Infrastructure Investment in Network Industries: The Role of Incentive Regulation and Regulatory Independence

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Abstract

This paper finds that coherent regulatory policies can boost investment in network industries of OECD economies. Rate-of-return regulation is generally thought to result in overinvestment, while incentive regulation is believed to entail underinvestment. Yet, previous empirical work has generally found that the introduction of incentive regulation has not systematically changed investment in network industries. According to the theoretical literature, regulatory uncertainty exposes both types of regimes to the danger of underinvestment. However, regulatory uncertainty is arguably higher under rate-of-return regulation because investment decisions (what can be included in the rate base) are usually evaluated in a discretionary manner, while firms operating under incentive regulation are less affected by this behaviour. In addition, incentive regulation encourages investment in cost-reducing technologies. Using Bayesian model averaging techniques, this paper shows that incentive regulation implemented jointly with an independent sector regulator (indicating lower regulatory uncertainty) has a strong positive impact on investment in network industries. In addition, lower barriers to entry are also found to encourage sectoral investment. These results support the importance of implementing policies in a coherent framework.

JEL Code: L51, L97, L98.

Keywords: network industries, regulation, incentive regulation, price cap, cost-plus regulation, rate-of-return regulation, regulatory independence, investment.

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1. Introduction

Liberalisation, privatisation and the introduction of incentive regulation has often been viewed as a way to promote infrastructure investment in network industries. For example, the separation of electricity generation and transmission in the United States was intended to boost investment by encouraging more entry into the market (Ishii and Yan, 2006). Yet, problems arising after the opening-up of network industries have often been attributed to falling investment in network infrastructure. For example, a series of fatal train accidents in the United Kingdom (Southall in 1997, Paddington in 1999 and Hatfield in 2000) was widely blamed on under-investment, while the blackouts in California in 2001 and in New York, London, Italy, Denmark and Sweden in 2003 were largely blamed on under-investment in electricity generation or transmission grids (Bialek, 2004; Pollitt, 2007; Hirschhauser *et al.* 2004; Joskow, 2006).).

Part of the divergence between *ex ante* expectations and *ex post* outcomes can be explained by incoherencies in the overall framework of the reforms. For example in the electricity sector, Jamasb and Pollitt (2005) argue that introducing sustainable competition in electricity generation and distribution requires action with respect to liberalisation, privatisation and regulation. First, vertical unbundling of generation, transmission and distribution (and horizontal splitting in generation) is necessary to ensure competition by preventing a vertically-integrated company acting strategically to curb competition and to prevent new entry. Second, privatisation of public incumbents in generation and distribution is desirable to ensure a level playing field which may otherwise be prevented by their easier access to capital than for new entrants. Finally, setting up an independent regulator is needed to supervise the transmission network operator and regulate prices were needed. It is also claimed that the choice of the regulatory regime may also have a bearing on the outcome. For instance, traditional forms of regulation such as rate-of-return regulation that caps the return on the capital and more recent forms of regulation comprising price cap regulation that incentivises the regulated firms to become more efficient may influence the investment decisions of the firms.

Against this backdrop, this paper reviews theory and empirical evidence on the effect of regulation on investment in network industries and on the relevance of consistency of the regulatory framework for sectoral investment behaviour. The paper then assesses empirically the impact of the overall regulatory framework on sectoral investment in network industries in a sample of OECD countries. The main findings of the literature review and the empirical analysis are the following:

First, theory suggests that none of the existing regulatory regimes is immune to the danger of over- or under-investment in network infrastructure. Whether a particular regime provides firms incentives to invest depends to a large extent on the particular set-up of the system. While rate-of-return regulation is traditionally thought to result in over-investment, the more recent literature emphasised that under-investment can also occur under certain circumstances. The regulated firm may choose to under-invest if the timing of the regulatory cycle is too short to recoup investment costs or, it may also decide not to invest, delay investment or invest sequentially (or to increase its leverage) in the case of regulatory uncertainty. The regulated firm may also cut back investment in the face of uncertainty arising from the use of *ex post* rather than *ex ante* information with regard to the inclusion of investment in the rate base.

Second, while it is widely accepted that incentive price regulation is a powerful tool to eliminate short-run cost inefficiencies, it is also thought to incite regulated firms to under-invest in network infrastructure with a view to increase short-term profits. Like rate-of-return regulation, incentive regulation may depress investment if the regulatory cycle is not long enough to break even, if the regulator revises efficiency targets before the next review period, if it sets unrealistic efficiency targets or if the rate base is evaluated with the wisdom of hindsight. The fact that risk is shifted back from consumers to shareholders implies higher risk and higher cost of capital also potentially translating into less investment.

Third, regulated firms may nevertheless want to increase investment spending because incentive price regulation offers more opportunities to increase revenue and profit by investing in cost-reducing technologies. A regulated firm will engage to upgrade its existing infrastructure if it decreases operating costs, if it permits the launch of new profitable services or to improve service quality.

Fourth, the empirical literature suggests that shifting away from traditional rate-of-return regulation did not generally cause under-investment in network industries. For instance, overall investment in the UK railway sector did increase in the aftermath of privatisation and the introduction of incentive regulation. Empirical studies also highlight that incentive regulation was very helpful in promoting the deployment of new technologies in the US telecommunications sectors in the late 1980s and early 1990s.

Finally, the empirical results in this paper suggest that the introduction of incentive price regulation or the establishment of an independent sector regulator do not have a positive influence on investment by themselves. However, once these policies are implemented jointly, they are

associated with a significant increase in investment. This result highlights the importance of the overall coherence of the general regulatory environment in supporting investment incentives. Furthermore, the cross-sectional empirical analysis suggests that lower entry barriers encourage investment in the network industries, confirming earlier panel data results by Alesina *et al.* (2005).

The outline of the paper is the following. Section 2 reviews the theoretical arguments with regard to the relation between the regulatory framework and investment in network industries. Section 3 provides an overview of the empirical literature. Sections 4 and 5 discuss the methodology and data. Finally, Section 6 presents the results.

2. Investment behaviour under different regulatory regimes

It is well-known that an unregulated monopoly tends to produce lower quantities and charge higher prices than would be required by welfare maximisation. This may imply that the monopolist under-invests in network capacity relative to the social optimum. Furthermore, the monopolist will invest later than is socially optimal because it compares the costs related to its investment only with producer surplus and fully ignores consumers' surplus.

One way of raising social welfare is to introduce competition in network industries that are dominated by a monopolist.[2] However, parts of the vertically-integrated network industries remain natural monopolies and will remain dominated by a single firm because of large fixed costs and economies of scale or scope relative to demand. But even if competition can be introduced in other parts of the industry, the state may want to maintain regulation if market power persists resulting from too few market participants and the small market share of new entrants, especially in the initial stages of liberalisation. Furthermore, when competition is not feasible, appropriate regulatory frameworks can, nonetheless, simulate a competitive environment. The question is, therefore, to what extent these different regulatory regimes influence investment incentives.

Differences in price regulation have often been seen as particularly important in determining investment incentives. While cost-based or rate-of-return regulation is generally thought to bring about over-investment (Averch and Johnson, 1962), incentive price regulation is often considered

2. Liberalisation and competition can bring large efficiency gains in industries with lower economies of scale and scope (such as telecommunications) but efficiency gains may be more limited in the presence of large economies of scope (like in the railway sector) (Newbery, 2003 and Pittman, 2005).

as introducing the risk of under-investment in the longer run (Armstrong and Sappington, 2006). However, this characterisation is too stark as the extent to which a particular regime supports investment depends considerably on the overall set-up of the regime. In this context, the next sub-sections discuss the factors that will result in over- and under-investment.

2.1. Rate-of-return regulation and over-investment

Under rate-of-return regulation, prices are set to account for the production costs of the firm and the margin (the "plus factor") that is allowed by the regulator or agreed on between the regulator and the firm.[3] The "plus factor" can specifically relate to the return the firm is allowed to earn on its capital. This return, often coined "fair" rate of return, should allow the firm to recover investment costs. The prices are adjusted upon the initiative of the regulated firm, the regulator or consumer representatives if production costs increased or decreased after the last regulatory review.

Rate-of-return regulation may encourage the regulated monopoly to over-invest in network capacity and lead to allocative inefficiency. Over-investment occurs if the regulated fair rate of return exceeds the cost of capital leading the regulated monopoly to substitute capital for labour in order to increase profit. At the same time, the high capital-labour ratio will result in a production structure that is not cost efficient (Averch and Johnson, 1962; Takayama, 1969). Over-investment due to high capital-labour ratio will result in higher levels of quality if service quality is a function of capital intensity.[4] More generally, over-investment and the ensuing excess capacity may be used as a strategic tool to deter potential entrants and empire-building managers may be tempted to increase investments because a larger company size results in higher status and material rewards (Starkie, 2006).

2.2. Incentive price regulation and under-investment

The underlying idea of price cap regulation is to simulate conditions of perfect competition by imposing a price cap over the regulatory period adjusted for changes in (exogenous measures of)

3. The costs of a regulated firm can be split into operating costs, the rate of return on the firm's capital, and the depreciation of the firm's capital. In this context, the regulator sets the prices so that expected revenues for the period ahead equals expected operating costs for the next period, the rate of return on the firm's capital plus the depreciation of the capital stock.

4. The over-supply of service quality may be exacerbated when firms anticipate a change from a low-powered (rate-of-return) to a high-powered (incentive) regulatory price regime if they believe that they can continue to provide the same service quality relying on equipment installed before the regime change (Sappington, 2005).

input prices, quality and efficiency targets imposed by the regulator. The possibility that costs and prices can diverge during the regulatory period provides firms incentives to implement cost-reducing investment and innovations aimed at improving operating efficiency to outperform the efficiency target.

Incentive regulation, such as a price cap that does not account for quality changes appropriately, encourages the regulated firm to increase profit by reducing service quality at unchanged prices. And typically, there have been complaints that service quality declined shortly after price caps were introduced.[5] In order to prevent the firm from reaping extra profit by reducing quality, the regulator may wish to adjust the regulated price by some measure of quality.

2.3 Regulatory features affecting investment behaviour

There are a number of additional features of regulation besides the basic pricing regime that can result in under-investment.[6] These include basically, the so-called regulatory asset base, the timing of regulatory reviews and uncertainty about the regulator's actions ('regulatory opportunism').

The regulatory asset base and cost disallowances

The so-called "regulatory asset base" or "rate base" is a critical regulatory parameter, which constitutes the base for the calculation of the rate of return. If the rate base includes all assets of the firm, the firm may be tempted to invest imprudently. To avoid this problem, regulators may select investments that they allow to be included in the rate base.[7] Such "cost disallowances" may lead firms to cut back or reschedule investment plans (Guthrie, 2006). If the regulator assesses a firm's investment *ex post* rather than *ex ante*, it will use information that was not available at the time the investment decision was made. Consequently, the regulator may not allow the inclusion of the whole investment to the rate base.

5. This has been reported in the United Kingdom and the United States' telecommunication sectors, for example (Laffont and Tirole, 2001)

6. Other factors, not considered here, that can influence investment include difficulties in obtaining environmental licenses and planning permission or complying with health and safety requirements.

7. While this is primarily a concern for rate of return regulation, the regulator may take into account planned investment during regulatory price reviews in incentive price regulation. For example, Hern (2001) reports that the water regulator in the United Kingdom allowed generous capital expenditure programmes until 1999, at which point it set more ambitious efficiency targets with lower implied rate of returns.

A regulated firm that faces possible cost disallowance because the regulator relies on *ex post* information will be more prudent and will pick only those investment projects that are subject to low future shocks. In particular, a long time lag between the decision and the completion of an investment project makes investment vulnerable to future shocks. Hence, investors will act with caution in selecting projects with long lead time and smaller projects involving less sunk costs will be chosen over large projects that offer economies of scale. Industries with fast technological progress are also more likely to be hit by demand shocks and by a fall in capital costs. Therefore, an *ex post* evaluation of investment by the regulator would make incumbents in these sectors overly cautious.

Timing of the regulatory review

When the regulatory cycle is sufficiently long relative to investment, firms will invest to benefit from cost-reducing investments in the case of incentive price regulation and because all costs are passed onto consumers under rate-of-return regulation. If the firm can choose the timing of the investment and if the timing of the regulatory reviews is exogenous, the firm will invest after the regulatory review to maximise payoff. The closer to the next review, the more likely that investment will be delayed until after the beginning of the next regulatory period and only then will the firm seek to lower costs. If prices are reviewed in reaction to the profitability of the firm operating under rate-of-return regulation, the firm will refrain from implementing investments as the firm's rate of return approaches the upper bound. Instead, it will invest right after the review when the rate of return is reset.[8] When the regulatory cycle is too short, firms operating under a price cap regime will not be able to benefit from improved efficiency and will have less incentive to invest. Under price caps, regulatory reviews are often scheduled every 4 to 5 years. Industries subject to comparatively slow technological progress and a low-volatility environment such as the water industry can have longer review periods of eight years with an option to request an early review (Guthrie, 2006).

8. Rate-of-return regulation could be viewed as a system where the rate of return of the regulated firm fluctuates in a range. If the actual rate of return drops below the "fair" rate of return, the firm will request a review for an upward price adjustment, whereas if the firm's profitability increases beyond the "fair" rate of return, well-organised consumers may request a review to decrease prices or the regulated firm itself can ask for lower prices in anticipation to the consumers' reaction. As a result, the realised dates of reviews are determined endogenously as a function of the firm's profitability (Joskow, 1974). Endogenous timing has the advantage for the firm that it can shift some of the risks onto consumers by requesting an early review if cost shocks arise.

The regulator's decision making and uncertainty

The move from rate-of-return to incentive price regulation shifts risk from consumers to shareholders and consequently raises the cost of capital for the regulated firm. The implications are that if the regulated firm is not allowed to earn a return on its capital that incorporates the higher risk (the implicit rate of return determined by the price cap), it will not invest in new assets (Alexander and Irwin, 1996). This risk would be exacerbated in cases when the regulator is unduly influenced by politicians or the public and may be tempted to set prices or the rate of return too low. Obviously, the regulated firm may choose to reduce investment faced with the risk that its rate of return on investment may be seriously constrained. This may further discourage high-return and, thus, more risky investments.

Uncertainty about the regulator's actions poses a non-negligible threat to investment in network industries. If the regulator is unable to make a credible commitment that it will not change prices after the firm invests, the firm will tend to under-invest.[9] The regulated firm may either delay investment or invest sequentially to see the outcome at the next regulatory review. Regulatory uncertainty does not only generate under-investment but will also affect the composition of the investment, as the regulated firm may choose a technology with lower fixed costs (Spiegel, 1996). The regulated firm can also react to the lack of commitment by issuing more debt. A rise in the regulated firm's leverage (debt-to-equity ratio) increases the probability of future financial distress which may in turn induce the regulator to allow higher prices.[10] However, higher prices may not eliminate the under-investment bias because the firm also faces the risk and costs of bankruptcy stemming from higher leverage (Spiegel and Spulber, 1994).

Under-investment resulting from regulatory uncertainty can be mitigated by establishing independent regulatory bodies.[11] For example, credibility can be achieved through financial, political and institutional independence from the government while being accountable to a mandate. This can enhance the time consistency of policy and minimise uncertainty about future actions. This sort of regulatory uncertainty can also be alleviated by implementing *ex ante* profit

9. The academic literature often uses the term "regulatory opportunism" to define this kind of regulatory behaviour.

10. For instance, Bradley, Jarrell and Kim (1984) and Bortolotti *et al.* (2007) report evidence that regulated firms have high debt to equity ratios in the United States and in Europe.

11. This is similar to the problem of a central bank that seeks to reduce inflation but that cannot fully commit itself to its final objective (Kydland and Prescott, 1977; Stern and Trillas, 2003).

sharing schemes that stipulate that the regulated firm must pay back part or the totality of the excess profit to consumers.[12]

Regulatory uncertainty may not be fully eliminated, however. For example, under incentive price regulation the potential efficiency gains may not be fully exploited if the regulated firm faces the risk that the regulator would impose price caps at the next regulatory review which are partly based on its past performance.[13] Under rate-of-return regulation, what is included in the regulatory asset base is likely to be a persistent area of uncertainty for the regulated firm.

Implications for the different pricing regimes

In sum, the differences in investment behaviour between rate-of-return and incentive price based regulation can rest on features of the regulatory regime. As firms under rate-of-return regulation are comparatively unresponsive to changes in demand, the regulator needs to play an important role in determining what investment is needed. Furthermore, due to the inherent tendency of investment being allocatively inefficient there will always be a conflict between the firm and the regulator over what is included in the regulatory asset base. To some extent, this conflict will be *ex post* and regulatory decisions may not adequately reflect *ex ante* risks. In this light, the regulator needs to be well informed to minimise allocative inefficiency and ensure that investment is sufficiently reactive to changes in demand and technology. By contrast, firms operating under incentive price regulation regimes will have higher levels of allocative efficiency and will have incentives to invest in cost-saving technology. Such firms, however, face higher *ex ante* market-driven risk, which -- other things being equal -- requires a higher rate of return. To the extent that regulatory risk and uncertainty are present (driven by the timing of the reviews and changes to the implicit rate of return during pricing reviews, for example), investment will also be affected. Regulatory uncertainty and risk can be potentially mitigated by granting the regulator independence and a suitable mandate.

12. Profit sharing was introduced in 1987 in the US telecommunication sector and by 1993 almost half of US states adopted this regime (just to switch to price cap from the mid-1990s). Under profit sharing, several rates of return may be specified. Below a given rate of return (for instance 10%), the regulated firm can keep all profits, for a range of rates of return (for instance between 10% and 15%), it can retain part (for instance 50%) of the profits, whereas above a specific level (for instance 15%), excess profit has to be disbursed to consumers. Threshold rates of return, the shares to be paid above the threshold and the regularity with which profit rates are monitored have implications on the extent to which profit sharing reduces or increases incentives for cost efficiency and investments (Greenstein, McMaster and Spiller, 1995).

13. This is known as the 'ratchet effect' which creates an upper bound on the regulated firm's efficiency gains (Freixas, Guesnerie and Tirole, 1985) and lowers the firm's cost-reducing investment.

3. Empirical evidence

Rail

Some of the problems following the liberalisation in the 1990s of rail tracks in the United Kingdom have been blamed on massive under-investment. A more detailed analysis of the underlying figures suggests however no systematic under-investment in comparison with the previous system at the sectoral level. Pollitt (2000) finds that in constant 1995 prices between 1981 and 1995 investment increased significantly in British Rail (as well as in airports and in the water industries, while no significant changes took place in telecommunications, electricity and gas industries). Investment in rail transportation did not drop but rather increased in 1999 following privatisation in 1997. Furthermore, the investment rate was high in historical terms after privatisation (compared to the 1970s and 1980s) and the introduction of incentive regulation (Clark, Elsby and Love, 2001).[14] Overall, incentive regulation did not appear to cause a major disruption in sectoral investments of the regulated sectors. The overall investment figures in the British railway sector until 1999 mask, however, a steady increase in investment in the railway network and a fall in investment in rolling stock (Affuso and Newbery, 2000).[15]

Telecommunications

There are a number of studies that show a strong positive relationship between investment and incentive price regulation in the US telecommunication industry. For instance, Ai and Sappington (2002) note that past research has shown that incentive regulation was more powerful than traditional rate-of-return regulation during the late 1980s and early 1990s for the deployment of

14. Measuring investment at constant prices or as a percentage of GDP may not appropriately capture the quality dimension of investment. For instance, Clark, Elsby and Love (2001) show that while being stable over the 1980s, total investment in roads in the United Kingdom picked up between 1990 and 1994 and then sharply declined from 1994 to 1999, in part because road maintenance became more efficient over time. Kinnunen (2006) argues that the decline in real investment in Finnish electricity distribution after liberalisation is not necessarily an indication of lower volumes of physical investment. The same amount of network can be built at lower cost if new technology or the implementation of it becomes less costly.

15. Affuso and Newbery (2000) point out two possible reasons for a decline in rolling stock investment. First, contracts awarded to the train operation companies shorter than the lifetime of the rolling stock discourages investment. Second, in accordance with real option theory, train operators may postpone investment in the face of uncertainty with regard to future demand. Affuso and Newbery (2000) analyse the determinants of discretionary investment (investment other than committed to the regulator) of 25 train operators between 1997 and 1999. Their estimation results indicate that shorter contracts promote discretionary investment and that higher demand uncertainty and higher profits are positively correlated with discretionary investment.

new technology. They then demonstrate that different forms of incentive regulation helped encourage the deployment of fibre optic cable during the 1990s. However, the different forms of incentive regulation they considered were not generally more conducive to raising overall investment relative to firms operating under rate-of-return regulation.[16] Greenstein, McMaster and Spiller (1996) also find strong econometric evidence in favour of the investment promoting effect of price cap regulation in the US telecommunication sector. In particular, when controlling for local demographic and economic factors, firm-specific financial indicators and the general regulatory environment, the authors unravel that investment in fibre-optic cable deployment, ISDN and software updates during the late 1980s and early 1990s was substantially higher under price cap regimes. They estimate that in the United States at the end of the period under study, fibre-optic cable deployment would have been by 75% higher if price cap regimes had been in place everywhere.

A two-way causal link seems to exist between the incumbent's and facilities-based entrants' decisions to deploy fibre ring in the same city (Woroch, 2000).[17] On the one hand, incumbents react swiftly to the deployment of fibre rings by new entrants. This can be interpreted as a predatory response or because new entry is viewed as signalling new profit opportunities. On the other hand, new entrants invest in their own network as a result of the incumbent's investment decisions. Furthermore, the estimation results reveal that the incumbent's level of investment does not depend on the regulatory policy with regard to the access of their network by new providers whilst new entrants invest more if they can access the incumbent's network.

Other evidence is less supportive of the role of incentive regulation in promoting the deployment of new technology. For example, Floyd and Gabel (2003), using a cross sectional dataset for 2001, find that some types of incentive regulation are associated with both lower and higher investment rates for four kinds of new technologies, relative to rate-of-return regulation.[18] To some extent, these findings may also reflect other differences in the regulatory regime. For instance, empirical evidence for the US telecommunication sector suggests that regulators tend to

16. The results of Ai and Sappington (2002) also provide some weakly significant and not very robust evidence that incentive regulation and competition may reinforce each other's effect on investment. Their approach controlled for multi-collinearity in a large pool of possible explanatory variables and they accounted for potential endogeneity of the regulatory regime.

17. The sample contains firm level data concerning 128 US cities from 1983 to 1992.

18. The types of new technologies were packet switching, digital signal 1, digital signal 3 and optical carrier.

set lower access prices and more liberal entry conditions in price-cap regimes than in rate-of-return regimes (Lehman and Weisman, 2000).

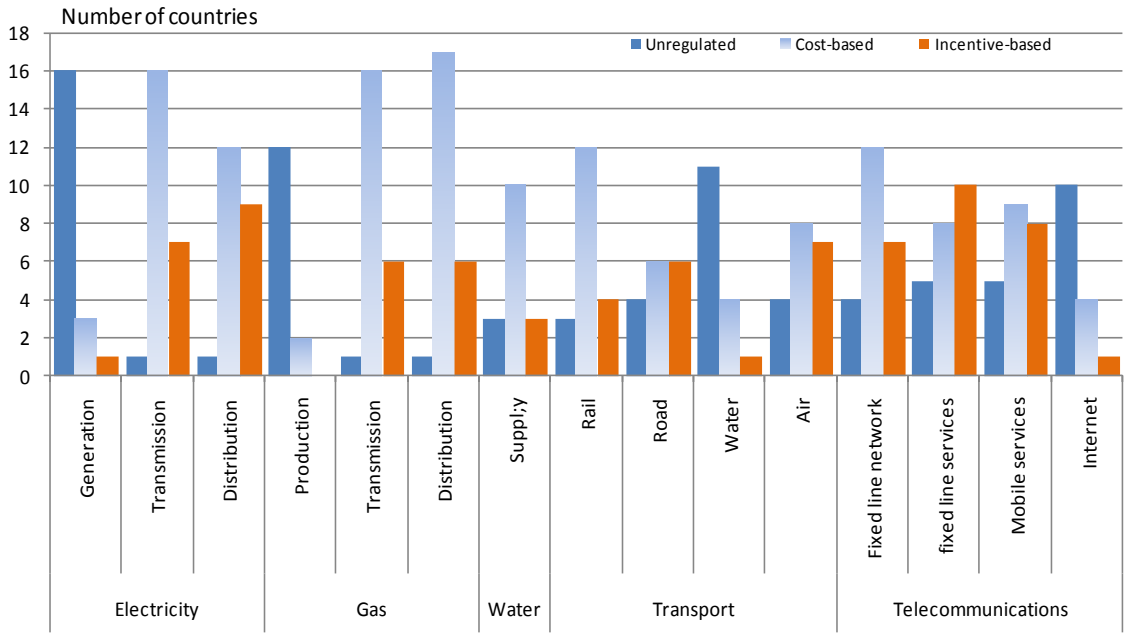
We contribute to the literature in the remainder of the paper by looking at the impact of the regulatory regime and regulatory independence on sectoral investment in selected OECD countries. We first describe our data and our empirical model, then go on by presenting our estimation strategy and finally present the estimation results.

4. Data issues and testable relationships

The primary interest of the empirical work lies in assessing the impact of the regulatory setup on investment decisions in: electricity, gas and water supply; road, rail, water and air transportation; and telecommunications. Information on the type of regulatory regime and the independence of the sectoral regulator was derived from ad hoc surveys concerning infrastructure regulation and investment in OECD member countries (see Annex). Regulatory regimes are divided into three broad categories: cost-based regulation (rate of return regulation), incentive price regulation; and no regulation (or where pricing has been deregulated).

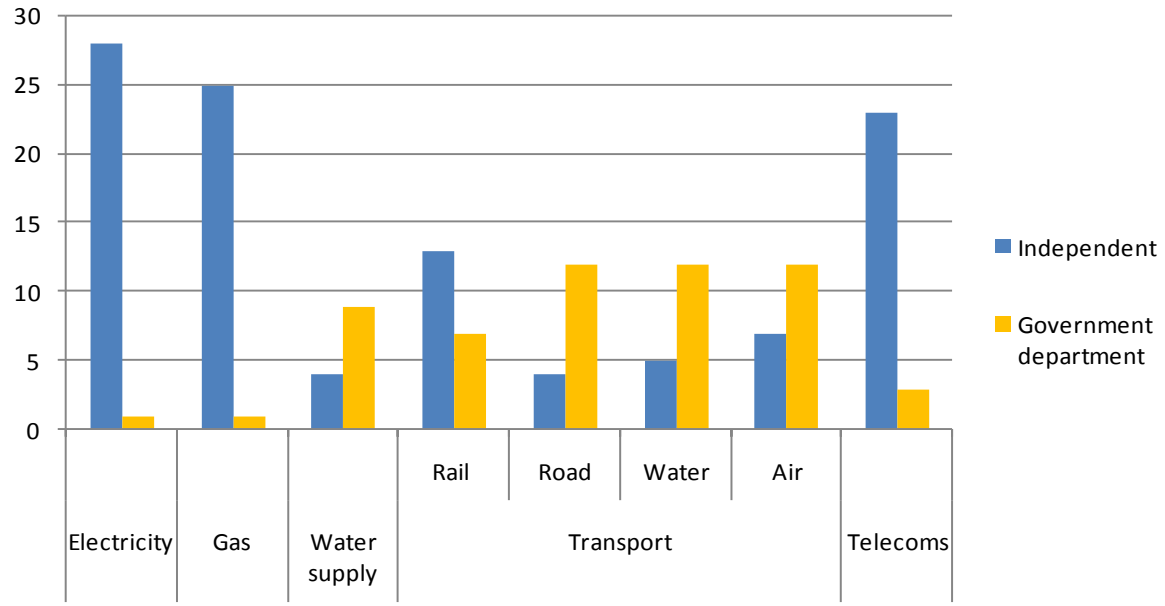
Questionnaire responses indicate that cost-based regulation is the most popular form of regulation (Figure 1). Out of the 15 sectors covered, nine sectors are dominated by cost-based regulation, four sectors are mostly deregulated (electricity and gas generation, water transportation and internet services), while incentive regulation is the most popular form of regulation in fixed line telecommunications services. Furthermore, incentive regulation has a non-negligible role in other seven sectors (electricity and gas transmission and distribution, road and air transportation and fixed line networks).

Figure 1. Regulatory regimes (late 2007 or early 2008)



Source: OECD infrastructure questionnaire responses

Figure 2. Regulatory independence (late 2007 or early 2008)



Source: OECD infrastructure questionnaire responses

Figure 2 shows that regulators are overwhelmingly independent in the electricity, gas and telecommunications sectors, while regulators tend to be part of government agencies or ministries in transportation and in the water industry. Two measures of regulatory independence were constructed. The first was whether the regulator was independent of the government. The second measure was a gauge of *de facto* independence assessing the extent to which the executive can influence the regulator's decisions and operation (using responses from the OECD infrastructure questionnaire).[19] The two variables are not significantly different. The type of price regulation regime was interacted with the regulator's independence variable to see whether complementarities between them matter for sectoral investment.

As questionnaire responses only provide a snapshot of regulation in late 2007 and early 2008, the data on the type of regulatory regime do not have a time dimension. For this reason, only cross-sectional regressions are carried out in the analysis (with sectoral investment being the dependent variable). The regulatory variables include variables capturing the presence of incentive regulation (inc), the absence of any price regulation (dereg) (unregulated or deregulated), the presence of an independent sector regulator (ri), and an interaction term of incentive regulation and regulatory independence (inc*ri). The other explanatory variables are lagged investment (I_{t-1}), long-term real interest rate (r) deflated with sectoral deflators, and variables capturing the general regulatory environment: entry barriers ($entry$)[20] and public ownership (po).[21,22] As a result, a linearised version of the following investment function was estimated:

$$I = f(I_{t-1}, r, entry, po, inc, dereg, ri, inc * ri) \tag{1a}$$

Investment data are obtained from the OECD's STAN and SNA (Sectoral National Accounts) databases. These two databases have two serious shortcomings. Firstly, the level of

19. The *de jure* measure of independence was adjusted for the possibility of the executive overruling the regulator's decisions. The *de facto* measure of independence was calculated as the average of the *de jure* independence and the possibility of overruling.

20. The definition of entry barriers differs across sectors to reflect sector-specific characteristics. For more details, see Conway and Nicoletti (2006). The data can be downloaded from:

http://www.oecd.org/document/32/0,3343,en_2649_34323_35791136_1_1_1_1,00.html

21. Entry barriers and public ownership were used in Alesina et al (2005) who performed a panel data analysis of sectoral investment.

22. The dependent and explanatory variables are averages for 2001-2006, except the two variables capturing the regulatory regime (inc and dereg). In addition, the explanatory variables are included with a lag of one period (using averages for 1995 to 2000), except inc and dereg.

disaggregation is limited to three broad categories: first, electricity, gas and water supply; second, transportation (road, rail, water, air and associated storage); and third, telecommunications (which also includes postal services). Secondly, capital stock data needed to calculate the investment-to-capital stock ratio are available only for a limited number of OECD countries and are not fully comparable across countries. In principle, one could compute capital stock series using investment flows and the perpetual inventory method, but these estimates are extremely sensitive to the underlying assumptions. Given long asset lives, one often still needs an estimate of the value of the capital stock to anchor the series, which is not readily available. As a result, sectoral value added is used instead to construct an investment to value added ratio at the sectoral level. Overall, the sectoral dataset covers 13 countries for the three sectoral aggregates.

5. Estimation method: Bayesian averaging of classical estimates

The main empirical approach is Bayesian averaging of classical estimates of the possible explanatory variables (*e.g.* as applied to growth regressions in Sala-i-Martin *et al.* 2004). For comparison purposes, results of OLS estimates are also reported. Bayesian averaging is a comprehensive analytical tool to check the extent to which any given explanatory variable improves the explanatory power of the estimated models when it is included. In other words, it investigates the probability with which any given variable would be included in the estimated models. This approach requires the estimation of all possible combinations of the candidate explanatory variables (of number K) that is 2^K.

Bayesian averaging of classical estimates (BACE) first determines the (estimated) posterior probability attributed to each single model M_i including a given variable, conditioned on the underlying dataset y ($P(M_i|y)$).

$$P(M_i|y) = \frac{P(M_i)T^{-k_j/2}SSE_i^{-T/2}}{\sum_{i=1}^{2^K} P(M_i)T^{-k_i/2}SSE_i^{-T/2}} \qquad (2a)$$

where SSE is the sum of squared residuals, T is the number of observations, k denotes the number of explanatory variables included in the specific model and K is the number of all explanatory variables considered. Expression (2a) shows the extent to which any given model contributes to explaining the dependent variable as compared to the other models. Expression (2a) is then

summed up for the models that contain the variable of interest to obtain the posterior inclusion probability of this variable.

$$P(X_m|y) = \sum_{j=1}^{n} \frac{P(M_j)T^{-k_j/2}SSE_j^{-T/2}}{\sum_{i=1}^{2^K} P(M_i)T^{-k_i/2}SSE_i^{-T/2}} \tag{2b}$$

Where $P(X_m|y)$ is the posterior inclusion probability of a given variable. j denotes the models that include variable X_m and n equals $2^K/2$. If the posterior inclusion probability is higher than the prior inclusion probability, one can conclude that the specific variable should be included in the estimated models. Since here all possible combinations of the explanatory variables are estimated, the prior inclusion probability is 0.50.

The posterior mean conditional on inclusion ($E(\beta|y)$) is the average of the individual OLS estimates weighted by $P(M_j|y)$. The unconditional posterior mean considers all regressions, even those without the variable of interest. Hence, the unconditional posterior mean of any given variable can be derived as the product of the conditional posterior mean and the posterior inclusion probability. The posterior variance of β ($Var(\beta|y)$) can be calculated as follows:

$$Var(\beta|y) = \sum_{j=1}^{2^K} P(M_j|y)Var(\beta|y, M_j) + \sum_{j=1}^{2^K} P(M_j|y)(\hat{\beta}_j - E(\beta|y))^2 \tag{3}$$

The posterior mean and the square root of the variance (standard error) conditional on inclusion can be used to obtain t-statistics and to determine the significance of the individual variables upon inclusion.

Model averaging is vulnerable to the violation of the basic assumption of homoscedasticity and to the presence of outliers (Doppelhofer and Weeks, 2008). Thus White's heteroscedasticity-corrected standard errors are used not only for the full sample but also for sub samples that exclude one country at a time. This makes it possible to evaluate the impact of individual countries on the robustness of the results and to eliminate potential outliers.

6. Empirical Results

OLS regressions results obtained for the 13 countries with three sectoral aggregates each show that lagged investment, barriers to entry and the interaction term including regulatory independence and incentive regulation are significantly correlated with contemporaneous investment (Table 1).[23] Barriers to entry are found to influence investment negatively. The coefficient estimate of -0.046 indicates that a one step reduction in the barriers to entry indicator would be associated with a 4.6% increase in the investment ratio.[24] The combination of regulatory independence and incentive price regulation has a significant positive effect on investment, though when taken separately the two policy variables do not have any significant effect on investment. This suggests that a right policy mix is important in determining investment.

Table 1 reports the main results for the different regulatory variables using Bayesian model averaging. If both country and industry fixed effects are used, the most robust findings are that for the whole sample and all sub-samples (where one country at a time is dropped) posterior inclusion probabilities are always higher than 0.50 in the case of entry barriers and the interaction term combining incentive regulation with regulatory independence. Moreover, the size of the estimated coefficient is similar to that of the OLS estimate. Table 1 also indicates that in the cross section under consideration public ownership is not an important driver of investment rates and that the absence of price regulation tends to lower investment. Yet this latter result is not robust to changes in country coverage, since it vanishes once the United States is dropped from the sample.

The size of the coefficient estimates for the different subsamples suggests that on average a 1 step change in the interaction term (*e.g.* a change from 1 to 2) would induce an average increase of the investment ratio by 4.9 percentage points. The lowest and highest coefficient estimates give a lower and upper bound of the increase in the investment ratio of respectively 1.6 percentage points and 6.5 percentage points. A move from the bottom to the top in the observed distribution of the interaction term -- from 0 to 4.5 -- would on average increase the investment ratio by 22.2 percentage points, with the lower and upper bounds being 7.2 percentage points and 29.3 percentage points.

23. The estimations use both country-fixed effects and then country- and industry-fixed effects as well as the explanatory variables lagged one period. An exception is the variable capturing incentive regulation because observations are only available for the most recent period.

24. This finding is broadly in line with results reported in Alesina *et al.* (2005). Using panel data estimation methods, Alesina *et al.* (2005) find that the coefficient estimate for the barriers to entry variable is around -0.01.

Table 1. **Estimation results, sectoral investment data**
with country and industry fixed effects

	OLS		**Bayesian model averaging**		
	Coefficient	p-value	posterior inclusion probability	posterior mean conditional on inclusion	posterior standard error conditional on inclusion
Lagged investment	**0.865**	**0.000**	**1.000**	**0.880**	0.166
Real interest rate	0.009	0.130	0.654	0.006	0.003
Barriers to entry	**-0.046**	**0.008**	**0.998**	**-0.043**	0.012
Public ownership	0.004	0.701	0.151	0.000	0.002
Regulatory independence	-0.026	0.556	0.184	-0.004	0.006
Incentive regulation	-0.003	0.866	0.141	0.000	0.002
No price regulation	-0.016	0.133	0.975	-0.015	0.008
Independence and incentive regulation interaction term	**0.060**	**0.002**	**0.996**	**0.053**	0.014
Adj. R-squared	0.741				
Regressions run			256		
Prior inclusion probability			0.5		

Note: posterior inclusion probability measures the extent to which any given model contributes to explaining the dependent variable as compared to the other models. Bold figures for the posterior inclusion probability indicate that it is higher than the prior inclusion probability of 0.5. The posterior mean conditional on inclusion is the mean of the individual OLS estimates weighted by the posterior inclusion probability of the individual models including a given variable.

7. Concluding remarks

This paper studied the impact of the regulatory setup on sectoral investment in network industries. Earlier empirical literature suggested that shifting away from traditional rate-of-return regulation did not generally cause under-investment in network industries. For instance, overall investment in the UK railway sector did increase in the aftermath of privatisation and the introduction of incentive regulation. Empirical studies also highlighted that incentive regulation was very helpful in promoting the deployment of new technologies in the US telecommunications sectors in the late 1980s and early 1990s.

The empirical results in this paper based on cross-section OLS regressions and on Bayesian model averaging suggest that the introduction of incentive price regulation or the establishment of an independent sector regulator do not have a positive influence on investment by themselves. However, once these policies are implemented jointly, they are associated with a significant increase in investment. This result highlights the importance of the overall coherence of the general regulatory environment in supporting investment incentives. Furthermore, the empirical results show that lower entry barriers encourage investment in the network industries.

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ANNEX: Data description

The dependent and explanatory variables are averages for 2001-2006, except the two variables capturing the regulatory regime (inc and dereg). In addition, the explanatory variables are included with a lag of one period (using averages for 1995 to 2000). For the averages, the data series for barriers to entry and public ownership stop in 2003. The other data series end in 2005 or 2006.

Dependent variable

Sectoral investment: investment series in current prices over gross value added in current prices. The use of current prices avoids problems arising from changes in quality and in composition. Data for three sectors are collected: 1.) electricity, gas & water, 2.) transport (including water, road, rail and air transport and storage), 3.) telecommunications. The primary source of the data is the OECD's STAN database (in places complemented by the EU-KLEMS database)

Regulatory indicators

Barriers to entry and public ownership: the source of the data is the OECD's ETCR database. For the energy sector, a weighted average using sectoral gross value-added is calculated using data for electricity, gas and water. For the transport sector, an arithmetic average is computed using data for rail, road and air transportation. The series take the values from 1 to 6. Higher values indicate higher barriers to entry and higher public ownership.

Regulatory independence source: responses to questionnaires sent out to OECD governments. The variable takes the value of 1 if the regulator is independent and takes zero if there is no regulator, or the regulator is a government agency. Data for subsectors are averaged to get the sectoral figures as for barriers to entry and public ownership. The values are not exclusively 0 and 1 because of the averaging.

Incentive regulation source: responses to questionnaires sent out to OECD governments. The variable ranges from 0 to 6. For the energy sector, it is calculated as a weighted average using sectoral gross value-added for electricity, gas and water. For each subsector, the variable can take the value of 0 (no incentive regulation) or 1 (presence of incentive regulation). The averages are multiplied by 6 to achieve the scale of 0 to 6. For the transport sector, an arithmetic average is computed using data for rail, road and air transportation in a similar manner. The variable is obtained the same way for the telecommunication sector using information for the four subsectors: fixed line network, fixed line services, mobile phone, and internet.

Absence of price regulation source: responses to questionnaires sent out to OECD governments. The variable ranges from 0 to 6. The construction of this variable corresponds to that of incentive regulation. The subsector-level dummy variable takes the value of 1 if there has never been price regulation or if prices has been fully deregulated, and 0 otherwise.

Controls

Real interest rate source: AMECO of the European Commission and STAN. Long-term nominal interest rates (i) deflated by past annual changes in the sectoral deflator (ddef) drawn from the Stan database. The annual inflation rate is obtained as ((1+i)/(1+ddef)-1)*100.

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