracts still link the gas price to the development of the oil price. The lagged adjustment process embedded in long-term gas contracts is represented by the significance of the lagged oil price. The overall effect, which is here the sum of $LogOil$ and $LogOil_{t-1}$, is of similar magnitude across all approaches. End-user prices are raised by about 2.8 % if the oil price increases by 10 %.

Table 2: End-user prices and the impact of regulatory reforms

Log Price_hh	Fixed effects	One-step system GMM	LSDVC (BB)
Log Price_hh$_{t-1}$	0.684***	0.682***	0.709***
	(0.061)	(0.056)	(0.067)
Log Price_hh$_{t-2}$	−0.180***	−0.170***	−0.183***
	(0.023)	(0.023)	(0.046)
TPA	0.045**	0.047**	0.047**
	(0.020)	(0.019)	(0.023)
Long Run Multiplier	0.092**	0.097**	0.098**
	(0.036)	(0.035)	(0.049)
Liberal	0.023	−0.029	−0.018
	(0.042)	(0.045)	(0.041)
Long Run Multiplier	0.047	−0.059	−0.038
	(0.086)	(0.031)	(0.086)
Barriers	−0.003	−0.005	−0.003
	(0.017)	(0.018)	(0.020)
Long Run Multiplier	−0.007	−0.010	−0.006
	(0.034)	(0.036)	(0.043)
Ownership	−0.033*	−0.033*	−0.026*
	(0.017)	(0.018)	(0.015)
Long Run Multiplier	−0.067*	−0.067*	−0.056*
	(0.035)	(0.037)	(0.032)
VI_TSO	0.082**	0.082**	0.082**
	(0.028)	(0.029)	(0.032)

Table 2: continued

Log Price_hh	Fixed effects	One-step system GMM	LSDVC (BB)
Long Run Multiplier	0.165***	0.167***	0.173**
	(0.051)	(0.054)	(0.072)
OU_TSO	0.052	0.049	0.042
	(0.030)	(0.032)	(0.040)
Long Run Multiplier	0.104	0.100	0.089
	(0.060)	(0.066)	(0.083)
VI_DSO	0.009	0.008	0.008
	(0.014)	(0.016)	(0.030)
Long Run Multiplier	0.018	0.017	0.017
	(0.029)	(0.132)	(0.063)
Log Oil	0.168***	0.284***	0.164***
	(0.036)	(0.069)	(0.046)
Log Oil_{t-1}	0.109**	−0.052	0.102**
	(0.038)	(0.129)	(0.039)
MS_Prod	0.123***	0.112**	0.108**
	(0.041)	(0.044)	(0.051)
MS_Supp	−0.080*	−0.073	−0.075**
	(0.042)	(0.050)	(0.034)
Import_pc	−0.111*	−0.126*	−0.113
	(0.057)	(0.068)	(0.080)
Log Price_ind	0.097**	0.104***	0.102**
	(0.041)	(0.033)	(0.047)
Year dummies	yes	yes	yes
R squared (within)	0.852	–	–
Arellano-Bond AR(2) test	–	0.339	0.771
No. of observations	195	195	195

Notes: Standard errors in parentheses are robust to heteroskedasticity and to within group serial correlation. LSDVC: initialized with the Blundell and Bond (1998) estimator (BB) and standard errors calculated via bootstrapping (1,000 runs); AR(2) test with regard to first step BB estimation. Standard errors for long run effects have been calculated with the delta method. ***, **, * denote significance at 1%, 5% and 10%.

Concerning effects of market structures, the results for our market concentration variables are ambiguous. As expected, prices rise with an increase in market concentration on the wholesale level (MS_Prod). At the same time, market concentration in natural gas service (MS_Supp) tends to reduce retail prices. This counterintuitive result is caused by two effects. First, countries with relatively low end-user prices at the beginning of our

observation period report higher initial concentration rates (e.g. eastern European countries). Second, a reduction of MS_Supp quite often coincides with an increase in retail prices (e.g. France, Hungary, Ireland and The Netherlands). However, results should be treated with care as this variable exhibits only a very low within-variation. Import volumes ($Import\_pc$) influence retail prices in 2 out of 3 models as expected: prices drop with increasing supply. However, the variable is only weakly significant. The trade-off between industrial and residential end-user prices as shown by Steiner (2001) as well as by Hattori and Tsutsui (2004) cannot be confirmed in our estimation. Indeed, the positive signs of the variable $LogPrice\_ind$ indicate that high industrial prices go along with higher household prices.

To sum up, all three of our estimators, the FE estimation with robust standard errors, the System-GMM and the dynamic LSDVC, lead to similar results. None of the approaches find a significant effect of ownership unbundling on the level of end-user prices for residential customers.

5 Conclusions

Ownership unbundling of gas transmission system operators (TSOs) as the most rigid form of vertical disintegration from competitive and regulated operations is still an issue in the discussions about a suitable future regulatory framework of the European gas market. The controversial debate preceding the third legislative package has led to a compromise that allows now for both legal and ownership unbundling, and leaves the choice to Member States. However, the problem of whether or not the rigid ownership unbundling is economically more beneficial than other forms of unbundling has not yet been solved. While economic theory reports ambiguous results, we have answered the question empirically by analysing the developments of natural gas end-user prices in different countries of which some already have established ownership unbundling (e.g. U.K.) while others have not (e.g. France).

Analysing an unbalanced panel of 18 EU countries over 19 years with a number of static as well as dynamic estimators reveals no evidence for a price-decreasing effect of ownership unbundling. However, the breaking-up of formerly vertically integrated TSOs with at least introducing the more modest legal unbundling has resulted in lower end-user prices. Furthermore, third-party access and privatisation show significant influence with the latter leading to higher price levels. Their effect even doubles in the long run. These results are consistent across our estimations.

From a policy point of view, our results do not support a further separation of the different stages of the natural gas value chain. On the contrary, as countries which at least legally separated transmission networks already seem to have reaped the economic benefits, a further tightening of unbundling rules for gas TSOs does not seem to be economically reasonable.

However, as most of the countries in our analysis established ownership have unbundled gas TSOs only very recently, our results should be treated with care. To arrive at a clearer picture on this issue a re-evaluation might be carried out in few years. An

interesting topic for further research could be the empirical analysis of the impact of different forms of vertical separation of transmission networks on the investment level in the European gas sector. Regarding the dynamic efficiency, a debate is currently going on that is very similar to the one that has been at the centre of this paper.

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Appendix

Table A.1: Descriptive statistics and information on the unbundling status of gas TSOs

Country	Log Price_hh[a]	Log Price_ind[a]	Log Oil[b]	Import_pc[c]	TSO unbundling[b]	
					Legal	Ownership
Austria	5.896	5.121	–	0.703	2002	–
	(0.142)	(0.086)		(0.169)		
Belgium	5.917	5.004	–	1.161	2001	–
	(0.113)	(0.156)		(0.218)		
Czech Rep.	6.037	6.099	–	0.664	2006	–
	(0.234)	(0.190)		(0.106)		
Denmark	5.943	–	–	0.000	2001	2005
	(0.247)			(0.000)		
Finland	4.833	4.731	–	0.606	–	–
	(0.224)	(0.128)		(0.120)		
France	5.963	5.175	–	0.550	2004	–
	(0.098)	(0.240)		(0.088)		
Germany	5.814	5.096	–	0.725	2005	–
	(0.090)	(0.120)		(0.126)		
Greece	6.051	5.556	–	0.094	2007	–
	(0.124)	(0.181)		(0.102)		
Hungary	5.799	5.924	–	0.685	2000	2006
	(0.206)	(0.285)		(0.198)		
Ireland	6.092	5.594	–	0.392	–	–
	(0.183)	(0.387)		(0.362)		
Italy	6.143	5.182	–	0.689	2002	–
	(0.071)	(0.079)		(0.230)		
Luxembourg	5.639	–	–	1.701	–	–
	(0.126)			(0.569)		
Netherlands	5.800	4.968	–	0.556	2004	2005
	(0.161)	(0.181)		(0.421)		
Poland	6.068	5.844	–	0.176	–	2005
	(0.503)	(0.133)		(0.031)		
Portugal	6.804	5.840	–	0.135	–	2006
	(0.024)	(0.095)		(0.146)		
Slovak Rep.	5.758	5.919	–	0.955	2006	–
	(0.462)	(0.181)		(0.117)		
Spain	6.431	5.372	–	0.341	2001	2006
	(0.093)	(0.185)		(0.217)		
UK	5.891	5.034	–	0.108	1996	1997
	(0.146)	(0.291)		(0.111)		
All	5.891	5.419	3.248	0.569	–	–
	(0.419)	(0.473)	(0.353)	(0.469)		

Notes: For the first four variables mean values as well as standard deviations (in brackets) are presented. [a]End-user prices for households (hh) and industry (ind) in $USD_{2000}/10^7$ kcal. Source: IEA. [b]WTI oil price in USD_{2000}/barrel. Source: IEA. [c]Gas imports (ktoe) per capita. Source: IEA. [d]Date of implementation (legal enactment). Source: Benchmarking Reports of the European Commission as well as interviews of the designated regulatory authorities.

Table A.2: Correlation matrix of regulatory indicators

Indicator	Entry	TPA	Liber-al	Barr-iers	Owner-ship	PO_ Prod	PO_ TSO	PO_ DSO	Owner-ship	VI	VI_ Prod	VI Supp	VI_ DSO	VI_ TSO	OU_ TSO	Struc-ture	MS_ Prod	MS_ Supp	MS_ TSO
Entry[a]	1																		
TPA[b]	.826	1																	
Liberal[b]	.849	.817	1																
Barrieres[b]	.738	.350	.339	1															
Ownership[a]	.419	.202	.282	.403	1														
PO_Prod[b]	.428	.223	.264	.448	.894	1													
PO_TSO[b]	.380	.175	.211	.425	.901	.940	1												
PO_DSO[b]	.245	.094	.081	.289	.767	.768	.780	1											
Ownership	.368	.163	.198	.420	.907	.969	.975	.812	1										
VI[a]	.550	.582	.575	.255	.215	.214	.118	.122	.149	1									
VI_Prod[b]	.469	.429	.421	.312	.147	.157	.060	.056	.085	.832	1								
VI_Supp[b]	.723	.676	.768	.348	.331	.293	.233	.148	.238	.710	.446	1							
VI_DSO[b]	.082	.248	.179	−.111	.041	.050	.011	.089	.042	.607	.146	.305	1						
VI_TSO	.697	.630	.684	.389	.351	.332	.251	.225	.271	.734	.598	.711	.330	1					
OU_TSO	.419	.306	.418	.226	.272	.263	.132	.231	.184	.419	.393	.441	.095	.544	1				
Structure[a]	.463	.341	.520	.300	.520	.477	.442	.169	.431	.371	.303	.435	.100	.397	.244	1			
MS_Prod[b]	.519	.398	.551	.271	.526	.506	.415	.295	.418	.431	.398	.472	.075	.516	.378	.792	1		
MS_Supp[b]	.284	.235	.343	.196	.394	.337	.327	.099	.321	.325	.219	.291	.218	.265	.179	.855	.473	1	
MS_TSO[b]	.297	.157	.340	.264	.296	.278	.310	−.029	.279	.070	.065	.263	−.128	.125	−.032	.722	.376	.480	1

Note: [a]Aggregate indicator of the OECD database ETCR; [b]Sub-indicator of the OECD database ETCR.

Table A.3: Correlation matrix and auxiliary fixed effects estimation for control variables

A. Correlation matrix

Variable	Log Price_ind	Log Oil	Supply_pc	Prod_pc	Export_pc	Import_pc	GDP_pc
Log Price_ind[a]	1						
Log Oil[a]	.325	1					
Supply_pc[b]	−.267	−.036	1				
Prod_pc[c]	−.302	−.085	.848	1			
Export_pc[c]	−.250	−.065	.784	.939	1		
Import_pc[c]	.102	.103	.229	−.232	−.051	1	
GDP_pc[d]	−.670	.082	.336	.275	.247	.091	1

B. Fixed effects estimation[e]

Variable	Log Price_hh	Log Oil	Prod_pc	Import_pc	GDP	Year dummy	R squared (within)	No. of obs.
Log Price_ind	−0.002	0.555***	−0.227**	0.074	−0.616***	yes	0.559	233
	(0.059)	(0.092)	(0.102)	(0.269)	(0.166)			

Notes: Standard errors in parentheses are robust to heteroskedasticity and to within group serial correlation. ***, **, * denote significance at 1%, 5% and 10%. [a] End-user prices for industry in $USD_{2000}/10^7$ kcal. Source: IEA. [b] WTI oil price in USD2000/barrel. Source: IEA. [c] Total gas supply (Supply_pc), gas production (Prod_pc), gas exports (Export_pc) and gas imports (Import_pc) all in ktoe per capita. Source: IEA. [d] Gross domestic product in 10^4 USD_{2000} per capita. Source: IEA. [e] Based on a fixed effects estimator with robust standard errors (Froot 1989 and Williams 2000). Standard errors in parentheses are robust to heteroskedasticity and to within group serial correlation. ***, **, * denote significance at 1%, 5% and 10%. The counterintuitive result of the negative impact of GDP per capita is caused by a cross-sectional (eastern European countries with a relatively small GDP per capita tend to have higher end-user prices) and a time series effect (decreasing end-user prices over time, e.g. in Ireland).

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