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# Has Deregulation Increased Investment in Infrastructure? Firm-Level Evidence from OECD Countries

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# HAS DEREGULATION INCREASED INVESTMENT IN INFRASTRUCTURE? FIRM-LEVEL EVIDENCE FROM OECD COUNTRIES

**ECONOMICS DEPARTMENT WORKING PAPER No. 892**

**By Sónia Araújo**



**JT03307200**



**English - Or. English**

## ABSTRACT/RÉSUMÉ

### Has deregulation increased investment in infrastructure? Firm-level evidence from OECD countries

This paper investigates the role played by deregulation on firms' investment decisions in infrastructure sectors. The analysis covers the period 1980-2006, which was characterised by increased liberalisation and privatisation across OECD countries. We assess the relationship of different dimensions of the regulatory framework, such as the degree of barriers to entry, public ownership, vertical unbundling and the existence of an independent regulator with firm level investment behaviour. We find that the impact of regulation on investment is both sector and firm specific. A reduction in the degree of legal barriers to entry spurs investment in the electricity sector, but only for large firms. In telecommunications, the converse is true with barriers to entry having a negative effect on smaller firms' investment rates. The existence of an independent regulatory authority spurs investment by telecommunication companies but this effect seems to be driven by large firms alone while it is associated with a reduction in investment levels by smaller companies in the gas sector. In Europe, the degree of vertical integration is positively associated with investment rates in the electricity sector.

*JEL Classification:* D22; K2; L5; L92; L94; L95; L96

*Keywords:* investment; infrastructure; regulation; firm level data

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### La déréglementation favorise-t-elle les investissements en infrastructure? Analyse basée sur les entreprises des pays de l'OCDE

Ce papier vise à étudier l'effet des politiques de déréglementation sur les investissements des entreprises des secteurs des infrastructures. L'analyse s'étend sur la période 1980-2006, qui a été caractérisée par la libéralisation et la privatisation des secteurs des infrastructures dans les pays de l'OCDE. Nous évaluons le rapport de plusieurs dimensions du cadre réglementaire, comme le niveau des barrières à l'entrée, détention publique, intégration verticale et l'existence d'un régulateur sectoriel indépendant avec le niveau d'investissement des entreprises. L'analyse montre que l'impact du cadre réglementaire sur l'investissement varie selon le secteur et le type d'entreprise. Une réduction des barrières à l'entrée encourage l'investissement dans le secteur de l'électricité, mais seulement pour les grandes entreprises. Dans le secteur des télécommunications, l'effet est l'inverse, avec un effet négatif des barrières à l'entrée sur l'investissement des entreprises les plus petites. L'existence d'un régulateur sectoriel indépendant favorise l'investissement dans le secteur des télécommunications, mais cet effet semble être produit uniquement par les grandes entreprises du secteur, tandis que pour les entreprises les plus petites du secteur du gaz un régulateur indépendant défavorise l'investissement. En Europe, le degré d'intégration verticale est positivement associé au taux d'investissement dans le secteur de l'électricité.

*Classification JEL:* D22 ; K2 ; L5 ; L92 ; L94 ; L95 ; L96

*Mots clés :* investissement ; infrastructure ; réglementation ; données de firmes

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# HAS DEREGULATION INCREASED INVESTMENT IN INFRASTRUCTURE? FIRM-LEVEL EVIDENCE FROM OECD COUNTRIES

**by Sónia Araújo**[1]

## 1. Introduction

Network industries represent a sizeable share of countries' GDP, and the most dynamic part of the economy. In OECD countries, energy, water, transport and communications account from about 5% of economy wide value-added in Ireland and the United States to above 10% in Turkey, Czech Republic and the Slovak Republic. These sectors also employ a significant share of the labour force, with values ranging between 5% in Portugal and the United States to 10% in Greece, Hungary and the Slovak Republic.

Due to their highly capital-intensive nature, investment in these sectors represents a sizeable share of economy-wide investments. In OECD countries, investment in network industries accounts for between one-tenth and one-quarter of total investment. Investment in network infrastructure are particularly important because they not only affect growth directly but also foster growth and productivity in sectors that use network products and services as inputs in their production process. Using data for 21 OECD countries between 1970 and 1990, Röller and Waverman (2001) find evidence of a significant positive causal link between telecommunications infrastructure and economic growth. Consistent with the existence of network externalities in IT technologies, the effects are nonlinear and the links to economic growth are magnified when a critical level of infrastructure is already in place. Koutroumpis (2009) estimates that investment in new broadband networks had a positive impact on EU-15 GDP in the period 2002-7, accounting for 16.92% of total GDP growth.

Recently, several studies have been stressing the need of substantial investment in core infrastructure in the coming decades (OECD, 2006, 2007, IEA 2007). For instance, interconnection capacity in electricity networks is often congested. This is not surprising as in a number of OECD countries there appears to be relatively little net addition to generation capacity since the late 1980s (Sutherland *et al.*, 2009).

Given the extremely large fixed costs entailed in infrastructure investment and the irreversibility of investment decisions, investment in these sectors is particularly sensitive to the regulatory environment. The regulatory environment, including its institutional settings, plays an important role by ensuring an efficient use and expansion of infrastructure through pricing policies and the timing of investment returns. Most OECD countries have experienced a process of regulatory reform in network industries (utilities and transportation) which included a reduction in the degree of public ownership, the establishment of sector independent regulatory agencies (IRA) and the elimination or softening of entry regulations that were unduly restrictive of market mechanisms. The timing, scope, and starting points, however, varies across countries and sectors. The United States started regulatory reforms earlier, already in the 1970s. The UK

1. Acknowledgements: I would like to thank David Bartolini, Giuseppe Nicoletti, Douglas Sutherland, and Paul Schreyer for useful comments and fruitful discussion, as well as to several members of the OECD Economics Department. The views expressed in this paper are those of the author and do not necessarily represent those of the institution to which she is affiliated.

and New Zealand followed through while in other countries, notably France and Italy, deregulation started much later. Differences in the extent of deregulation are also found at the sector level, as liberalisation and privatisation have been extreme in telecommunications services but much more limited in the electricity and especially in the railways sector.

This paper investigates the impact of regulatory reform on firm investment behaviour in four network industries, which were traditionally sheltered from competition and subject to a process of regulatory reform in the recent decades: electricity, gas, railways and telecommunications. Deregulation is likely to have exerted an impact on the incumbents' adjustment to more competition and likely to shape the investment behaviour of the new entrants into these markets.

This paper is close to Alesina *et al.* (2005), who look at the effect of regulation on investment in 21 OECD economies between 1975 and 1998, using sectoral data. Their most significant result is that entry liberalisation plays an important role in investment. In their time-series analysis, the authors find that the rate of investment can potentially rise up to 1½ percentage points on average (the average investment rate being around 7%), if barriers to entry fall by a significant amount, taking a country from the third quartile to the first quartile of the country distribution of barriers to entry.

This study departs from their analysis in a number of ways: firstly, we use firm-level data; secondly, the analysis provides sector-specific estimates. Evidence emerging from statistics on investment patterns in network industries reveals that there are sharp differences in cross-sector investment dynamics in the past two decades. While the rate of gross fixed capital formation in the energy and water supply sectors has declined continuously since the 1970s, falling on average from about 1.5% of GDP to below 1% of GDP,[2] investment in the broad category of transport, storage and communications has remained relatively stable in most countries, above 2% of GDP on average. This evidence advocates for a sector specific analysis.

Thirdly, we extend the analysis to the period 1980-2006, and hence incorporate information of late comers to regulatory reform, such as continental European countries, including Czech Republic, Hungary and Poland; fourthly, the country level coverage is larger, encompassing 28 OECD countries. Another contribution of this work is that it investigates the effect of an independent regulatory authority (IRA) on firm-level investment, which was not done by Alesina *et al.* (2005). The dummy variable for the existence of an IRA is quite comprehensive, covering all 4 sectors in 28 OECD countries in the period 1980-2006.

The main result of the empirical analysis is that the effect of deregulation on firm's investment incentives is sector specific and size specific. For instance, it is found that a reduction in the level of barriers to entry acts is associated with an increase in investment rates of large firms operating in the electricity sector, while encouraging investments by small firms in the telecommunication industry. The intuition lies in the way in which firms take investment decisions. Those are strategies that depend ultimately on the expected flow of future profits, which depends on several factors, the most important of which is the level of competition in the market. Therefore, a regulatory reform may have a different impact in terms of competition both across sectors and size.

The paper is organised as follows. Section 2 discusses several channels through which regulation can influence investment in network infrastructure. Section 3 presents an overview of changes in the regulatory environment in the electricity, gas, railways and telecommunications in OECD countries in the period 1980-2006. Section 4 presents the empirical methodology while section 5 discusses the main findings and the robustness of the results. Conclusions are drawn in section 6.

2. However, investment has remained relatively high in some countries, such as Iceland and Korea.

## 2. Regulation and infrastructure investment

Apart the case of natural monopoly, the intervention of the State in network industries resulted in a restriction of the possibility to compete in the market, by granting legal monopoly to State-owned firms. Since the 1980s, however, OECD countries have embarked on a process of deregulation, liberalising entry and removing other market features that hinder competition. In several countries, regulatory reforms were accompanied by a reduction or even elimination of the presence of publicly-owned sector monopolists.

Privatisation policies were based on the assumption that private ownership is superior from the point of view of productive efficiency, at the same time more sophisticated regulatory techniques made arm's length regulation more desirable than direct public intervention. For instance, according to the property rights literature, private ownership generates stronger incentives for monitoring, cost efficiency and innovation than public ownership, because the owners of a private firm (or managers acting on behalf of the owners) have residual rights over the cash-flow of the firm while the minister, civil servants and public manager can only partially appropriate the benefits of cost reduction or quality improvements (Hart *et al.*, 1997, Schleifer and Vishny, 1997, Schleifer, 1998).

The decline of public ownership also reflects increasing recognition, among OECD governments, that it can create conditions contributing to inefficient investment. Policy makers may allocate resources to a given region or infrastructure project at the expense of others with potentially higher returns in other regions or sectors. For example, governments may use state-owned companies to pursue policy objectives such as contrasting unemployment or inflation – through a pricing policy that has nothing to do with business objectives. Recently, Cadot *et al.* (2006) and Castells and Solé-Ollé (2005) report evidence of the influence of political factors in the allocation of infrastructure investment across regions. Likewise, underinvestment in public firms may occur if, confronted with fiscal pressures, public authorities do not value the long-term benefits of investment in infrastructure. For instance, in the UK, tight fiscal control due to macroeconomic monetary policy commitments prevented British Telecom (BT) from investing in network modernisation. Underinvestment was actually at the origin of the privatisation decision as equity sale was preferred to debt given the legal difficulty of distinguishing between BT borrowings from public sector borrowings (Armstrong *et al.*, 1994). Over the next four years after privatisation, BT raised its rate of investment by almost 50% in real terms, which led to a rapid expansion in output and to more than double its profits. As a consequence, BT became able to finance investment out of retained profits and resourcing to outside financing only at modest levels (Newberry, 1999).

Politicians may also be driven by electoral concerns, so the timing and the size of investments may follow the electoral cycle rather than efficiency concerns. Özatay (2005) and Paiva and Moita (2006) find empirical support for the effect of political cycles in regulated industries. Finally, public managers may be influenced by rent-seeking objectives. For instance, public managers may pursue empire-building strategies to strengthen their support with the politicians that appointed them (*e.g.* by expanding capacity and employment in public enterprises). This will result in overinvestment if managers can take advantage of soft budget constraints or state guarantees. In this case, privatisation can lead to a reduction in investment as empire building strategies are dismantled.

Another key element that shapes firms' investment behaviour is the level of competition in the market. High market concentration may favour investment as the firm with market power reaps all the rents stemming from the investment. Recent theoretical and empirical work on investment in R&D suggests that there is a trade-off between monopoly profits and competition in enhancing investment and innovation. For instance, Aghion *et al.* (2005) exploit a series of major policy reforms in the United Kingdom over the 1970s and 1980s and find evidence of an inverted-U relationship between competition

and investment in innovation in a panel of seventeen industries (at the two-digit level) over the period 1973-1994.[3]

However, theoretical and empirical evidence is not clear-cut. Liberalisation, that is, the introduction of more competition, can also foster investments as firms' strive for efficiency gains. On the other hand, the presence of public-owned companies in the sector may create a disincentive for privately-operated firms to invest. In this case, the lack of a level playing field – often due to the state-owned company soft budget constraint – is a disincentive for private firms to invest. Furthermore, there may be confusion between the role of the state as the regulator and owner, which serves to amplify regulatory discretion and risk. According to Boone's studies (2000, 2001), competition provides sharper incentives to stimulate productivity and investment in innovation and in cost-saving technologies. This might be the case behind the strong wave of innovations in mobile telecommunication, and in the development of low-cost air transports.

Another important characteristic of deregulation in network industries has been the separation of the natural monopoly elements of the industry so that competition can be introduced in the other segments. While allowing the introduction of competition, vertical separation may not necessarily result in an incentive to invest. Firstly, a vertically-integrated firm that owns the network would restrict capacity strategically in order to deter entry of other downstream service providers. Sector regulators can address this issue by restraining incumbents from abusing market power *ex-ante*, even in the absence of full unbundling, by setting quality standards, introducing rewards and penalties, or implementing parity standards, whereby the vertically-integrated firm is obliged to offer to its competitors the same quality that it offers to its own downstream affiliates. Secondly, if economies of scale and scope are lost while co-ordination problems and transaction costs become more important, underinvestment in infrastructure provision may occur.

In some sectors the problems created by vertical separation are arguably severe. Significant economies of scope may limit the potential for efficiency gains stemming from increased liberalisation and competition (Newbery, 2002). In the railway industry, companies operating train services are not given the incentives to lower high marginal costs for the network operator, while the latter has little incentive to improve its services since it does not benefit from higher revenue from train operators. This misalignment of incentives has led to under provision of rail track services. An OECD study (2006b) suggests that the resulting losses of economies of scope increase production costs by between 20% and 40%, when the sector is fully separated.

The U.K. experience in the railway sector illustrates the difficulty in coordinating and ensuring sufficient investment in a vertically unbundled industry. British Rail was privatised in the early 1990s when the British government divided the company into twenty-five passenger train-operating companies (TOCs), two freight TOCs while one company, Railtrack, owned the track, signalling, tunnels, bridges, level crossing and all but a handful of train stations, and financed itself from track and station access fees charged to TOCs. Service quality deteriorated after privatisation and vertical unbundling, due to coordination problems between Railtrack and the TOCs, which were not provided with incentives to organise their schedules and rationalise the number of trains operating at a given time as charges did not vary much with the number of trains operated by each TOC. As a consequence, track lines became congested with additional trains, the reliability and train punctuality worsened while track maintenance was made more difficult. Negotiations over capacity enhancement between the rail regulator (the Office of the Rail Regulator), Railtrack and the TOCs, were largely unsuccessful and investment on track maintenance was also delayed (Gómez-Ibáñez, 2003). Finally in 2002, the British government reorganised

3. See also Motta (2004: Chapter 2) for a discussion of the relationship between market structure and investment in innovation.

the sector, and Railtrack was converted into a non-profit company, Network Rail, with no shareholders but governed by representatives of passenger groups, the TOCs, rail unions and the general public.

The main objection against vertical separation is the loss of coordination benefits related to choices upstream that affect investment in the downstream segment of the industry in the upstream segments of the industry (separating electricity generation from transmission). For instance, it may be cheaper to choose a more expensive location for generation in order to economise on investments in transmission (Newbery, 1999). It also requires more complex regulation, as the regulator needs to decide on how to price transmission services and how to decentralise decisions of where to locate electricity generation and investments in new transmission where different parts of the interconnected network are under different ownership and control.

These examples highlight the fact that the effects of privatisation and liberalisation on investment are ambiguous at the theoretical level, and its identification remains an empirical question, which is also sector-specific, as is shown in this paper.

Another important factor affecting investment in regulated network industries is the nature of the regulatory authority. In network sectors, investment is often lumpy due to indivisibilities and entails high sunk costs. If faced with an uncertain environment, private providers of infrastructure services may delay investment. In the end, the government's lack of commitment, leaving open the possibility of opportunistically expropriating the utility or to undertake price changes after an investment has taken place, leads to underinvestment in regulated industries (Besanko and Spulber, 1992). This was the case of the introduction of the US Telecommunications Act of 1996, which aimed at introducing competition in local telephone services. Its ambiguous implementation left considerable discretion to the Federal Communications Commission. The uncertainty was amplified by the legal challenges made by incumbents, which ended up discouraging the large-scale investments needed for the roll out of fibre-optic services to individual residencies (Couper *et al.*, 2003).

Efficient investments levels in network infrastructure require a stable and credible regulatory framework, which should also be independent from political pressures. Ensuring the regulator's independence is crucial to preventing regulatory capture. Against this background, the design of independent regulatory agencies, with their own budget and a clear delegation of powers can alleviate the uncertainty surrounding an investment project and mitigate the hold-up problem (Bartolini, 2010). Empirical evidence corroborates theoretical models. Edwards and Waverman (2006) find that regulatory independence reduces the degree of political influence on regulatory outcomes in the telecommunications sector in the EU 15 founding member countries. In a sample of 92 publicly traded utilities and transportation infrastructure companies for the same group of countries, Cambini and Rondi (2010) find that the setting up of IRAs is associated with higher investment rates in the period 1994-2005.

It is therefore desirable that, while remaining accountable to the government, legislature and consumers, the regulatory authority is separated and autonomous from the government. In order to prevent the risk of the regulator's actions introducing uncertainty and thereby damping investment incentives or setting prices too low to sustain investment, the regulator should be provided with a comprehensive legal mandate, including arbitration mechanisms, criteria and procedures for appealing its decisions.

## 3. Regulatory reform in OECD countries

This section provides an overview of regulatory reforms in OECD countries in the electricity, gas, railways and telecommunications sections. It compares outcomes achieved in several regulatory dimensions at the country and sector level and comments on the pace of reforms. The analysis is based on two information sources: the OECD Indicators of Regulation in Energy, Transport and Communications

(ETCR) and the national administrations' responses to the OECD Questionnaire on Infrastructure Investment, completed by the end of 2007.

### *3.1. The OECD ETCR indicators*

The ETCR indicators measure restrictions to competition in a number of different (horizontal or vertical) segments of seven industries, including electricity, gas, rail transport, and telecommunications. They have been estimated at an annual frequency over the period 1975 to 2003 for 21 OECD countries, based on a number of published sources, as well as on replies to the *OECD Regulatory Indicators Questionnaire* (for the 2007, 1998 and 2003 data points). The indicators cover transmission, distribution and supply in electricity and gas; infrastructure as well as passenger and freight services in rail transport; and trunk, long distance and mobile services in telecommunications (Table 1).

Table 1. **The coverage of the ETCR indicators**

| | **Activities Covered** |
|---|---|
| Electricity | Generation, transmission, distribution, supply |
| Gas | Production, import, transmission, supply |
| Railways | Passenger and freight transport, operation of infrastructure |
| Telecoms | Trunk, international, mobile |

The ETCR indicators are "objective", in the sense that they measure explicit regulatory settings and market conditions, rather than "subjective" assessments of gathered through opinion surveys. In this way, indicators are comparable across countries and differences in indicator values across time and countries can be traced to changes or differences in specific regulatory settings.

The indicators are sector specific, accounting for different structural features, including differences in technological characteristics across sectors. Hence, their coverage and content vary across sectors. They are computed using a bottom-up approach in which regulatory data are quantified using a scoring algorithm and then aggregated into summary indicators by sector of activity in each of the three (electricity and telecoms) or four regulatory areas (gas and railways): [4]

- *Barriers to entry*: this indicator focuses on third party access (TPA) and the extent of choice of supplier for consumers in electricity, gas, railroad and telecom sectors. For electricity, the indicator also accounts for the existence of a liberalised wholesale market for power, which is an important issue in most OECD countries. Whereas limitations on access to production or import markets have been lifted in almost all OECD countries, they are still an issue in the gas sector, and therefore included in the indicator for this sector. Entry regulation in rail transport distinguishes between free entry (with access fees to the rail network infrastructure), franchising to several firms and franchising to a single firm. For EU countries, the latter is scored the same as the mere application of the EU 1991 Directive (which is not very demanding in terms of opening up rail markets to competition). For the telecommunications sector the indicator focus on legal limitations on the number of competitors.
- *Public ownership*: the indicator addresses the degree of public ownership in the electricity, gas, railways and telecom sectors, which ranges from fully public to fully private. In the electricity and gas sectors, the indicator allows for mixed ownership arrangements in which the natural

4. The regulatory areas covered by each indicator depend on data availability and the relevance of the various regulatory areas for each sector. Incumbents' market power is considered not to be an issue for many OECD countries in the electricity sector while vertical integration is typically not a relevant issue in telecommunications. See Conway and Nicoletti (2006).

monopoly segment remains under public control, while in the railway sector the indicator considers the percentage shares owned by the government in the largest company in each segment: infrastructure, passenger transport and freight transport. In the telecommunications sector, the indicator considers the percentage shares owned by the government in the public telecommunications operator and in the largest firm in the mobile telecommunications.

- *Vertical integration*: this indicator measures the extent to which competitive activities (such as electricity generation, gas production, electricity and gas supply) are separated from segments of the sector that remain natural monopolies such as the national grid and/or local distribution. This indicator is available for electricity, gas and railroads. The degree of separation ranges from full integration to mere legal/accounting separation to separation into different companies owned by different shareholders. The underlying assumption in the computation of this indicator for gas and electricity is that the scope for anticompetitive behaviour is largest when a company simultaneously controls the network and operates upstream or downstream competitive markets. As regards railways, the assumption is that the advantages stemming from unbundling in terms of easier regulatory supervision and stronger downstream competition outweigh the potential for economies of scope from integrating infrastructure and passenger and freight transport.
- *Market structure*: this indicator attempts to capture the extent to which the regulatory framework is able to moderate the market power of incumbents and promote competition. It records the market shares of the largest company in the different segments of the industry for gas and telecommunications and on the maximum number of operators that compete in the same geographical area in railways.

The indicators assume values between 0 and 6, with higher values reflecting increasing restrictiveness of competition. The regulatory data used for the calculation of each indicator, its structure and weighting scheme for the electricity, gas, rail transport and telecommunications sectors are displayed in Tables 13 to 16 in Annex 1.

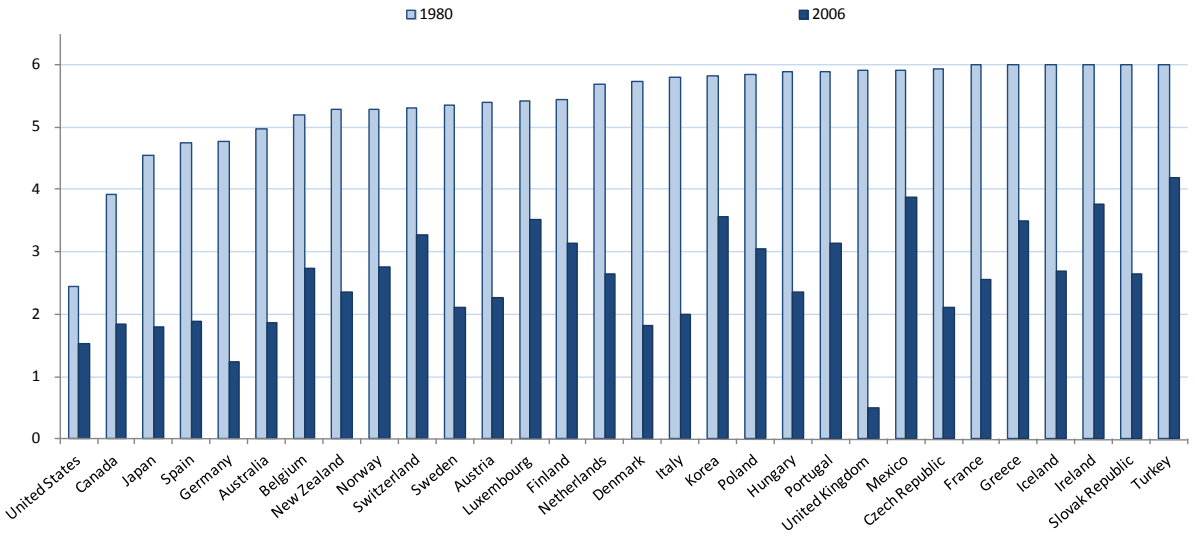
Besides Alesina *et al.* (2005), many other studies have used the ETCR Indicators to access the effect of regulatory frameworks on different dimensions of economic performance. For instance, Nicoletti *et al.* (2003) use the ETCR indicators to investigate the effect of regulation on FDI and the presence of foreign affiliates, while Griffith and Harisson (2004) estimate the impact of regulation on productivity in several network industries. Nicoletti and Scarpetta (2003) use the ETCR indicators to proxy for competitive pressures and analyse the impact of competition on total factor and labour productivity, while Nicoletti and Scarpetta (2005), Bassanini and Duval (2006) and Amable *et al.* (2006) look into the effect of product market regulation on aggregate employment and unemployment rates. Estevão (2005) uses the aggregate ETCR indicator to show that overly regulated product markets in the euro area undermine the effects of labour market reforms in output growth and employment. Berger and Danninger (2006) also use the sectoral ETCR indicator to look at the effects on sectoral employment growth.

### *3.2. Liberalisation and privatisation of energy, telecommunications and railway transportation*

Regulatory settings that restrict competition in energy, transportation and telecommunications sectors have traditionally been among the heaviest in OECD countries. In the 1970s regulation was restrictive in all OECD countries, although more so in Europe and Japan (Conway and Nicoletti, 2006). This is due to the fact that these sectors have been characterised by the presence of natural monopoly segments and network externalities and also because firms in these sectors have been charged with the pursuit of non-economic objectives (such as universal service obligations). Over time, technological progress, improvements in governance and regulatory techniques as well as increasing international exposure has progressively allowed for the liberalisation and privatisation in these sectors.

In the telecommunications and electricity sectors, competition was introduced by the redefinition of the extent of the natural monopoly element, and as a result of technical progress. For instance, electricity generation is potentially competitive while transmission and distribution are not. As such, many countries have unbundled/broken up their electrical utilities into separate companies for generation, long-distance transmission and local transmission. Wireless, long-distance and local telephone services are now often provided by different companies, since competition is possible in long-distance and wireless services but more difficult in local hard-wire services.

Figure 1. **Overall regulation in energy, railway transportation and telecommunications, 1980-2006**




*Note:* Simple averages of the regulatory indicators for electricity, gas, railways and telecommunications sectors. 0 to 6 scale, from least to most restrictive.
*Source*: OECD ETCR Indicators.

Technological enhancement contributes to spur competition and reduce market power in network infrastructure. For instance, the potential for competition in electricity generation increased after the adoption of new technologies reduced the minimum size of a cost-efficient plant (Gómez-Ibáñez, 2003). The development of microwave, satellite and fibre optical transmission technologies facilitated competition in long-distance telephony.

The United States was the first country to embark in regulatory reforms and at the beginning of the 1980s was the country with the least restrictive regulatory framework in the sectors under analysis, as is highlighted in Figure 1. Other countries such as the United Kingdom, Canada, New Zealand, the Nordic European countries and Japan initiated reforms around the mid-1980s. In Australia and most other European countries the bulk of reform occurred from the mid-1990s onwards. In 2006, the United Kingdom was the country with the least restrictive overall framework.

Figure 2 displays the contributions to reductions in the aggregated sectoral indicators in the period 1980-2006 broken down by decade for the overall OECD countries. Regulatory reforms hit mainly telecoms and electricity sectors, while being less intense in railways. The bulk of regulatory reform in OECD countries took place in the period 2000-6, except for telecommunications, where most legal restrictions were lifted on both fixed and wholesale services during the 1990s. Reforms in the railway sector are more recent, and mainly affect freight rather than passenger transportation. Furthermore, few countries did fully unbundle firms operating in this sector, opting for legal or accounting separation.

Figure 2. **The timing of reform in energy, railway transportation and telecommunications, 1980-2006**

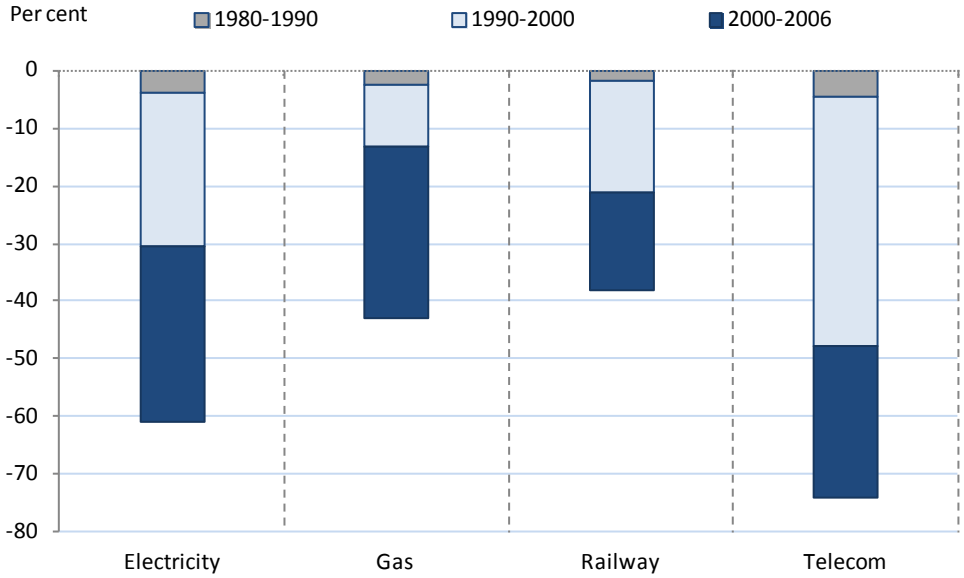
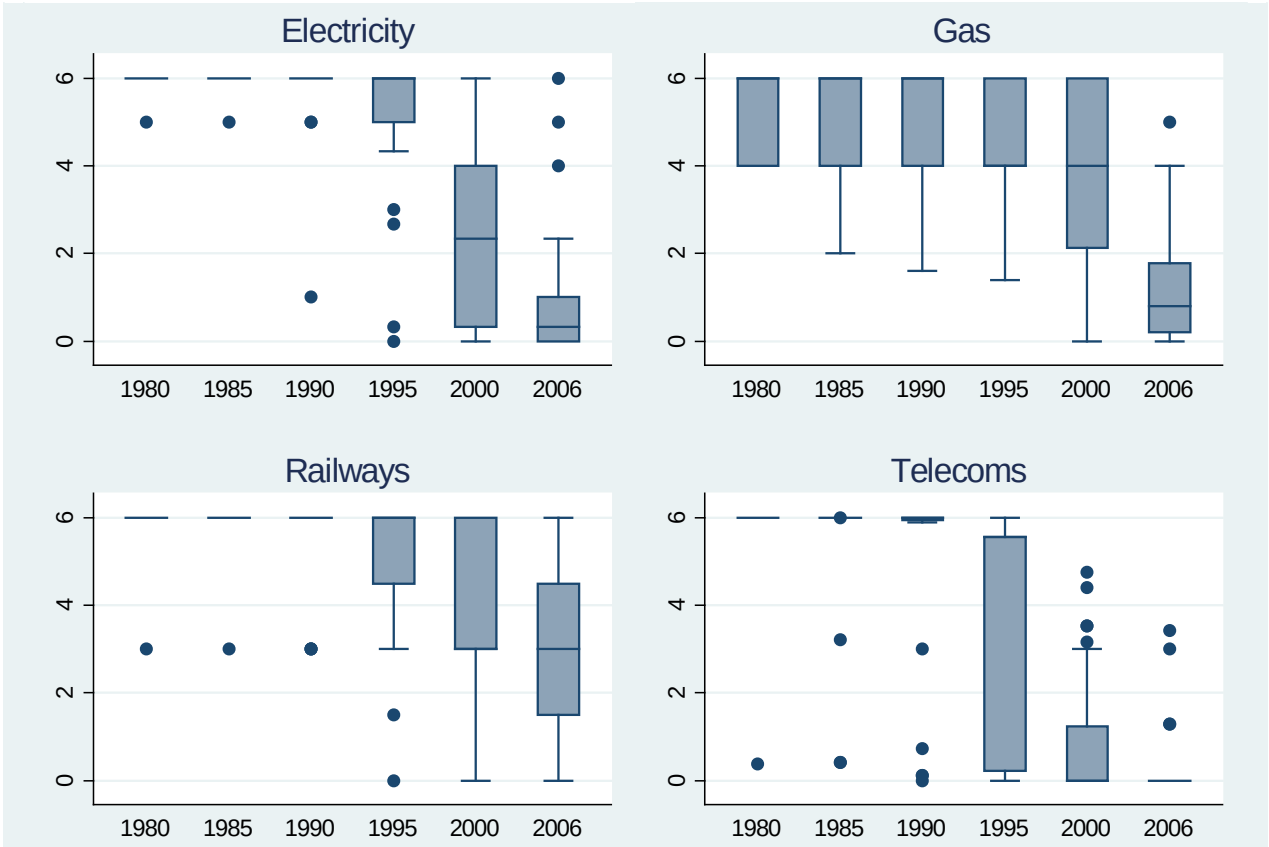



Figure 3. **Barriers to entry in infrastructure sectors, 1980-2006**
Scale 0-6 from lowest to highest degree of barriers to entry



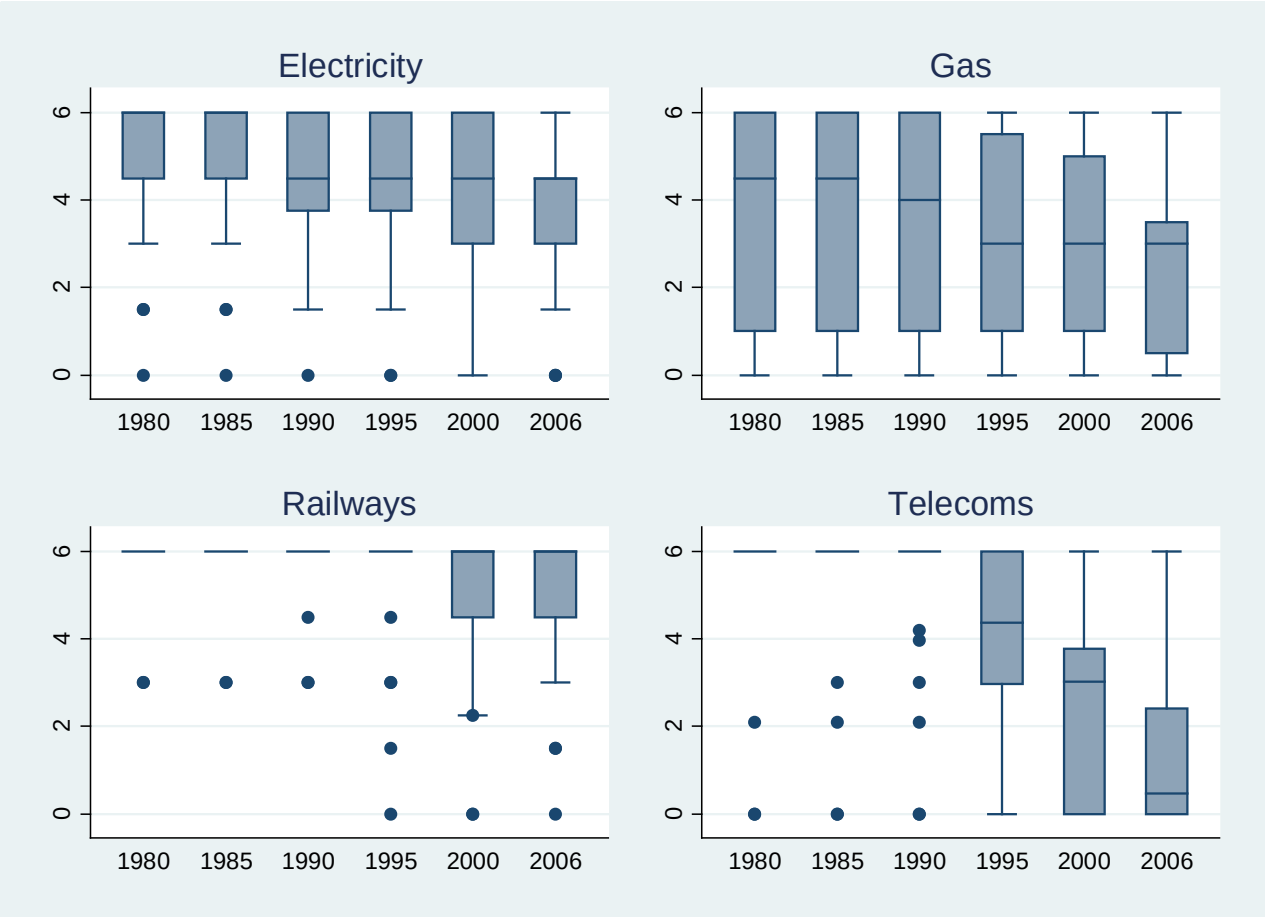

*Note*: The box plots display the box that covers observations between the 1st and 3rd quartiles, as well as the median (the horizontal bar). The whiskers extending from the box give the range that captures the observations which lie within 1.5 times the inter-quartile range from the 1st and 3rd quartile. Points outside this range are considered outliers.

*Source*: OECD ETCR Indicators.

There was a substantial ease of the legal barriers of entry during the last decade (Figure 3). As regards the electricity sector, in 2006 almost all OECD countries had implemented regulated third party access (TPA), with only Germany and Switzerland using negotiated TPA and Mexico without a TPA regime at all. In telecommunications the process started a bit earlier, and by 2006 it was the sector for which entry was mostly liberalised. In the railway sector there is a variety of practices, with Australia, Finland, Ireland, Luxembourg and Turkey having stringent barriers to entry, while Denmark, Czech Republic, Australia and Canada have completely liberalised entry.

Until the late 1980s, public ownership was predominant in almost all countries, particularly in the rail and telecommunication utilities (Figure 4). In many OECD countries governments embarked on privatisation programmes and significant reductions in the level of public ownership occurred in Australia, Czech Republic, Denmark, Germany, Netherlands, Slovak Republic, Spain, Sweden and the United Kingdom. Public ownership remains high in Mexico. In 2006, public ownership was more prevalent in railways then in other sectors.

Figure 4. **Public ownership in infrastructure sectors, 1980-2006**
Scale 0-6 from lowest to highest degree of public ownership



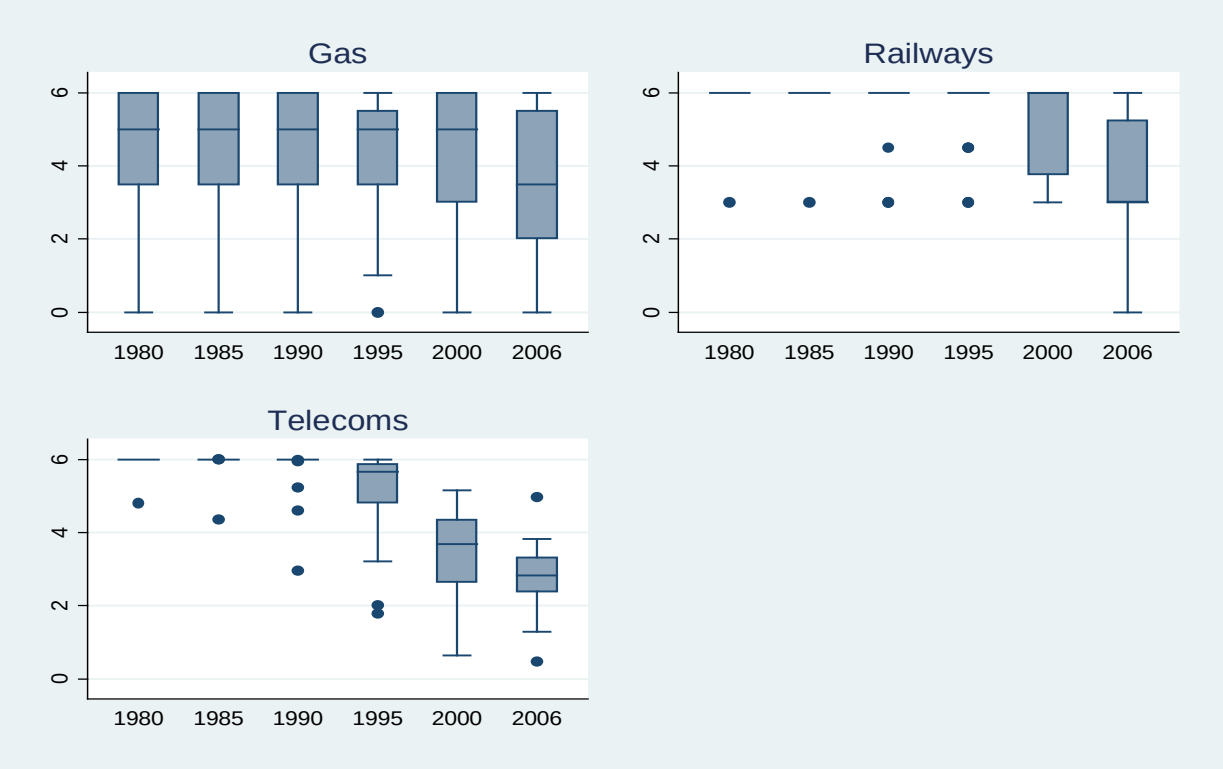

*Note*: The box plots display the box that covers observations between the 1st and 3rd quartiles, as well as the median (the horizontal bar). The whiskers extending from the box give the range that captures the observations which lie within 1.5 times the inter-quartile range from the 1st and 3rd quartile. Points outside this range are considered outliers.

*Source*: OECD ETCR Indicators.

In spite of general success in entry liberalisation and the albeit more modest reductions in the level of public ownership, network markets remain concentrated in many OECD countries in 2006, particularly in France, Greece, Ireland, Luxembourg, Netherlands, Switzerland and Turkey (Figure 5). Throughout the

period, the United Kingdom was very successful in spurring competition, as the indicator on market structure plunged from 6 (the maximum) to 0 (the minimum). Other countries with overall lower levels of market concentration are Japan and New Zealand.

Figure 5. **Market structure in infrastructure sectors, 1980-2006**
Scale 0-6 from lowest to highest degree of market structure

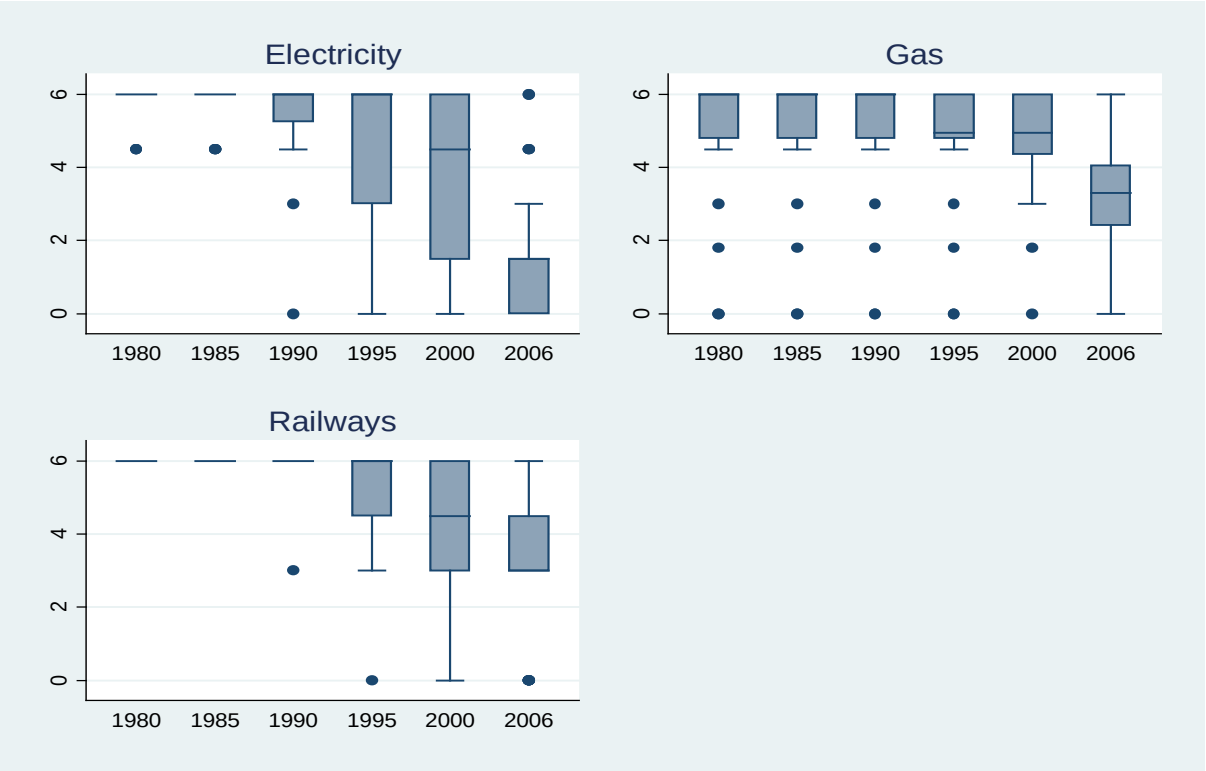



*Note*: The box plots display the box that covers observations between the 1st and 3rd quartiles, as well as the median (the horizontal bar). The whiskers extending from the box give the range that captures the observations which lie within 1.5 times the inter-quartile range from the 1st and 3rd quartile. Points outside this range are considered outliers.
*Source*: OECD ETCR Indicators.

In 1980, the operation of the infrastructure and service provision in the energy sectors and railway transportation were generally integrated in the same company (Figure 6). Once again, regulatory reform differs across OECD countries. There is a diversity of options in what concerns vertical integration in the railroads sector across the OECD, running from vertically-integrated public enterprises to vertically separated private companies. In the electricity sectors, only a handful of countries – Japan, Korea, Mexico, Switzerland and the United States – permit vertically-integrated firms in the electricity sector.

The indicator for regulatory independence is constructed from country responses to the OECD *Questionnaire on Infrastructure Investment*, issue during the Fall of 2007. The questionnaire looks at several dimensions of regulatory independence, such as regulatory authorities' legal status (*i.e.*, whether the regulatory authority is a ministerial agency, a department in a Ministry or an independent body with its own legal status and budget), their power and mandates, including rule making power, adjudicatory power, rights to apply fines and sanctions, the power to award, enforce and revoke licences and their relations with the Executive. In this paper, we consider that the sector regulator is independent if it is an independent agency body with its own legal status and budget and if its decisions cannot be overturned by the executive. In this case, "IRA", takes the form of a dummy variable equal to "1", "0" otherwise.

Figure 6. **Vertical integration in infrastructure sectors, 1980-2006**
Scale 0-6 from lowest to highest degree of vertical integration



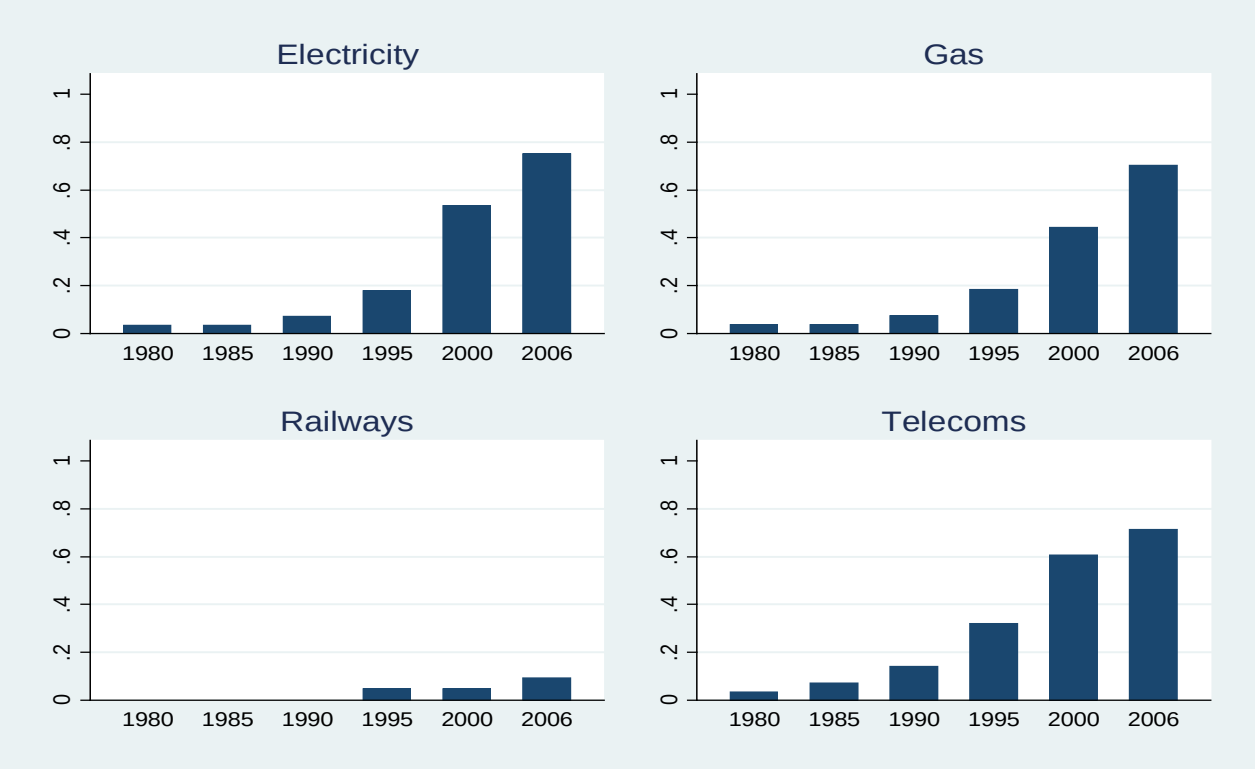

*Note*: The box plots display the box that covers observations between the 1st and 3rd quartiles, as well as the median (the horizontal bar). The whiskers extending from the box give the range that captures the observations which lie within 1.5 times the inter-quartile range from the 1st and 3rd quartile. Points outside this range are considered outliers.

*Source*: OECD ETCR Indicators.

A caveat of this measure is that it focuses on formal independence rather than real authority, *i.e.*, the effective control over its own decisions. Aghion and Tirole (1997) show that an increase in power delegation enhances the regulator's incentive on acquisition of information which is relevant for decision making, but results in loss of control by politicians. In this setup, the degree of powers that are delegated to regulatory authorities face a trade-off between the politicians' loss of control and the degree of initiative of regulators, which can in turn affect the credibility of regulatory authorities. Gilardi (2002, 2005) created an index of regulatory independence which measures more dimensions of regulatory independence than the dummy variable used in this study. Both measures focus on regulatory independence from the executive and politicians and neither measure addresses the issue of regulatory capture neither by the regulated firms' stakeholders nor on the regulatory body management of the relationship between the transmission network operator and distributors and service providers. Although the topic is for sure relevant, gathering information and designing such a measure would not be a straightforward task.

The institution of IRAs took off during the 1990s. In 1980 only Canada (in telecommunications) and Norway (electricity and gas) had institutionalised independent sector regulatory authorities. By 2006 IRAs were prevalent in the telecommunications, electricity and gas sectors. However, they are almost inexistent in railways.

Figure 7. **Regulatory independence, 1980-2006**




*Source*: OECD Questionnaire on Infrastructure Investment.

## 4. Dataset and econometric methodology

The methodological approach used in this paper relies on estimating the Euler equation of the standard neoclassical model of capital accumulation subject to symmetric and quadratic adjustment costs.

The application of the Euler equation to the analysis of firm-level investment was motivated by the need of incorporating expectations about the future profitability of investment plans. The Euler equation method deals with this issue by taking first differences in the derivation of the investment equation, so that the current marginal product of capital (which is given by the sales-capital ratio when the production function is Cobb-Douglas) an the expected one-period change in adjustment costs are all that is needed to describe the change in expectations about the future profitability of the investment.

An alternative approach would be to follow Tobin's Q model, which relates the rate of investment to the ratio between the stock market's valuation of the firm's existing capital stock and its value at replacement costs. This approach uses financial market data to measure the shadow value of capital. To estimate the investment behaviour of regulated firms, it is preferable to use the Euler equation because the Q method is based on the assumption that the stock market valuation of the company correctly measures the fundamental net present value of the firm. If this assumption does not hold, the shadow value of capital will be measured with error and there are no immediate instruments available to correct for this measurement error (Bond and Meghir, 1994). Measurement errors would perhaps even be magnified in the case of regulated and/or partially privatised sectors as stock market valuations do not reflect marginal Q.

The Euler equation is derived from dynamic optimisation in the presence of symmetric, quadratic costs of adjustment, where a representative firm holding rational expectations maximises its present value,

*i.e.* the discounted value of its expected profits. Firms' optimal investment path is estimated by removing the shadow value of capital (by equating the Euler equation to the first-order conditions for investments) and substituting expected values by their realised values. The estimated equation relates yearly firm investment rates (defined as investment-to-capital ratios) to one-year-lagged levels of the linear and quadratic investment rate, cash flow-to-capital ratios, and the user cost of capital.

The Euler equation can be augmented to take into account specific market conditions. Similarly to Bond *et al.* (2003), we introduce the output-to-capital ratio term to account for either non-constant returns to scale or by monopolistic competition in the product market. The Euler equation is also augmented to include variables that attempt to capture specific features of the regulatory environment faced by firms. The user cost of capital term in the Euler equation is replaced in the empirical specification by time effects and firm-specific effects in the estimated regression similarly to Bond *et al.* (2003):

$$\left(\frac{I}{K}\right)_{icst} = \beta_1\left(\frac{I}{K}\right)_{ics,t-1} + \beta_2\left(\frac{I}{K}\right)^2_{ics,t-1} + \beta_3\left(\frac{Y}{K}\right)_{ics,t-1} + \beta_4\left(\frac{CF}{K}\right)_{ics,t-1} + \beta_5 REG_{cs,t-1} + \gamma_t + \eta_i + \varepsilon_{icst} \quad (1)$$

where *I* denotes gross investment, *K* the previous year's capital stock, *Y* output, *CF* cash-flow, *REG* is the set of sector specific regulatory indicators, $\gamma$ unobserved year fixed effects and $\eta$ firm specific fixed effects.

The lagged dependent variable captures dynamic adjustments of the investment rate to changes in the other covariates included in the model. It is expected that the coefficient on the linear lagged value is positive (greater than one), while the coefficient on its square negative (greater than one in absolute value), reflecting adjustment costs. The output-to-capital ratio controls for imperfect competition or decreasing returns to scale.[5] It is eliminated from the Euler equation under perfect competition; otherwise the coefficient on this term is positive.

The Euler equation is derived under the null of no financial constraints. The theoretical model implies that the coefficient on the cash flow term is negative, under the assumption that the firm can raise as much finance as it desires at a given cost. Under the alternative, investment rate is positively related to cash flow through the effect of financial constraints and the Euler equation is mispecified. However, for any given sample a significant coefficient of the cashflow variables does not necessarily signals that variations in the availability of internal funds affect investment levels, but can rather act as a proxy for omitted expected profitability variables. In this context, the cashflow variable has been used in the context of sample-splitting tests to estimate the impact of financial constraint on investments (see Bond *et al.*, 2003 for a discussion).

Deregulation can also affect the availability of internal funds by fostering competition and a decrease in mark-ups. However, this effect is likely to hold for small, and young firms who have entered these markets due to the liberalisation process, but not for the incumbent companies, with large collateralisable assets. The sensitivity of investment spending to cashflow is assessed at the sectoral level and by further splitting the sample into large and small companies.

The regulatory variables used are time varying country-industry indicator variables that capture the restrictiveness of regulatory provisions to competition. As discussed above, the expected sign of the coefficients of the degree of barriers to entry, public ownership, vertical integration is ambiguous, while it is expected that the establishment of IRAs leads to higher investment rates, by easing the threat of

5. Both imperfect competition and decreasing returns to scale relax the linear homogeneity of the net revenue function and have observationally equivalent implications for the Euler equation (Bond and Meghir, 1994).

regulatory opportunism. To take into account the potential endogeneity of regulatory variables, only lagged values of these variables are introduced in the regression equation. To account for the possibility that regulatory effects are sector specific, specific regressions are run for each individual sector. As deregulation may affect firms of different size differently, regressions are also run separately for large and small firms.

The dataset comprises publicly traded utilities in the electricity, gas and telecommunication sectors and railways operators. Firms' financial information used to construct the firm specific covariates comes from the Worldscope (Thomson Financial) database. Investment flows are obtained from uses of funds accounts, which contain primary information on additions to fixed capital stocks. Output is proxied by firm sales and cashflow by operating profits. More details on the dataset and variable construction can be found in Annex 2.

Equation (1) is estimated using the Arellano-Bond (1991) difference GMM estimator first proposed by Holtz-Eakin *et al.* (1988) to control for biases due to unobserved firm-specific effects and endogenous explanatory variables and is appropriate for dynamic models with many cross-section observations and few time periods.

The number of observations for the railways sector is small. Indeed, the main drawback of the use of GMM is that for panels with a small time dimension, the number of instruments may grow large with respect to the available number of observations, which will lead to GMM performing poorly in small samples.[6] In this case, N is also small which will cause the Arellano-Bond autocorrelation test to be unreliable (Roodman, 2006).

As such, the Euler equation for this sector is estimated using the Within Groups estimator. While the Within Groups estimator controls for unobserved heterogeneity, it can provide downward biased estimates for the coefficients of lagged dependent variables, and possibly of the other coefficients in panels with a small number of time periods (Nickell, 1981). The bias of the Within Groups estimator tends to be mitigated in samples with large $T$ (but it does not vanish completely). The sample of firms in the railway sector is an unbalanced panel where the average firm being observed for 9.75 years, which may raise a concern about the suitability of the Within Groups estimator.

On the other hand, this bias may not be problematic, since the coefficients of the lagged dependent variable are not the direct coefficients of interest in this study. Moreover, the correlations between the lagged dependent variable and the regulatory variables are small, making the use of the Within Groups estimator less worrisome for the estimation of the effect of regulatory changes on firms' investment rates. Given that there are not many studies of the railway sector, the analysis can still shed some light on the effects of the regulatory environment on firm-level investment in railways.

The difference GMM has been mentioned as yielding unstable coefficients for many variables when used to estimate Euler equations and authors have preferred system to first differences GMM (see for instance, Becker and Sivadasan, 2010 and Cambini and Rondi, 2010). Blundel and Bond (1988) show that the first difference GMM can lead to large finite sample biases when applied to estimate autoregressive models for persistent series from moderately short panels. This weak instruments problem arises due to the weak correlations between the first differenced variables and their lagged levels. Blundel and Bond (1999) suggest that these estimation biases may be reduced by employing the system GMM estimator instead of first differences. The system GMM uses lagged first differences as instruments for equations in levels in addition to the lagged levels as instruments for the equations in first differences.

6. See Kiviet for a discussion (1995).

Table 2 reports the times series properties of the firm-level variables used in the estimation. It displays simple AR(1) specifications, similar to the analysis in Blundell and Bond (1999). The unit root hypothesis is rejected for all sectors and hence there is no reason to prefer the system GMM to the first differences GMM.

Table 2. **Alternative estimates of AR(1) specification for firm-level covariates**

| | OLS | Within Groups | DIFF (t-2, .) | DIFF (t-2, t-3) | SYSTEM (t-2, .) | SYSTEM (t-2, t-3) |
|---|---|---|---|---|---|---|
| **ALL SECTORS** | | | | | | |
| Investment-to-capital ratio | 0.233*** | 0.128* | 0.447*** | 0.475*** | 0.490*** | 0.505*** |
| | (0.008) | (0.065) | (0.093) | (0.101) | (0.086) | (0.091) |
| Output-to-capital ratio | 0.697*** | 0.565 | 0.901* | 0.929* | 0.583*** | 0.598*** |
| | (0.006) | (0.426) | (0.493) | (0.495) | (0.073) | (0.060) |
| Cashflow-to-capital ratio | 0.780*** | 0.210*** | 0.347 | 0.394 | 0.358 | 0.410 |
| | (0.015) | (0.066) | (0.391) | (0.435) | (0.377) | (0.421) |
| **ELECTRICITY** | | | | | | |
| Investment-to-capital ratio | 0.615*** | 0.143 | 0.702*** | 0.861*** | 0.709*** | 0.803*** |
| | (0.018) | (0.088) | (0.166) | (0.181) | (0.118) | (0.115) |
| Output-to-capital ratio | 1.071*** | -0.584*** | -0.611*** | -0.617*** | -0.005 | -0.196*** |
| | (0.016) | (0.044) | (0.018) | (0.013) | (0.008) | (0.029) |
| Cashflow-to-capital ratio | 0.530*** | -0.407*** | 0.051 | 0.065 | -0.321*** | -0.392*** |
| | (0.022) | (0.145) | (0.072) | (0.066) | (0.102) | (0.066) |
| **GAS** | | | | | | |
| Investment-to-capital ratio | 0.490*** | 0.320** | 0.720*** | 0.785*** | 0.710*** | 0.762*** |
| | (0.025) | (0.140) | (0.076) | (0.115) | (0.057) | (0.090) |
| Output-to-capital ratio | 0.719*** | 0.532*** | 1.895 | 2.009 | 1.364** | 1.405** |
| | (0.012) | (0.129) | (1.287) | (1.378) | (0.625) | (0.664) |
| Cashflow-to-capital ratio | 0.736*** | 0.371*** | 0.575*** | 0.603*** | 0.577*** | 0.595*** |
| | (0.019) | (0.067) | (0.153) | (0.157) | (0.110) | (0.111) |
| **RAILWAYS** | | | | | | |
| Investment-to-capital ratio | 0.611*** | 0.346** | 0.311*** | 0.418*** | 0.364*** | 0.473*** |
| | (0.055) | (0.132) | (0.110) | (0.064) | (0.134) | (0.074) |
| Output-to-capital ratio | 0.719*** | 0.532*** | 1.895 | 2.009 | 1.364** | 1.405** |
| | (0.012) | (0.129) | (1.287) | (1.378) | (0.625) | (0.664) |
| Cashflow-to-capital ratio | 0.736*** | 0.371*** | 0.575*** | 0.603*** | 0.577*** | 0.595*** |
| | (0.019) | (0.067) | (0.153) | (0.157) | (0.110) | (0.111) |
| **TELECOMS** | | | | | | |
| Investment-to-capital ratio | 0.125*** | 0.091 | 0.264*** | 0.271*** | 0.306*** | 0.305*** |
| | (0.011) | (0.060) | (0.073) | (0.085) | (0.070) | (0.075) |
| Output-to-capital ratio | 0.621*** | 0.970*** | 1.271*** | 1.376*** | 0.506*** | 0.526*** |
| | (0.009) | (0.237) | (0.145) | (0.054) | (0.099) | (0.081) |
| Cashflow-to-capital ratio | 0.822*** | 0.240*** | 0.373 | 0.434 | 0.387 | 0.456 |
| | (0.028) | (0.059) | (0.404) | (0.461) | (0.367) | (0.428) |

Note: All regressions include year fixed effects. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

## 5. Results

### *5.1. Main findings*

Table 3 presents the results for aggregate and sector specific regressions using the within groups estimator. Table 3 clearly shows that regulatory frameworks do not have the same impact across industries. For instance, while barriers to entry seem to have a negative effect on firm-level investment in the aggregate regressions which include the four sectors under investigation, this effect is never found in any individual sector regressions. An increase in the level of public ownership is associated with higher investment rates in the gas sector while affecting negatively investment in railways. The coefficient on the dummy for the existence of an IRA is highly significant for the telecommunications sector, exerting a positive effect on firm-level investment rates.

Table 3. **Euler equation results: within groups estimates**

| Dependent variable: Investment-to-capital ratio | ALL | Electricity | Gas | Railways | Telecoms |
|---|---|---|---|---|---|
| Investment-to-capital ratio (t-1) | 0.558*** | 0.256 | 0.909*** | 0.181 | 0.278*** |
| | (0.183) | (0.210) | (0.333) | (0.444) | (0.047) |
| Squared investment-to-capital ratio (t-1) | -0.222* | -0.059 | -0.385** | -0.041 | -0.023*** |
| | (0.120) | (0.201) | (0.178) | (0.557) | (0.004) |
| Output-to-capital ratio (t-1) | 0.024*** | 0.029* | 0.024*** | 0.036 | 0.003 |
| | (0.007) | (0.016) | (0.009) | (0.067) | (0.003) |
| Cashflow-to-capital ratio (t-1) | -0.008 | -0.048 | 0.186* | -0.063 | -0.010 |
| | (0.040) | (0.050) | (0.098) | (0.071) | (0.008) |
| IRA (t-1) | -0.004 | 0.012 | 0.007 | 0.022 | **0.072*** ** |
| | (0.010) | (0.009) | (0.021) | (0.014) | (0.026) |
| BE (t-1) | **-0.004*** | -0.003 | -0.001 | 0.001 | 0.001 |
| | (0.002) | (0.003) | (0.003) | (0.009) | (0.007) |
| PO (t-1) | -0.001 | -0.003 | **0.010**** | **-0.016*** | 0.004 |
| | (0.006) | (0.009) | (0.005) | (0.008) | (0.007) |
| VI (t-1) | 0.000 | 0.004 | -0.001 | 0.007 | |
| | (0.003) | (0.005) | (0.003) | (0.018) | |
| const | 0.104*** | 0.128** | -0.041 | -0.099 | 0.128*** |
| | (0.040) | (0.063) | (0.061) | (0.119) | (0.029) |
| R-squared | 0.099 | 0.101 | 0.169 | 0.122 | 0.213 |
| Observations | 2646 | 1412 | 1078 | 156 | 1040 |

Note: All regressions include year fixed effects. Standard errors allow for intragroup correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

Due to the likely bias of the within groups estimates in the presence of a lagged dependent variable, equation (1) is estimating using GMM techniques.[7] We start by using all available instruments starting in lags dated (t-2) and then restrict the number of instruments to lags dated (t-2) and (t-3) and to (t-2) only. While Arellano and Bond (1991) suggest using all instruments available, with all possible lags to get consistent estimates, later practitioners such as Chatelain and Teurlai (2001) advise against this practice and recommend parsimony instead, as the employment of too many instruments leads the chi-square test to over-reject overidentifying restrictions.

7. The estimation of the Euler equation through GMM is implemented using Roodman's (2007) xtabond2 code written for STATA.

The exclusion of instruments, and especially the exclusion of all instruments except those dated (t-2) (last column) often substantially reduces the precision of the parameter estimates. The small sample size for railways precludes the use of GMM estimators for this sector but the sector is included in the pooled sector regressions.

Table 4. **Euler equation results for all sectors**

| **Dependent variable: Investment-to-capital ratio** | **Entire Sample** | | | **European Companies** | | |
|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** |
| Investment-to-capital ratio (t-1) | 0.816*** | 1.695*** | 1.877** | 0.076 | 1.582 | 31.292 |
| | (0.164) | (0.557) | (0.825) | (0.145) | (1.120) | (182.570) |
| Squared investment-to-capital ratio (t-1) | -0.311** | -1.030* | -1.178 | -0.052 | -3.41 | -117.566 |
| | (0.144) | (0.538) | (0.748) | (0.104) | (3.015) | (752.918) |
| Output-to-capital ratio (t-1) | 0.033** | 0.066 | 0.073 | 0.015*** | 0.029*** | 0.365 |
| | (0.016) | (0.043) | (0.053) | (0.004) | (0.010) | (2.364) |
| Cashflow-to-capital ratio (t-1) | -0.036 | -0.270 | -0.318 | -0.157*** | -0.006 | -0.511 |
| | (0.088) | (0.293) | (0.369) | (0.031) | (0.137) | (4.027) |
| **BE (t-1)** | **-0.005**** | **-0.007**** | **-0.007**** | -0.001 | -0.017 | -0.468 |
| | (0.002) | (0.003) | (0.004) | (0.003) | (0.012) | (3.462) |
| PO (t-1) | -0.001 | -0.006 | -0.007 | -0.001 | -0.033 | -1.093 |
| | (0.006) | (0.008) | (0.009) | (0.006) | (0.023) | (7.773) |
| VI (t-1) | 0.001 | -0.001 | -0.001 | 0.004 | 0.019 | 0.507 |
| | (0.003) | (0.005) | (0.006) | (0.005) | (0.012) | (3.612) |
| IRA (t-1) | -0.008 | -0.015 | -0.016 | -0.004 | -0.042 | -1.261 |
| | (0.009) | (0.011) | (0.013) | (0.011) | (0.034) | (9.802) |
| Observations | 2274 | 2274 | 2274 | 729 | 729 | 729 |
| Number of Firms | 323 | 323 | 323 | 102 | 102 | 102 |
| Arellano-Bond test for AR(1) (p-value) | 0.034 | 0.073 | 0.060 | 0.186 | 0.153 | 0.891 |
| Arellano-Bond test for AR(2) (p-value) | 0.879 | 0.483 | 0.487 | 0.067 | 0.192 | 0.879 |
| Hansen test of overidentifying restrictions | 0.075 | 0.663 | | 0.715 | 0.751 | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

First difference GMM confirms the results obtained by the within estimator: barriers to entry have a negative effect on investment when all the sectors are pooled (Table 4), a result also found by Alesina *et al.* (2005) with industry investment data. This result is quite robust: the coefficient is quite stable to the different set of instruments used and is always significant at the 5% level. We do not find evidence of any other regulatory framework impacting on investment rates in the pooled sector regressions. However, the sector specific regressions show quite a different picture: legal barriers to entry act as a deterrent of investment only in the electricity sector (Tables 5 to 7, inclusive). Instead, higher levels of public ownership seem to be associated with higher investment rates in the gas sector (Table 6). The coefficient on the level of public ownership is significant at the 10% level when all the instruments available are used but restricting the number of instruments renders the coefficient insignificant. In telecommunications, the existence of an IRA has a positive effect on investment: the coefficient is stable and always significant at the 1% level throughout the regressions making use of different sets of instruments (Table 7).

Table 5. **Euler equation results for electricity**

| **Dependent variable: Investment-to-capital ratio** | **Entire Sample** | | | **European Companies** | | |
|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** |
| Investment-to-capital ratio (t-1) | 0.705*** | 1.383** | 171.187 | -0.098 | -0.045 | 1.897 |
| | (0.209) | (0.579) | (4411.829) | (0.340) | (0.737) | (3.629) |
| Squared investment-to-capital ratio (t-1) | -0.310 | -0.887* | -148.683 | 0.059 | -0.686 | 7.947 |
| | (0.219) | (0.468) | (3836.431) | (0.196) | (0.716) | (12.236) |
| Output-to-capital ratio (t-1) | 0.040** | 0.062 | 12.909 | 0.076** | 0.087 | -0.323 |
| | (0.016) | (0.045) | (334.650) | (0.035) | (0.096) | (0.505) |
| Cashflow-to-capital ratio (t-1) | -0.098 | -0.284 | -90.005 | -0.161 | 0.207 | 0.133 |
| | (0.078) | (0.282) | (2333.212) | (0.141) | (0.343) | (1.395) |
| **BE (t-1)** | -0.004 | **-0.007*** | -0.608 | 0.000 | -0.004 | 0.029 |
| | (0.004) | (0.004) | (15.620) | (0.003) | (0.006) | (0.036) |
| PO (t-1) | -0.004 | -0.007 | -0.765 | -0.007 | -0.017 | 0.085 |
| | (0.009) | (0.010) | (19.788) | (0.007) | (0.012) | (0.085) |
| VI (t-1) | 0.004 | 0.004 | -0.235 | **0.010**** | **0.015*** | **-0.054** |
| | (0.005) | (0.006) | (6.098) | (0.005) | (0.008) | (0.070) |
| IRA (t-1) | 0.004 | -0.013 | -3.999 | 0.005 | -0.01 | 0.113 |
| | (0.009) | (0.015) | (103.513) | (0.010) | (0.019) | (0.123) |
| Observations | 1210 | 1210 | 1210 | 563 | 563 | 563 |
| Number of Firms | 173 | 173 | 173 | 82 | 82 | 82 |
| Arellano-Bond test for AR(1) (p-value) | 0.065 | 0.024 | 0.969 | 0.179 | 0.924 | 0.253 |
| Arellano-Bond test for AR(2) (p-value) | 0.170 | 0.300 | 0.970 | 0.214 | 0.127 | 0.261 |
| Hansen test of overidentifying restrictions | 0.178 | 0.472 | | 0.995 | 0.552 | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

Table 6. **Euler equation results for gas**

| **Dependent variable: Investment-to-capital ratio** | **Entire Sample** | | | **European Companies** | | | |
|---|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **Within Estimator** |
| Investment-to-capital ratio (t-1) | 0.964*** | 1.242*** | 1.302*** | 0.780*** | -0.687 | -0.447 | 0.687*** |
| | (0.229) | (0.249) | (0.233) | (0.196) | (1.419) | (1.059) | (0.210) |
| Squared investment-to-capital ratio (t-1) | -0.392** | -0.499*** | -0.496*** | -1.965** | 3.16 | 2.816 | -1.867* |
| | (0.166) | (0.161) | (0.154) | (0.852) | (4.323) | (3.044) | (0.890) |
| Output-to-capital ratio (t-1) | 0.016* | 0.015 | 0.003 | 0.014*** | 0.024* | 0.020* | 0.013*** |
| | (0.008) | (0.010) | (0.019) | (0.003) | (0.012) | (0.012) | (0.004) |
| Cashflow-to-capital ratio (t-1) | 0.364* | 0.188 | 0.093 | 0.065 | -0.423 | -0.285 | 0.075 |
| | (0.201) | (0.259) | (0.241) | (0.066) | (0.561) | (0.498) | (0.076) |
| BE (t-1) | -0.004 | -0.002 | -0.001 | -0.001 | 0.013 | 0.009 | -0.001 |
| | (0.004) | (0.004) | (0.004) | (0.003) | (0.013) | (0.013) | (0.003) |
| **PO (t-1)** | **0.010*** | **0.007** | **0.006** | **0.008**** | **0.008** | **0.008** | **0.009** |
| | (0.005) | (0.004) | (0.004) | (0.004) | (0.008) | (0.007) | (0.005) |
| VI (t-1) | 0.001 | 0.001 | 0.001 | **-0.006**** | **-0.029** | **-0.022** | **-0.007**** |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.027) | (0.023) | (0.003) |
| IRA (t-1) | 0.001 | -0.001 | -0.002 | **-0.028***** | **-0.076** | **-0.060** | **-0.032**** |
| | (0.017) | (0.014) | (0.014) | (0.009) | (0.047) | (0.050) | (0.011) |
| const | | | | | | | 0.213*** |
| | | | | | | | (0.020) |
| Observations | 926 | 926 | 926 | 122 | 122 | 122 | 139 |
| Number of Firms | 134 | 134 | 134 | 16 | 16 | 16 | 17 |
| R-squared | | | | | | | 0.662 |
| Arellano-Bond test for AR(1) (p-value) | 0.110 | 0.105 | 0.096 | 0.016 | 0.545 | 0.543 | |
| Arellano-Bond test for AR(2) (p-value) | 0.310 | 0.340 | 0.303 | 0.159 | 0.476 | 0.562 | |
| Hansen test of overidentifying restrictions | 0.765 | 0.187 | | 1.000 | 1.000 | | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

Turning to firm-specific variables, the Euler equation captures well firms' investment decisions in the gas sector, with both lagged terms of the dependent variable being significant and with the expected signs, indicating adjustment costs. The lagged linear term of the dependent variable is always significant in the electricity and telecommunications sectors. Instead, the coefficient on output-to-capital ratio is significant and positive when (t-2) and deeper lags are employed, except in telecommunications, where the coefficient is significant only when the number of instruments is restricted to the most recent available lags. The coefficient is positive, as expected, consistent with the presence of imperfect competition. Firms in the electricity sector do not exhibit excessive sensitivity to cashflow, while there is some evidence that the converse is true for firms in the gas and telecommunications sector.

Table 7. **Euler equation results for telecommunications**

| **Dependent variable: Investment-to-capital ratio** | **Entire Sample** | | | **European Companies** | | | |
|---|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **Within Estimator** |
| Investment-to-capital ratio (t-1) | 0.337*** | 0.263*** | 0.232** | 0.397*** | 0.401*** | 0.135 | 0.352*** |
| | (0.076) | (0.100) | (0.106) | (0.055) | (0.071) | (0.185) | (0.042) |
| Squared investment-to-capital ratio (t-1) | -0.048 | -0.022 | -0.01 | -0.038*** | -0.035* | 0.046 | -0.030*** |
| | (0.033) | (0.041) | (0.041) | (0.012) | (0.018) | (0.048) | (0.004) |
| Output-to-capital ratio (t-1) | 0.005 | 0.008** | 0.007** | 0.01 | -0.007 | 0.088 | 0.015 |
| | (0.004) | (0.003) | (0.003) | (0.008) | (0.014) | (0.199) | (0.009) |
| Cashflow-to-capital ratio (t-1) | 0.008 | 0.034* | 0.038* | -0.027 | 0.072 | 0.214 | -0.021*** |
| | (0.021) | (0.021) | (0.022) | (0.039) | (0.077) | (0.184) | (0.003) |
| BE (t-1) | 0.001 | 0.001 | 0.001 | 0.003 | 0.005 | 0.009 | 0.003 |
| | (0.007) | (0.008) | (0.008) | (0.008) | (0.009) | (0.014) | (0.009) |
| PO (t-1) | 0.005 | 0.004 | 0.004 | -0.010 | **-0.015*** | -0.045 | -0.010 |
| | (0.007) | (0.008) | (0.008) | (0.008) | (0.008) | (0.040) | (0.010) |
| **IRA (t-1)** | **0.069*** ** | **0.070*** ** | **0.070*** ** | **0.042*** | 0.023 | 0.038 | **0.046** ** |
| | (0.025) | (0.026) | (0.026) | (0.022) | (0.022) | (0.061) | (0.022) |
| const. | | | | | | | 0.148*** |
| | | | | | | | (0.044) |
| Observations | 847 | 847 | 847 | 309 | 309 | 309 | 378 |
| Number of Firms | 160 | 160 | 160 | 55 | 55 | 55 | 67 |
| | | | | | | | 0.361 |
| Arellano-Bond test for AR(1) (p-value) | 0.004 | 0.016 | 0.018 | 0.226 | 0.046 | 0.113 | |
| Arellano-Bond test for AR(2) (p-value) | 0.426 | 0.311 | 0.293 | 0.299 | 0.188 | 0.795 | |
| Hansen test of overidentifying restrictions | 0.995 | 0.549 | | 1.000 | 0.833 | | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

### *5.2. Firm heterogeneity*

The analysis so far focused on individual sectors response to several characteristics of the regulatory environment. Results point out to sector specific reactions to the same characteristics of regulation. For instance, the institution of an IRA is associated with an increase in firm-level investment rate while it does not seem to exert an impact on investment in other sectors. A puzzling result is the significant and negative effect of barriers to entry when all sectors are pooled (Tables 3 and 4, for the within groups and first differenced estimates, respectively), indicating that a decrease in the legal level of barriers to entry in an industry is associated with higher investment rates. However, the coefficient on barriers to entry is significant only in the electricity sector when instruments dated (t-2) and (t-3) are used, at the 10% significance level.

To understand what is driving this result, we further split the sample in two ways: firstly, we run sector specific regressions for large and small firms. The adoption of a legal framework that aims at promoting competition is likely to exert a different effect on firms of different size. It is also likely to impact differently on the investment behaviour of incumbents and new entrants in the market. Since infrastructure sectors are capital intensive, firm size is defined as those firms in each country and sector whose total assets are higher than the 75$^{th}$ percentile of the distribution of fixed assets. This split will

typically pick up the incumbent firms in each sector, which will be classified as a large firm. Secondly, we re-run Equation (1) for the sub-group of European firms. European markets were generally subject to stricter regulation till very recently (with the UK being the exception); deregulation started later but in some countries and sectors legal barriers to competition are now set at very low levels, which led to changes in the regulatory environment being more acute than in other OECD countries. Another reason to focus on European firms is the fact that the overall sample has a great many number of American firms, with the results reflecting the conditions in the US market. Being a federal state, the US regulatory environment is not the same across states and the level of the indicators tend to reflect the regulatory environment either for the most representative state or for the more populous one. This is also the case of Australian and Canadian data.

The results need to be analysed with caution. When the sector sub-samples are split further into European and large and small companies, the Hansen test of overidentifying restrictions can exhibit an implausible good p-value of 1.000, a sign of too many instruments (Roodman, 2006), even when the number of instruments is restricted to only two period lags. This is the case of the sub-sample of European firms in the gas industry and all sub-samples in the telecommunications sector. In these cases, we provide within-groups estimates as a benchmark result. In general, the within-groups estimates are similar to the first differenced estimates when all available instruments are used in the sub-samples of European gas companies and large telecommunications companies.

Table 8. **Euler equation results for all sectors: large *vs* small companies**

| **Dependent variable: Investment-to-capital ratio** | **Large Companies** | | | **Small Companies** | | |
|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** |
| Investment-to-capital ratio (t-1) | 0.765*** | 0.972*** | 1.033*** | 0.670*** | 1.520** | 2.130 |
| | (0.262) | (0.307) | (0.300) | (0.255) | (0.694) | (1.659) |
| Squared investment-to-capital ratio (t-1) | -0.204 | -0.212 | -0.303 | -0.344 | -1.083* | -1.642 |
| | (0.195) | (0.229) | (0.228) | (0.217) | (0.557) | (1.445) |
| Output-to-capital ratio (t-1) | 0.014*** | 0.015** | 0.006 | 0.024 | 0.074 | 0.132 |
| | (0.005) | (0.006) | (0.013) | (0.017) | (0.057) | (0.151) |
| Cashflow-to-capital ratio (t-1) | 0.095 | 0.012 | 0.017 | -0.044 | -0.398 | -0.802 |
| | (0.160) | (0.050) | (0.045) | (0.084) | (0.351) | (0.983) |
| **BE (t-1)** | **-0.007**** | **-0.006**** | **-0.006*** | 0.000 | -0.004 | -0.006 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.005) | (0.008) |
| PO (t-1) | 0.002 | 0.005 | 0.003 | -0.001 | -0.006 | -0.010 |
| | (0.009) | (0.008) | (0.008) | (0.004) | (0.008) | (0.015) |
| VI (t-1) | 0.000 | 0.000 | 0.000 | 0.002 | 0.002 | 0.001 |
| | (0.003) | (0.002) | (0.003) | (0.005) | (0.008) | (0.010) |
| IRA (t-1) | -0.009 | -0.015 | -0.014 | -0.008 | -0.014 | -0.015 |
| | (0.013) | (0.014) | (0.014) | (0.011) | (0.012) | (0.015) |
| Observations | 1127 | 1127 | 1127 | 1147 | 1147 | 1147 |
| Number of Firms | 125 | 125 | 125 | 198 | 198 | 198 |
| Arellano-Bond test for AR(1) (p-value) | 0.036 | 0.048 | 0.039 | 0.005 | 0.003 | 0.012 |
| Arellano-Bond test for AR(2) (p-value) | 0.089 | 0.139 | 0.115 | 0.306 | 0.258 | 0.277 |
| Hansen test of overidentifying restrictions | 0.228 | 0.203 | | 0.472 | 0.896 | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

In the sub-sample of small telecommunications companies, output-to-capital ratio is found to be not significant in the within groups estimates while in all first-differenced GMM estimates its coefficient is significant and positive at the 5% level. In the sub-sample of European telecoms, the coefficient on the cashflow variable is similar in magnitude to the first-difference estimate when all available instruments are

used. It is highly significant in regression using the within estimator but not in the ones using GMM first differences.

Overall, the results show marked heterogeneity in the effects of regulation on firm level investment. The significant negative coefficient on barriers to entry is driven by large firms alone (Table 8). The regressions show results when firms in the electricity, gas and railways sector are pooled but not telecommunications companies, as the level of vertical integration is not available for this sector. Disaggregated sector regressions show that investment behaviour differs between large and small firms of different sector. The negative coefficient on barriers to entry found for large firms (Table 8) and electricity companies (Table 5) seems to be driven by large electricity companies (Table 9) as the coefficient on barriers to entry is not significant for companies in the gas sector (Table 10). Instead, the level of barriers to entry is highly statistical significant for the sub-group of small telecommunication companies (although employing all available instruments starting in (t-2) lags and restricting the instrument set to (t-2) and (t-3) lags gives implausibly high values of the Hansen statistic, the coefficient is significant at the 1% level when (t-3) instruments are used. Moreover, the coefficient is quite stable and negative, which indicates that a rise in the level of barriers to entry is associated with smaller investment rate in smaller telecommunications companies (Table 12). This result demonstrates a clear pro-competitive effect of the reduction of legal barriers to entry in telecommunication markets as new (smaller) firms investment in capacity.

Table 9. **Euler equation results for electricity: large *vs* small companies**

| **Dependent variable: Investment-to-capital ratio** | **Large Companies** | | | **Small Companies** | | |
|---|---|---|---|---|---|---|
| | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** |
| Investment-to-capital ratio (t-1) | 0.637** | 1.606*** | -6.745 | 0.110 | 1.016*** | -9.410 |
| | (0.298) | (0.617) | (210.757) | (0.374) | (0.310) | (11.866) |
| Squared investment-to-capital ratio (t-1) | -0.398*** | -1.820** | 9.762 | 0.099 | -0.570*** | 7.746 |
| | (0.146) | (0.751) | (290.956) | (0.330) | (0.220) | (9.344) |
| Output-to-capital ratio (t-1) | 0.102 | -0.01 | 0.544 | 0.019 | 0.053** | -0.785 |
| | (0.067) | (0.132) | (14.784) | (0.026) | (0.026) | (0.958) |
| Cashflow-to-capital ratio (t-1) | 0.060 | 0.975** | -3.602 | 0.033 | -0.197 | 5.217 |
| | (0.341) | (0.483) | (112.644) | (0.143) | (0.152) | (6.031) |
| **BE (t-1)** | -0.011 | **-0.022*** | 0.053 | 0.003 | -0.002 | 0.054 |
| | (0.007) | (0.012) | (1.869) | (0.005) | (0.004) | (0.072) |
| PO (t-1) | -0.006 | -0.030 | 0.143 | -0.003 | **-0.008*** | 0.051 |
| | (0.019) | (0.034) | (4.335) | (0.004) | (0.005) | (0.075) |
| VI (t-1) | 0.000 | 0.007 | -0.035 | **0.013*** | **0.015*** | **0.014** |
| | (0.006) | (0.014) | (1.069) | (0.007) | (0.008) | (0.037) |
| IRA (t-1) | -0.007 | -0.030 | 0.200 | **0.026**** | **0.008** | **0.182** |
| | (0.014) | (0.028) | (5.807) | (0.012) | (0.011) | (0.219) |
| Observations | 481 | 481 | 481 | 729 | 729 | 729 |
| Number of Firms | 56 | 56 | 56 | 117 | 117 | 117 |
| Arellano-Bond test for AR(1) (p-value) | 0.069 | 0.341 | 0.972 | 0.013 | 0.021 | 0.403 |
| Arellano-Bond test for AR(2) (p-value) | 0.444 | 0.315 | 0.917 | 0.078 | 0.230 | 0.298 |
| Hansen test of overidentifying restrictions | 1.000 | 0.777 | | 0.697 | 0.487 | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

Vertical integration is also positively associated with higher investment level in electricity companies in Europe (Table 5). This result is consistent with coordination losses and the misalignment in investment incentives that may arise when firms are vertically separated. The effect of vertical integration also varies with firm size. An increase in the degree of vertical integration in the electricity sector is associated with higher investment rates by small firms but seems not to affect large firms. It is not clear what is driving this

result. This is an issue that needs to be clarified by looking into the size distribution of firms in each segment of the industry.

Table 10. **Euler equation results for gas: large vs small companies**

| Dependent variable: Investment-to-capital ratio | Large Companies | | | Small Companies | | |
|---|---|---|---|---|---|---|
| | (t-2, .) | (t-2, t-3) | (t-2) | (t-2, .) | (t-2, t-3) | (t-2) |
| Investment-to-capital ratio (t-1) | 1.119*** | 1.399*** | 1.382*** | 0.589 | 0.523 | 0.811* |
| | (0.317) | (0.360) | (0.340) | (0.423) | (0.380) | (0.462) |
| Squared investment-to-capital ratio (t-1) | -0.418* | -0.461* | -0.445* | -0.350 | -0.32 | -0.404 |
| | (0.232) | (0.252) | (0.242) | (0.278) | (0.236) | (0.257) |
| Output-to-capital ratio (t-1) | 0.015*** | 0.014** | 0.013 | 0.037 | 0.048 | 0.028 |
| | (0.005) | (0.007) | (0.013) | (0.070) | (0.106) | (0.101) |
| Cashflow-to-capital ratio (t-1) | 0.202 | 0.127 | -0.087 | 0.513* | 0.481 | 0.436 |
| | (0.171) | (0.170) | (0.128) | (0.287) | (0.456) | (0.442) |
| BE (t-1) | -0.006 | -0.004 | -0.002 | 0.002 | 0.003 | 0.003 |
| | (0.005) | (0.005) | (0.004) | (0.007) | (0.008) | (0.008) |
| PO (t-1) | 0.005 | 0.003 | 0.001 | 0.001 | 0.003 | 0.001 |
| | (0.005) | (0.006) | (0.005) | (0.012) | (0.015) | (0.015) |
| VI (t-1) | 0.000 | 0.001 | -0.001 | -0.001 | 0.000 | 0.003 |
| | (0.004) | (0.003) | (0.003) | (0.008) | (0.013) | (0.012) |
| IRA (t-1) | -0.007 | -0.022 | -0.02 | **-0.058**** | **-0.060**** | **-0.051*** |
| | (0.017) | (0.019) | (0.018) | (0.023) | (0.025) | (0.026) |
| Observations | 532 | 532 | 532 | 394 | 394 | 394 |
| Number of Firms | 59 | 59 | 59 | 75 | 75 | 75 |
| Arellano-Bond test for AR(1) (p-value) | 0.118 | 0.130 | 0.127 | 0.072 | 0.091 | 0.077 |
| Arellano-Bond test for AR(2) (p-value) | 0.142 | 0.228 | 0.201 | 0.929 | 0.925 | 0.825 |
| Hansen test of overidentifying restrictions | 1.000 | 0.088 | | 1.000 | 0.877 | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

The existence of an IRA seems to act as a deterrent of investment for small firms in the gas sector (Table 10) but seems to be associated with higher investment rates by small firms in the electricity sector.

The highly statistical significant and positive effect on firm-level investment found in the telecommunications sector seems to be driven by large firms, although the statistical significance of this coefficient is reduced in the smaller sub-sample (Table 11). The existence of an independent regulatory authority does not to affect small firms' investment behaviour (Table 12).

The sample only comprises 16 European firms operating in the gas sector, which precludes the use of GMM estimators as the instrument set used were never valid even when restricted to one time period. As such, we present results for the European sub-sample using the Within estimator. The results on the restricted sample for European firms, presented in Table 6, confirm the positive effects of public ownership on firm-level investment in the gas sector that were found in the larger sample. In Europe, the existence of an independent regulatory authority is associated with a decrease in investment rates in the gas sector, while the converse is true for firms in telecommunications.

The sector aggregate results presented in the former section also mask firm level heterogeneity on the relationship between the availability of internal funds and investment. The aggregate regressions for the electricity sector did not reveal any sensitivity of investment to cashflow, while disaggregated results provide some evidence that large firms' investment decisions are positively correlated with cashflow, while such an effect is not found for small firms. This result is in line with the study by Devereux and Schiantarelli (1990), who find a stronger evidence of financial effects on investment among larger firms.

However, the effect is reversed in the telecommunications sector: the coefficient on cashflow is positive and significant at the 10% level (using instruments dated (t-3)) for small firms, while negative for large companies. There are no financial effects found in the disaggregated regressions in the gas sector.

Table 11. **Euler equation results for telecommunications: large companies**

| **Dependent variable: Investment-to-capital ratio** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **Within Estimator** |
|---|---|---|---|---|
| Investment-to-capital ratio (t-1) | 0.356* | 0.170** | -0.269 | 0.295*** |
| | (0.210) | (0.080) | (1.461) | (0.092) |
| Squared investment-to-capital ratio (t-1) | -0.039 | 0.008 | 0.287 | -0.021 |
| | (0.058) | (0.023) | (0.913) | (0.024) |
| Output-to-capital ratio (t-1) | 0.058** | 0.043 | -0.264 | 0.079*** |
| | (0.029) | (0.040) | (1.049) | (0.016) |
| Cashflow-to-capital ratio (t-1) | -0.069*** | -0.070** | 0.229 | -0.053*** |
| | (0.023) | (0.031) | (0.956) | (0.013) |
| BE (t-1) | 0.008 | 0.009 | 0.013 | 0.008 |
| | (0.007) | (0.009) | (0.016) | (0.008) |
| PO (t-1) | -0.007 | -0.008 | 0.026 | -0.006 |
| | (0.010) | (0.012) | (0.113) | (0.011) |
| **IRA (t-1)** | **0.097**** | **0.107*** | **-0.011** | **0.110**** |
| | (0.044) | (0.057) | (0.379) | (0.050) |
| const | | | | 0.107*** |
| | | | | (0.037) |
| Observations | 428 | 428 | 428 | 495 |
| Number of Firms | 57 | 57 | 57 | 63 |
| R-squared | | | | 0.393 |
| Arellano-Bond test for AR(1) (p-value) | 0.052 | 0.129 | 0.718 | |
| Arellano-Bond test for AR(2) (p-value) | 0.110 | 0.155 | 0.503 | |
| Hansen test of overidentifying restrictions | 1.000 | 0.999 | | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

### *5.3. Implications of regression estimates on the effects of reforms on investment rates*

How large are regulatory effects? To assess how changes in the regulatory environment affect investment in infrastructure sectors, we conduct a simulation experiment where one element of the relevant indicator is changed from "most restrictive" to "least restrictive" regulation.[8] This exercise reveals that:

- *Barriers to Entry*. For large firms in the electricity sector, starting from the "most restrictive" regulation and moving from no third party access (TPA) to the transmission grid to regulated TPA, or liberalising the wholesale market for electricity, or allowing consumers to freely choose their electricity supplier would increase large firms' investment rate by 3.3 percentage points. Implementing all the reforms simultaneously would increase the investment rate by 13.2 percentage points. For small telecommunication firms, moving from franchising each segment of the market to one firm alone to free entry would boost investment rates by 11.4 percentage points.

8. Being a dummy variable, the effect of a change in IRA is evaluated from 'no' independent regulator to the existence of a sector independent regulatory authority. Changes in investment rates are computed at the median levels of the other covariates.

- *Independent Regulator*. In the telecommunications sector, setting an independent regulatory authority would increase the investment rate in the sector by 7 percentage points, from 1.5% to 8.4%.

Table 12. **Euler equation results for telecommunications: small companies**

| **Dependent variable: Investment-to-capital ratio** | **(t-2, .)** | **(t-2, t-3)** | **(t-2)** | **Within Estimator** |
|---|---|---|---|---|
| Investment-to-capital ratio (t-1) | 0.306*** | 0.266** | 0.258** | 0.270*** |
| | (0.085) | (0.132) | (0.123) | (0.064) |
| Squared investment-to-capital ratio (t-1) | -0.028 | -0.022 | -0.018 | -0.023*** |
| | (0.025) | (0.042) | (0.042) | (0.005) |
| Output-to-capital ratio (t-1) | 0.006** | 0.008** | 0.008** | 0.003 |
| | (0.003) | (0.003) | (0.004) | (0.003) |
| Cashflow-to-capital ratio (t-1) | 0.025 | 0.038* | 0.041* | -0.008 |
| | (0.019) | (0.022) | (0.023) | (0.009) |
| **BE (t-1)** | **-0.020*** ** | **-0.019*** ** | **-0.019*** ** | **-0.022*** ** |
| | (0.007) | (0.007) | (0.007) | (0.007) |
| PO (t-1) | 0.010 | 0.009 | 0.008 | 0.011 |
| | (0.018) | (0.022) | (0.022) | (0.020) |
| IRA (t-1) | 0.121 | 0.106 | 0.103 | 0.099 |
| | (0.120) | (0.113) | (0.110) | (0.106) |
| const. | | | | 0.166** |
| | | | | (0.065) |
| Observations | 419 | 419 | 419 | 545 |
| Number of Firms | 103 | 103 | 103 | 126 |
| R-squared | | | | 0.181 |
| Arellano-Bond test for AR(1) (p-value) | 0.025 | 0.043 | 0.045 | |
| Arellano-Bond test for AR(2) (p-value) | 0.643 | 0.501 | 0.486 | |
| Hansen test of overidentifying restrictions | 0.978 | 1.000 | | |

Note: All regressions include year fixed effects. Standard errors in parentheses are robust to heteroskedasticity and within serial correlation. * denotes a significant coefficient at the 10%, level, ** at the 5% level and *** at the 1% level.

## 6. Conclusion

This paper aims at making a contribution to the study of the impact of deregulation on firm investment in infrastructure sectors, which have traditionally been sheltered from competition in the majority of OECD countries. Since the 1980s they have gradually been subject to a process of regulatory reform, comprising entry liberalisation, vertical separation and a reduction of the public sector intervention through privatisation and arm's length regulation.

The empirical analysis focus on the electricity, gas, railways and telecommunications sectors and builds on the Euler equation of the standard neoclassical model of capital accumulation subject to adjustment costs. The main contribution of this paper to the existing literature is to show that there is a significant level of heterogeneity of firms' investment behaviour to the characteristics of the regulatory environment, both at the sector and at the firm level.

This paper confirms the finding of Alesina *et al.* (2005) that a reduction in the level of barriers to entry exerts a positive effect on firm-level investment. Sector specific regressions show however that this effect is only found for large firms operating in the electricity sector and more strongly in small firms in the telecommunications sector.

An increase in the level of vertical integration in the electricity sector is associated with rising investment rates in Europe. This effect is also found in small firms operating in the sector. The existence of an independent regulatory authority spurs small firms' investment while it does not seem to affect large firms' investment rates.

Firms in the gas sector seem to react rather differently to the regulatory environment. The level of public ownership is found to spur investment. Investment rates of small companies are negatively affected by the existence of an independent regulator, which constitutes a puzzling result.

In turn, the existence of an independent regulator is associated with higher investment rates in the telecommunications sector. Disaggregated regressions show that this effect is found only for the larger companies in the sector.

The small sample size for the railways sector precludes the use of robust GMM techniques. Within-groups estimates show a negative relationship between the level of public ownership and firm-level investment.

The different sector responses to the presence of an IRA are interesting and ask for a more in-depth analysis regarding the specificities of institutional design. There are also two other dimensions of the regulatory environment associated with IRAs' activities which may explain the different results found at the sector level: the possibility of regulatory capture and the price regime. While collecting data for the price regime would be a feasible task, regulatory capture is not easily assessed.

There are other dimensions of the regulatory environment which are equally not easily gauged. For instance, the indicator on the degree of barriers to entry used in this study only measures the level of legal barriers to entry. However, the durable and very specific nature of investments in infrastructure may act as a serious deterrent of entry in these industries, even if legal barriers to entry are lifted. They increase both the potential gains from winning and the costs of losing a battle for market share and the threat of entry may indeed not be credible. The fact that large firms are sensitive to a reduction in the level of legal barriers to entry in the electricity sector may indicate that incumbents undertake pre-emptive strategies by raising capacity. Still, pure competition effects cannot be ruled out.

The indicator on public ownership is designed to capture the overall level of state direct intervention in the sector through ownership stakes in the different segments of the relevant industry. It does not allow distinguishing between firms who have been previously state owned or may still be partially owned from the potential new private entrants in these markets. Analysing the specific ownership stakes of the State at the company level in the different segments of each industry would be a significant contribution to understand the different results obtained at the sector level. Another issue which adds complexity to unveiling the effect of public ownership is the fact that in the period under analysis the State often held golden shares in utility companies in some European countries. Golden shares grant effective control of semi-privatised companies, a situation which can potentially impact not only on the investment rates of these firms but also on the investment behaviour of other (private) firms in the sector. These are interesting issues that we leave for future research.

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*Annex 1*

## The structure of the OECD ETCR indicators

Table 13. **Indicator of regulatory reform for the electricity sector**

| | Weights by theme ($b_j$) | Question weights ($c_k$) | Coding of data | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Entry regulation:** | 1/3 | | | | | | | |
| How are the terms and conditions of third party access (TPA) to the electricity transmission grid determined? | | 1/3 | Regulated TPA<br>0 | | Negotiated TPA<br>3 | | No TPA<br>6 | |
| Is there a liberalised wholesale market for electricity (a wholesale pool)? | | 1/3 | yes<br>0 | | | | no<br>6 | |
| What is the minimum consumption threshold that consumers must exceed in order to be able to choose their electricity supplier ? | | 1/3 | No threshold<br>0 | <250 gigawatts<br>1 | Between 250 and 500 gigawatts<br>2 | Between 500 and 1000 gigawatts<br>3 | More than 1000 gigawatts<br>4 | No consumer choice<br>6 |
| **Public ownership:** | 1/3 | | | | | | | |
| What is the ownership structure of the largest companies in the generation, transmission, distribution, and supply segments of the electricity industry? | | 1 | Private<br>0 | Mostly Private<br>1.5 | Mixed<br>3 | Mostly Public<br>4.5 | Public<br>6 | |
| **Vertical Integration:** | 1/3 | | | | | | | |
| What is the degree of vertical separation between the transmission and generation segments of the electricity industry? | | 1/2 | Separate Companies<br>0 | | Accounting separation<br>3 | | Integrated<br>6 | |
| What is the overall degree of vertical integration in the electricity industry? | | 1/2 | Unbundled<br>0 | | Mixed<br>3 | | Integrated<br>6 | |
| **Country scores (0-6)** | | | $\Sigma_j b_j \Sigma_k c_k$ answer$_{jk}$ | | | | | |

Table 14. **Indicator of regulatory reform for the gas sector**

| | Weights by theme ($b_j$) | Question weights ($c_k$) | Coding of data | | |
|---|---|---|---|---|---|
| **Entry regulation:** | 1/4 | | | | |
| | | | Regulated TPA | Negotiated TPA | No TPA |
| How are the terms and conditions of third party access (TPA) to the gas transmission grid determined? | | 1/3 | 0 | 3 | 6 |
| What percentage of the retail market is open to consumer choice? | | 1/3 | (1-% of market open to choice/100)*6 | | |
| | | | No, free entry in all markets | Yes, in some markets | Yes, in all markets |
| Do national, state or provincial laws or other regulations restrict the number of competitors allowed to operate a business in at least some markets in the sector: gas production/import | | 1/3 | 0 | 3 | 6 |
| **Public ownership:** | 1/4 | | | | |
| | | | None | Between 0 and 100 % | 100% |
| What percentage of shares in the largest firm in the gas production/import sector are owned by government? | | 1/3 | 0 | 3 | 6 |
| What percentage of shares in the largest firm in the gas transmission sector are owned by government? | | 1/3 | 0 | 3 | 6 |
| What percentage of shares in the largest firm in the gas distribution sector are owned by government? | | 1/3 | 0 | 3 | 6 |
| **Vertical Integration:** | 1/4 | | | | |
| | | | Ownership separation | Legal/Accounting | Integrated |
| What is the degree of vertical separation between gas production/import and the other segments of the industry? | | 1/2 | 0 | 3 | 6 |
| What is the degree of vertical separation between gas supply and the other segments of the industry? | | 3/10 | 0 | 3 | 6 |
| Is gas distribution vertically separate from gas supply? | | 1/5 | 0 | 3 | 6 |
| **Market structure:** | 1/4 | | | | |
| | | | < 50% | between 50 and 90% | > 90% |
| What is the market share of the largest company in the gas production/import industry? | | 1/3 | 0 | 3 | 6 |
| What is the market share of the largest company in the gas transmission industry? | | 1/3 | 0 | 3 | 6 |
| What is the market share of the largest company in the gas supply industry? | | 1/3 | 0 | 3 | 6 |
| **Country scores (0-6)** | | | $\Sigma_j b_j \Sigma_k c_k$ answer$_{jk}$ | | |

Table 15. **Indicator of regulatory reform for the rail sector**

| | Weights by theme ($b_j$) | Question weights ($c_k$) | Coding of data | | | |
|---|---|---|---|---|---|---|
| **Entry regulation:** | 1/4 | | | | | |
| | | | Free entry (upon paying access fees) | Entry franchised to several firms | | Entry franchised to a single firm or regulated according to EU 1991 directive |
| What are the legal conditions of entry into the passenger transport rail market? | | 1/2 | 0 | 3 | | 6 |
| What are the legal conditions of entry into the freight transport rail market? | | 1/2 | 0 | 3 | | 6 |
| **Public ownership:** | 1/4 | | | | | |
| | | | No public ownership | Between 0 and 100 % | | 100% |
| What percentage of shares in the largest firm in operation of infrastructure sector is owned by government? | | 1/4 | 0 | 3 | | 0 |
| What percentage of shares in the largest firm in passenger transport sector is owned by government? | | 1/4 | 0 | 3 | | 6 |
| What percentage of shares in the largest firm in freight transport sector is owned by government? | | 1/4 | 0 | 3 | | 6 |
| | | | no | | | yes |
| Do national, state or provincial government holds equity stakes in business company : Railways | | 1/4 | 0 | | | 6 |
| **Market structure:** | 1/4 | | | | | |
| | | | >2 | Between 1 and 2 | | 1 |
| What is the maximum number of operators that compete in the same area / rail district in the passenger transport market? | | 1/2 | 0 | 3 | | 6 |
| What is the maximum number of operators in the freight transport market? | | 1/2 | 0 | 3 | | 6 |
| **Vertical Separation:** | 1/4 | | | | | |
| | | | Ownership separation | Legal separation | Accounting separation | No separation |
| What is the degree of separation between the operation of infrastructure and the provision of railway services (the actual transport of passengers or freight)? | | 1 | 0 | 3 | 4.5 | 6 |
| **Country scores (0-6)** | | | $\Sigma_j b_j \Sigma_k c_k$ answer$_{jk}$ | | | |

Table 16. **Indicator of regulatory reform for the telecommunications sector**

| | Weights by theme ($b_j$) | Question weights ($c_k$)[1] | Coding of data | | |
|---|---|---|---|---|---|
| **Entry regulation:** | 1/4 | | Free entry | Franchised to 2 or more firms | Franchised to 1 firm |
| What are the legal conditions of entry into the trunk telephony market? | | $1/4*w^t*(1-w^m)$ | 0 | 3 | 6 |
| What are the legal conditions of entry into the international market? | | $1/4*(1-w^t)(1-w^m)$ | 0 | 3 | 6 |
| What are the legal conditions of entry into the mobile market? | | $1/2*w^m$ | 0 | 3 | 6 |
| **Public ownership:** | 1/4 | | | | |
| What percentage of shares in the PTO are owned by government?[2] | | $1-w^m$ | | % government ownership / 100 * 6 | |
| What percentage of shares in the largest firm in the mobile telecommunications sector are owned by government? | | $w^m$ | | % government ownership / 100 * 6 | |
| **Market structure:**[3] | 1/4 | | | | |
| What is the market share of new entrants in the trunk telephony market? | | $1/4*w^t*(1-w^m)$ | | 6-normalised market share[2] | |
| What is the market share of new entrants in the international telephony market? | | $1/4*(1-w^t)(1-w^m)$ | | 6-normalised market share | |
| What is the market share of new entrants in the mobile market? | | $1/2*w^m$ | | 6-normalised market share | |
| **Country scores (0-6)** | | | | $\Sigma_j b_j \Sigma_k c_k$ answer$_{jk}$ | |

1 The weight $w^m$ is the OECD-wide revenue share from mobile telephony in total revenue from trunk, international, and mobile. The weight $w^t$ is the annual OECD-wide revenue share of trunk in total revenue from trunk and international telephony.
2 "PTO" stands for "Public telecommunications operator".
3 For the purposes of calculating the indicator the market share of new entrants has been normalised to be between 0 and 6 with 6 being the smallest market share over all countries and time and 0 being the largest.

*Annex 2*

## The dataset – public traded utilities and railway infrastructure

Although it is useful to employ a measure of productive capital in investment regressions, it is difficult to construct a sound measure of capital stock. As a firm's book value does not reflect the accurate value of its capital stock, it is common practice to apply the perpetual inventory method (PIM) to compute the replacement cost of capital. However, the implementation of this methodology relies on rather stringent and oversimplifying assumptions such as the application of the same discount rate at the sector level across countries, irrespective of the quality of infrastructure.

Moreover, the PIM also commonly assumes that replacement cost valuations are equal to historical costs for the first year of data and then drop the initial 5 years to mitigate this measurement error (see, for instance, Bond and Meghir, 1994). This precludes the application of this method to our dataset as the median firm is observed for 9, 8, 9 and 6 years in the electricity, gas, railways and telecommunications, respectively. Dropping 5 years of data and then using GMM would significantly reduce the dataset.

Contributing more decisively against the use of this method to estimate the value of productive capital is the fact that the median firm is observed by far less number of years than the average service life of capital assets in infrastructure sectors, which are extremely long lived (except for telecommunications, where the average life cycle is about 10 years). These considerations raise many doubts on the use of the PIM method to compute a reasonably good approximation of a firm's capital stock as there is not enough guidance regarding the age structure of the capital stock to correct for problems with book value data. Thus, although using the book value of capital stock may be flawed, we are not guaranteed to be closer to the truth by applying the perpetual inventory method to the book value capital stock.

To assess the impact of regulatory settings on investment it is crucial to identify companies' core business. The dataset included several multi-utility companies, involved simultaneously in gas and electricity delivery. To define the sector, 139 companies which did not have at least 80% of their revenues coming from one single sector, were dropped from the sample. The 80% rule was also used to exclude companies in the gas sector which were also involved in activities the oil sector. Worldscope does not report the geographical breakdown of the variables of interest. Companies whose domicile is not any of the OECD countries were eliminated from the sample, as it is likely that their core business lies elsewhere. Double counting of investment was avoided by verification of the presence of subsidiaries belonging to the same group. As much as possible, subsidiary firms were retained in the dataset, at the expense of the consolidated investment values for the group, so that the impact of regulation would not be masked by aggregation.

High investment rates are to be expected when new firms enter in capital intensive industries which were previously shielded from competition. However, to avoid results being influenced by outliers, firms with unusually high investment rates were removed from the sample. The final dataset is obtained by merging data the ETCR indicators with the data on firm-level investment. It results in an unbalanced panel, covering 565 firms operating in the electricity, gas, railways and telecoms sector in 28 OECD countries over the period 1980-2006. The country and sector coverage is listed in Table 17.

Table 17. **Distribution of firms by country and industry**

| Country/Sector | Electricity | Gas | Railways | Telecoms | Total |
|---|---|---|---|---|---|
| Australia | 7 | 4 | - | 9 | 20 |
| Austria | 1 | 1 | - | 1 | 3 |
| Belgium | 1 | 2 | 1 | 4 | 8 |
| Canada | 8 | 10 | 2 | 10 | 30 |
| Czech Republic | 9 | 3 | - | 1 | 13 |
| Denmark | 3 | - | - | 2 | 5 |
| Finland | 2 | - | - | 4 | 6 |
| France | 3 | 1 | 1 | 5 | 10 |
| Germany | 18 | 3 | - | 7 | 28 |
| Greece | 1 | - | - | 3 | 4 |
| Hungary | 4 | - | - | 1 | 5 |
| Ireland | - | - | - | 2 | 2 |
| Italy | 5 | 2 | 1 | 7 | 15 |
| Japan | 10 | 12 | 2 | 7 | 31 |
| Korea | 1 | 9 | - | 8 | 16 |
| Luxembourg | 2 | - | - | - | 2 |
| Mexico | 1 | - | - | 7 | 8 |
| Netherlands | 2 | - | - | 6 | 8 |
| New Zealand | 2 | 2 | - | 3 | 7 |
| Norway | 2 | - | - | 2 | 4 |
| Poland | - | - | - | 3 | 3 |
| Portugal | 1 | - | - | 3 | 4 |
| Spain | 10 | 2 | - | 1 | 13 |
| Sweden | 5 | - | 1 | 5 | 11 |
| Switzerland | 11 | - | - | 1 | 12 |
| Turkey | 2 | - | - | 1 | 3 |
| UK | 16 | 3 | 1 | 12 | 32 |
| USA | 71 | 97 | 10 | 84 | 262 |
| **Total** | **198** | **151** | **19** | **197** | **565** |

Table 18 presents the summary statistics for the covariates used in the model, disaggregated by sector. Over the sample period, the average investment rate is higher in the telecommunications sector. The maximum investment rate is also found in telecommunications, which is consistent with the technological developments and subsequent capital investments that occurred in this sector in the recent decades. The range of investment rates is lower in the railways sector. The telecommunications sector exhibits higher output- and cash flow-to-capital ratios. Turning to the regulatory variables, barriers to entry are more stringent in the electricity sector, while there is almost free entry in the telecommunications sector. Over the sample period, public ownership is more prevalent is the railways sector and lowest in the gas sector. Vertical integration is higher in the railways and electricity sector and lowest in the gas sector. Finally, the low mean values for the independent regulator variable indicate that, over the sample period, firms in electricity, gas, railways and telecommunications were mostly subject to a sector regulator that was not independent from the executive.

Table 18. **Summary statistics**

| Variable | N | min | p25 | p50 | mean | p75 | p90 | max | sd |
|---|---|---|---|---|---|---|---|---|---|
| ELECTRICITY | | | | | | | | | |
| Investment-to-capital ratio | 2054 | 0 | 0.03 | 0.05 | 0.08 | 0.08 | 0.12 | 3.8 | 0.15 |
| Output-to-capital ratio | 2054 | 0 | 0.24 | 0.33 | 0.6 | 0.48 | 0.77 | 144.9 | 4.17 |
| Cashflow-to-capital ratio | 1557 | -23.97 | 0.05 | 0.09 | 0.08 | 0.14 | 0.21 | 15.09 | 0.89 |
| IRA | 2160 | 0 | 0 | 0 | 0.32 | 1 | 1 | 1 | 0.47 |
| BE | 2160 | 0 | 1 | 5 | 3.98 | 6 | 6 | 6 | 2.35 |
| PO | 2160 | 0 | 1.5 | 1.5 | 2.6 | 4.5 | 6 | 6 | 1.81 |
| VI | 2160 | 0 | 4.5 | 4.5 | 4.59 | 6 | 6 | 6 | 1.82 |
| GAS | | | | | | | | | |
| Investment-to-capital ratio | 1510 | 0 | 0.05 | 0.08 | 0.11 | 0.11 | 0.19 | 3.24 | 0.15 |
| Output-to-capital ratio | 1509 | 0 | 0.35 | 0.56 | 0.71 | 0.84 | 1.25 | 17.81 | 0.84 |
| Cashflow-to-capital ratio | 1178 | -0.28 | 0.09 | 0.14 | 0.16 | 0.21 | 0.28 | 1.33 | 0.11 |
| IRA | 1550 | 0 | 0 | 0 | 0.36 | 1 | 1 | 1 | 0.48 |
| BE | 1550 | 0 | 1.4 | 2 | 2.44 | 4 | 5 | 6 | 1.49 |
| PO | 1550 | 0 | 0 | 0 | 0.43 | 0 | 2 | 6 | 1.26 |
| VI | 1550 | 0 | 0 | 2.4 | 2.13 | 3.3 | 6 | 6 | 2.28 |
| RAILWAYS | | | | | | | | | |
| Investment-to-capital ratio | 233 | 0 | 0.04 | 0.07 | 0.09 | 0.1 | 0.15 | 0.52 | 0.08 |
| Output-to-capital ratio | 233 | 0.08 | 0.25 | 0.42 | 0.59 | 0.56 | 0.71 | 31.52 | 2.05 |
| Cashflow-to-capital ratio | 167 | -1.02 | -0.07 | 0.08 | 0.06 | 0.21 | 0.26 | 0.38 | 0.22 |
| IRA | 239 | 0 | 0 | 0 | 0.05 | 0 | 0 | 1 | 0.22 |
| BE | 239 | 0 | 3 | 3 | 3.62 | 6 | 6 | 6 | 1.6 |
| PO | 239 | 0 | 3 | 3 | 3.99 | 6 | 6 | 6 | 1.43 |
| VI | 239 | 0 | 6 | 6 | 5.53 | 6 | 6 | 6 | 1.09 |
| TELECOMS | | | | | | | | | |
| Investment-to-capital ratio | 1350 | 0 | 0.07 | 0.11 | 0.19 | 0.18 | 0.37 | 11.61 | 0.42 |
| Output-to-capital ratio | 1350 | 0.02 | 0.37 | 0.5 | 1.76 | 0.95 | 2.73 | 203.84 | 7.78 |
| Cashflow-to-capital ratio | 1204 | -10.55 | 0.09 | 0.19 | 0.56 | 0.37 | 0.84 | 37.09 | 2.25 |
| IRA | 1375 | 0 | 0 | 0 | 0.33 | 1 | 1 | 1 | 0.47 |
| BE | 1375 | 0 | 0 | 0 | 0.8 | 0.34 | 3.75 | 6 | 1.76 |
| PO | 1375 | 0 | 0 | 0 | 1.1 | 2.57 | 3.72 | 6 | 1.77 |

Table 19 presents sector correlations between covariates used in this study. It shows a negative correlation between the ETCR indicators (barriers to entry, public ownership, market structure, vertical integration and overall sector regulation) and the existence of a sectoral independent regulator, except for the indicator on vertical integration for the gas industry. Thus, over the period 1980-2006, deregulation in infrastructure sectors was accompanied by the establishment of independent regulatory authorities in OECD countries. The correlations between vertical integration and barriers to entry and between the latter and the existence of an independent regulator are high in the electricity sector, demonstrating that regulatory reform affected many features of the regulated industries simultaneously. Public ownership and the degree of barriers to entry are also high in the railways sector.

Table 19. **Correlations between regressors**

| **ELECTRICITY** | **Inv/K** | **Output/K** | **CF/K** | **BE** | **PO** | **VI** | **IRA** |
|---|---|---|---|---|---|---|---|
| Investment-to-capital ratio | 1 | | | | | | |
| Output-to-capital ratio | 0.1455 | 1 | | | | | |
| Cashflow-to-capital ratio | -0.0574 | 0.2104 | 1 | | | | |
| BE | -0.0581 | -0.0779 | 0.0265 | 1 | | | |
| PO | 0.0903 | 0.0500 | -0.0555 | 0.2590 | 1 | | |
| VI | -0.0849 | -0.1189 | 0.0552 | 0.6244 | -0.0323 | 1 | |
| IRA | 0.0324 | -0.0235 | 0.0299 | -0.6945 | -0.1545 | -0.5352 | 1 |
| **GAS** | **Inv/K** | **Output/K** | **CF/K** | **BE** | **PO** | **VI** | **IRA** |
| Investment-to-capital ratio | 1 | | | | | | |
| Output-to-capital ratio | 0.0014 | 1 | | | | | |
| Cashflow-to-capital ratio | 0.1190 | 0.5028 | 1 | | | | |
| BE | -0.0455 | 0.0424 | -0.0621 | 1 | | | |
| PO | -0.0273 | 0.1845 | -0.0679 | 0.5790 | 1 | | |
| VI | -0.1285 | 0.0674 | -0.0652 | 0.5149 | 0.4066 | 1 | |
| IRA | -0.0518 | 0.0632 | 0.0265 | -0.4277 | -0.2080 | 0.2534 | 1 |
| **RAILWAYS** | **Inv/K** | **Output/K** | **CF/K** | **BE** | **PO** | **VI** | **IRA** |
| Investment-to-capital ratio | 1 | | | | | | |
| Output-to-capital ratio | 0.1487 | 1 | | | | | |
| Cashflow-to-capital ratio | -0.2219 | 0.3462 | 1 | | | | |
| BE | 0.3479 | 0.2312 | -0.3332 | 1 | | | |
| PO | 0.2341 | 0.2102 | -0.4947 | 0.7373 | 1 | | |
| VI | -0.0617 | -0.2713 | 0.0942 | -0.3312 | -0.6775 | 1 | |
| IRA | 0.4470 | 0.0051 | -0.3154 | 0.3073 | 0.3947 | -0.3124 | 1 |
| **TELECOMS** | **Inv/K** | **Output/K** | **CF/K** | **BE** | **PO** | **IRA** | |
| Investment-to-capital ratio | 1 | | | | | | |
| Output-to-capital ratio | 0.0595 | 1 | | | | | |
| Cashflow-to-capital ratio | 0.0739 | 0.6026 | 1 | | | | |
| BE | -0.0714 | -0.0461 | -0.0477 | 1 | | | |
| PO | 0.0322 | 0.0770 | 0.0107 | 0.4608 | 1 | | |
| IRA | -0.0161 | 0.0157 | -0.0004 | -0.0624 | 0.2185 | 1 | |

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