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Does ownership matter? The performance and efficiency of State Oil vs. Private Oil (1987–2006)

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ABSTRACT

This paper investigates the existence of ownership effects in the global oil and gas industry, i.e. whether there are systematic performance and efficiency differentials between National Oil Companies (NOCs) and privately owned International Oil Companies (IOCs). After discussing key issues of comparing 'State Oil' and 'Private Oil', I summarise important trends emerging from the dataset, which covers 1001 firm observation years over the period 1987–2006. Using panel-data regression analysis it is shown that NOCs significantly underperform the private sector in terms of output efficiency and profitability. They also produce a significantly lower annual percentage of upstream reserves, although this may not be an indication of firm efficiency. Overall, this paper suggests that a political preference for State Oil usually comes at an economic cost.

1. Introduction

In July 1913, as Europe was already sliding towards war, the First Lord of the British Admiralty, a young Winston Churchill, set out the importance of oil to the nation: "If we cannot get oil, we cannot get corn, we cannot get cotton and we cannot get a thousand and one commodities necessary for the preservation of the economic energies of Great Britain" (cited in Yergin, 1991, p. 160). Churchill considered security and diversity of oil supply to be of utmost importance—to achieve them the state could enter into long-term supply contracts as a temporary measure, but ultimately "the Admiralty should become the independent owner and producer of its own supplies of liquid fuel" (ibid). In 1914, the British government therefore acquired a controlling stake in the Anglo-Persian Oil Company, later renamed BP, setting a precedent for the many other state-owned or 'National Oil Companies' (NOCs) to follow. For there were many governments around the world that deemed energy "too important to be left to the market" (Robinson, 1993, p. 57).[1]

The UK government of course famously changed its course in the late 1970s and initiated a worldwide move towards market liberalisation and privatisation. Until not too long ago, a one-way road seemed to lead towards these policies – in 1999 the Chief Economist at Royal Dutch/Shell predicted that all NOCs would be privatised by the year 2040 (Klein, 1999) – but high energy prices, recent asset nationalisations and the apparent economic success of some producing states' NOCs have re-ignited the debate. To some, direct state control over resources is an indispensable feature of national sovereignty and political decision-making (Mommer, 2002). To others, it remains an article of faith that public ownership results in lower economic efficiency, and that possible market failures should be addressed through regulation instead (Shleifer and Vishny, 1998).

In this paper I use a comprehensive dataset of oil and gas companies, covering both privately and publicly owned firms over the period 1987–2006, to investigate whether ownership matters in economic terms, i.e. whether over the past two decades 'State Oil' or 'Private Oil' have shown superior performance and efficiency. If there exists a trade-off between economic outcome and socio-political considerations, the result can be used to quantify the economic cost of such trade-off. Direct comparisons between public and private companies are often complicated by structural differences between them (e.g. operational profile, non-commercial objectives, or the underlying geological asset quality), and previous oil sector research has not adequately controlled for such factors. The econometric analysis in this paper seeks to advance this issue by using a wider range of explanatory variables and by exploiting the panel structure of the data, although lack of disclosure by many firms and countries remains a key obstacle.

The remainder of this paper is structured as follows: Section 2 briefly reviews previous studies on ownership effects; Section 3 discusses potential structural differences between State Oil and Private Oil companies; Section 4 introduces the data source for the empirical analysis and – using descriptive statistics of the data content – provides a corporate perspective onto the changing

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[1] 'State' and 'government' will be used interchangeably in this paper.

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structure of the industry over the past two decades; Section 5 sets out the methodology for the panel regression analysis; Section 6 presents the results; Section 7 concludes.

2. Literature review: the impact of state ownership

Much has been written on the relationship between state ownership and corporate performance ever since Adam Smith observed that "characters do not exist who are more distant than the sovereign and the entrepreneur" (Smith, 1776, p. 771). The theoretical literature includes prominent strands of mainstream economics such as agency theory (Williamson, 1964; Jensen and Meckling, 1976; Fama, 1980), property rights theory (Alchian, 1965; Alchian and Demsetz, 1972), public choice theory (Olson, 1965; Niskanen, 1971; Buchanan, 1978), and theories of regulation (Averch and Johnson, 1962; Stigler, 1971). There have been exhaustive summary reviews (Vickers and Yarrow, 1988; Laffont and Tirole, 1993; Perotti, 1995; Pollitt, 1995; Shirley and Walsh, 2000; Megginson and Netter, 2001), most of which do not find conclusive arguments in favour of either state or private ownership. The latter seems more efficient in competitive markets without natural monopolies, externalities, or provision of public goods, but Stiglitz (2007) reminds us that such conditions are rarely found in practice.

A large body of empirical literature exists to investigate the existence and magnitude of ownership effects, i.e. inherent differences in performance and efficiency due to different levels of state ownership.[2] In a heavily cited paper Boardman and Vining (1989), examining the 500 largest non-US industrial companies in 1983, find that private firms significantly outperform both state-owned and mixed-ownership firms, but find no material differences between the latter two. In a later study the same authors (Vining and Boardman, 1992) use a sample of Canadian companies and find private firms superior to mixed firms, which in turn outperform state-owned enterprises (SOEs). Dewenter and Malatesta (2001) research the 'Fortune 500' largest international companies for the years 1975, 1985 and 1995. Controlling for firm size, location, industry, and business-cycle effects, they find private firms significantly more profitable, less labour-intensive and exhibiting lower levels of financial leverage than SOEs. Contrary to these results, studies including Caves and Christensen (1980) and Martin and Parker (1995) find no inherent superiority of private firm performance. Instead, these studies argue that competition in the product market is the key determinant of firm efficiency. Pollitt (1995) examines ownership effects in the electricity industry, and finds positive long-run results for private firms in power generation, but no comparable findings for short-run generation costs, or for transmission and distribution functions.

Overall, whilst a convincing majority of empirical studies finds evidence in favour of private ownership (Megginson and Netter, 2001), Villalonga (2000) points out that some of these studies are not fully convincing on an individual level as the comparisons are impaired by methodological difficulties. The choice of the appropriate measurement variable is one such issue, another is the fact that there are "interacting (non-separable) effects of ownership, competition and regulation" (Vickers and Yarrow, 1988, p. 39). Furthermore, it is often difficult to find appropriate groups of firms to compare—in many countries or sectors there exist only a small number of truly comparable companies, if any, under either form of ownership. Also, ownership itself might be endogenous i.e. subject to and the result of a system that includes both political and performance goals (Megginson and Netter, 2001). The judgement on the severity of these limitations is to some extent in the eye of the beholder, which is why different reviewers of the literature have come to different conclusions as to general direction of findings.[3]

Contrary to the large number of ownership studies in general, there is limited research so far specifically on the oil and gas industry. Al-Obaidan and Scully (1991) study efficiency differences between 44 international private and state-owned petroleum companies. Controlling for multi-nationality and operational integration, they find that state-owned enterprises are, on average, only 61–65% as technically efficient as private firms. Eller et al. (2007) use non-parametric Data Envelopment Analysis (DEA) as well as parametric Stochastic Frontier Analysis on a sample of 80 firms for the period 2002–2004. They calculate an average DEA technical efficiency score for NOCs of 0.27, compared to a sample average of 0.40 and an average score for the five biggest private companies of 0.73. Controlling for structural firm variables such as the degree of state ownership and domestic fuel subsidies moves all firms closer to the efficient frontier—but this might be a mere technical effect of adding additional variables (Adolphson et al., 1991). Based on 90 firms observed in 2004 Victor (2007) uses a single-variate regression to explore the relative efficiency of NOCs and private oil companies. She finds that the biggest private oil companies are nearly one-third better at converting reserves into output, and tend to generate significantly more revenue per unit of output. Victor (2007) concludes that some of the NOCs reserves are effectively "dead oil". My paper can be seen to build on these contributions, but investigates a broader range of issues using a significantly more comprehensive panel dataset.

3. Comparing State Oil and Private Oil

Investigating ownership effects within the global oil and gas industry avoids, or at least mitigates, some of the above-mentioned conceptual concerns of empirical studies: sector-specific effects are automatically controlled for; the global nature of the industry allows international competitors to be used as benchmarks; and public ownership is usually grounded in political motives rather than inherent market failures or financial losses, which rules out important sources of ownership endogeneity. But even within the industry important structural differences exist between firms, and whilst this applies to any firm-level comparison, the lack of disclosure at many NOCs makes it particularly difficult to control for such exogenous factors in a state vs. private setting.

Fig. 1 is a conceptual model of the operating and financial input–output flows at an oil and gas company. Production output can take the form of upstream crude oil or natural gas, refined oil products at the factory gate, and sales of oil products through wholesale or retail marketing.[4] This output is generated by three principal inputs, namely hydrocarbon reserves, investments into operating assets, and employees. In turn, physical production is

[2] A second type of empirical research examines the effects of ownership change (in most cases privatisation) over time (Megginson et al., 1994; Boubakri and Cosset, 1998; Gupta, 2005; Wolf and Pollitt, 2008). Both approaches are closely connected: Superiority of private ownership is a *necessary* condition for the success of privatisation, but not a *sufficient* one, since privatisation processes are dynamic and can include important changes other than ownership, such as political, regulatory and organisational changes (Villalonga, 2000).

[3] To illustrate the degree of subjectivity involved in the interpretation, Villalonga (2000) cites one study (Hirsch, 1965) that has been classified as favourable to state ownership, favourable to private ownership, and as neutral by at least one reputable reviewer each.

[4] Other possible outputs are either assumed to be included in the above (e.g. LNG, LPG, condensate) or excluded (e.g. petrochemicals, trading).

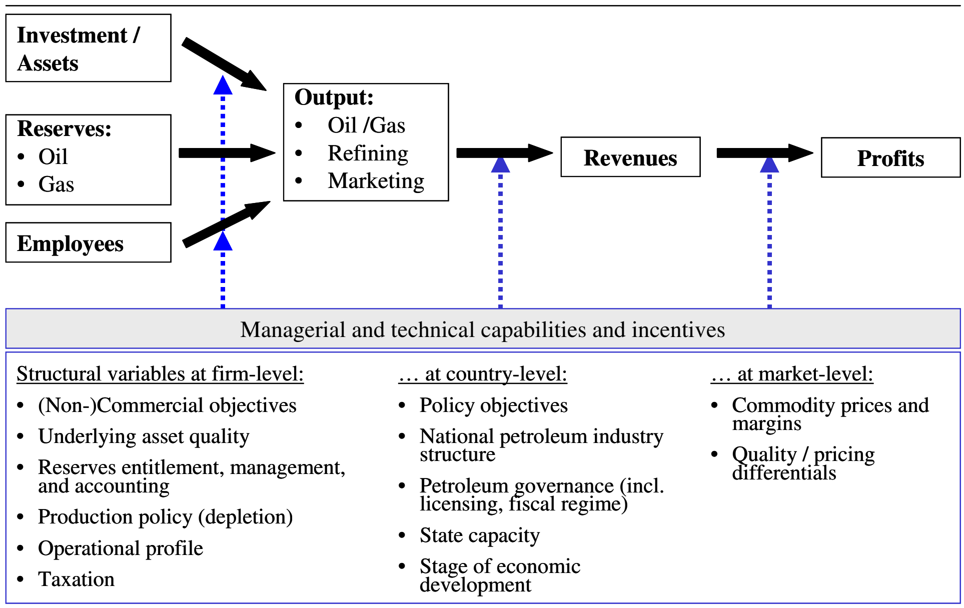

Fig. 1. Oil and gas profit chain (with key influence factors).

the key input to generate revenues and, ultimately, profits. Financial assets and oil and gas reserves are linked, as capital expenditure incurred in the development of upstream reserves is capitalised on the balance sheet as assets (so reserves could also be considered the outcome of capital spending, rather than a complementary input), but total assets also cover other business segments and therefore represent the full scope of the firm. On the downside, total assets reflect accounting rather than economic value, and might be severely distorted by inflation.

Of the oil and gas studies set out above, Al-Obaidan and Scully (1991) look at capital productivity (sales revenues or physical output divided by total assets) and labour productivity (revenues or physical output divided by number of employees). Eller et al. (2007) choose employment and reserves as simultaneous input variables, and revenues as output variable. Victor (2007) analyses the two ratios of physical output over reserves and revenues over reserves.

Ideally, the results of direct performance comparisons between firms would only reflect managerial and technical capabilities and incentives; the impact of ownership – which is hypothesised to have a direct bearing on them – could thus readily be measured. But in reality a number of other factors co-determine these performance measures. Fig. 1 lists such influence factors – which can be classified as firm-, country- or market-level – along the various stages of the production chain. I will briefly discuss them in turn, with a focus on the firm-level variables.

3.1. *Non-commercial objectives*

Critics argue that the use of standard performance measures, and profitability in particular, yields distorted results because most SOEs pursue objectives other than profit maximisation (Bozec et al., 2006). But for companies operating in competitive markets Boardman and Vining (1989) maintain that if such posited social benefits are *internal* to the firm (e.g. excess employment), they can only be achieved at a deadweight loss of social welfare; and if the benefits are *external* to the firm (e.g. provision of social infrastructure), then profitability comparisons can at least reveal the shadow prices of these commitments. This argument also applies to the petroleum industry, which is largely free from natural monopoly and thus can easily be run under competitive conditions.

3.2. *Underlying asset quality*

Resource endowments are a powerful determinant of performance of any natural resources industry. Availability of hydrocarbons, ease of access, supply and evacuation infrastructure, flow rates and production costs vary greatly between and within countries. Many NOCs are monopoly players blessed with a favourable resource endowment, but even where public and private firms compete, the state firms often have (historically or by law) preferential access to the most attractive assets, whether upstream fields, refinery plant locations, or retail networks. Of course not all aspects of asset quality are exogenously prescribed by geology or geography—the impact of investment, technology and management is not to be underestimated. Distinguishing one from the other is critical in reaching a final judgement on managerial performance.

3.3. *Oil and gas reserves data*

A number of important issues arise in the interpretation of reserve estimates. First, there might be differences in the legal framework of reserve entitlement. Private oil companies can only "book" equity reserves from successfully acquired licences, most of which are intended for near-future exploration, development and production. NOCs with monopoly powers, on the other hand, sometimes enjoy full entitlement to all reserves within a given area. Second, there is no uniform global approach to the estimation and certification of oil and gas reserves, and some of the various guidelines differ in important aspects.[5] Many NOCs do not follow any such recognised standards, and even some of the

[5] The most widely used are the Society of Petroleum Engineers (SPE) and the U.S. SEC systems, but important others are the Soviet 'ABC' reserve categories or the Canadian NI 51-101 standard. See Mitchell (2004) for a review of some of the differences.

large private IOCs follow the guidelines but do not employ outside reserve auditors to verify their internal assessment.[6] Third, as a consequence of this lack of universal standards, reserves data might be manipulated on political or other grounds (Campbell, 1997). Fourth, even where reserves are properly reported, different policies on reserve management can make comparisons difficult. The development of resources into reserves usually requires upfront investment, which private sector companies are usually unwilling to incur several years before the actual production phase. For a nation state, on the other hand, maximising the domestic reserve base as a signalling tool or policy instrument might well be an appropriate choice, as would indeed be the option to deliberately *delay* the development of the resource base as a hedge against inflation, a bet for higher commodity prices, or an insurance policy for future generations.

3.4. Production (depletion) policy

Eller et al. (2007) and Victor (2007) find NOCs producing a comparatively lower annual rate of reserves, and interpret this as a sign of lower technical efficiency. But at least three different reasons could explain such findings: (1) systematic overstatement of NOC reserves; (2) conservatism based on deliberate policies; or (3) technical and managerial deficiencies. The third case would indeed indicate lower efficiency—lack of capital, infrastructure, trained personnel and project expertise are factors not unheard of in the context of NOCs (Al-Mazeedi, 1992; Gochenour, 1992; Stevens, 2004). But in the first case the lower production rate is a statistical illusion, and in the second the associated welfare consequences might well be positive. The planning horizon for nation states differs from that of private oil companies, which – based on painful experiences – are never fully assured of their long-term property rights. Considerations of global supply and associated prices have always been explicit target variables for OPEC members. High recent oil prices rewarded (with hindsight) every producer that had restrained the production of "cheap" hydrocarbons in the past. Victor's (2007) terminology of "dead oil" in the hands of NOCs is therefore somewhat misleading.[7]

3.5. Operational profile

The various sub-segments of the oil and gas industry (E&P, R&M, petrochemicals) exhibit very different capital and personnel requirements, price volatility, competitive pressures, and ultimately profitability. Between 1996 and 2002, the return on capital employed in the upstream was on average 17.0%, whereas the comparable return for refining and marketing was 10.2% (UBS, 2004).

3.6. Taxation

Total government take from upstream taxation varies between 40% and 90% across the world (Johnston, 2007), leading to great differences in the companies' tax exposure. A number of NOCs operate under separate tax (and funding) rules from foreign participants in the same country—the details of such arrangements might not always be public and often reflect the relative power balance between government and NOC. The picture might be further complicated by monetary transfers between these two parties to account for social provision, fuel subsidies, etc.

3.7. Country-level variables

For monopolistic NOCs national policy objectives and industry structure and governance are essentially congruent with firm-level attributes. For globally operating IOCs such measurements need to be calculated as weighted averages of the portfolio of host nations, which unfortunately is impractical to do for large datasets.[8] State capacity in terms of administrative and regulatory quality is closely correlated with per-capita income (Kaufmann et al., 2005), i.e. the stage of economic development, which has been found to impact on oil company efficiency levels (Al-Obaidan and Scully, 1991).[9] Data on per-capita income is widely available and the link between home nation development and firm-level efficiency can be plausible hypothesised for both NOCs and IOCs, assuming global culture and practices for the latter.

3.8. Market-level variables

Crude and processed petroleum products are assumed to have uniform global prices, although particularly in the downstream this is a simplification. Their use in panel-data analysis thus primarily serves the cause of comparability across time.

When comparing State Oil and Private Oil, as many of these structural variables as possible should be controlled for in order to obtain unbiased measures of performance and efficiency. Unfortunately, many structural variables are either unobservable or, in the case of NOCs, not disclosed to the public. In Section 5 I will discuss how panel-data analysis can go some way of addressing this key methodological issue.

4. Dataset

The main data source for my analysis of ownership effects is the annual ranking of the world's 50 largest oil and gas companies, published as a supplement to the 'Petroleum Intelligence Weekly' (PIW). PIW gathers operating and financial data on over 130 firms. The six operating data categories are oil reserves, gas reserves, oil production, gas production, refinery capacity, and oil product sales volumes; financial data includes revenues, net income, balance sheet assets, as well as number of employees and the level of state ownership. The ranking then features the 50 companies that are top in the equal-weighted sum of the six operating rankings. It is usually published in December, based on the disclosed information of the previous calendar year, and the first ranking dates from 1988. Individual years from this ranking have been analysed before, but this is the first time a full 20-year history has been collected. Operating data is usually available for all companies in the sample, whereas financial indicators for NOCs are often lacking. Revenues, net income, and total assets are converted to US Dollars at average yearly exchange rates.

[6] Pemex reduced its proven reserve estimate from 60 billion barrels in 1997–22 billion in 2002 (−64%), mainly as a result of independent reserve audits according to SEC definition. Royal Dutch/Shell in January 2004 had to reduce its estimate for proven reserves by 20% following an external audit.

[7] But even if deferred production is justifiable on welfare grounds, one might question the implementation of such national policies at the firm level rather than through the licensing system (Al-Kasim, 2006).

[8] Taking a very long-term perspective, the analysis of globally operating IOCs could treat country-level variables are endogenous, because (contrary to NOCs) management has discretion over where to invest.

[9] Per-capita incomes are also negatively correlated with state ownership in petroleum firms ($r^2 = -0.60$ in our sample), but the causality between these three variables (GDP, state ownership, governance) is not entirely resolved (Rigobon and Rodrik, 2004; Sachs et al., 2004; Kaufmann et al., 2005).

Table 1
Operating statistics of 'typical' companies by ownership type.

	O&G reserves			O&G production			Refining capacity		
	1987	2006	CAGR (%)	1987	2006	CAGR (%)	1987	2006	CAGR (%)
Own-1:									
-Mean	36,944	76,137	3.9	997	2602	5.2	489	1017	3.9
-Median	6497	36,396	9.5	704	1827	5.1	456	570	1.2
Own-2:									
-Mean	2985	24,059	11.6	543	2519	8.4	648	986	2.2
-Median	3170	6819	4.1	589	1114	3.4	515	325	–2.4
Own-3:									
-Mean	1682	2794	2.7	404	758	3.4	976	310	–5.9
-Median	1682	1809	0.4	404	489	1.0	976	265	–6.6
Own-4:									
-Mean	3407	7187	4.0	910	1432	2.4	1172	1238	0.3
-Median	1799	4221	4.6	475	730	2.3	580	347	–2.7

Notes: Oil and gas reserves are expressed in millions of barrels of oil equivalent, production and refining capacity in thousands of barrels of oil equivalent per day. In 1987, there was only one company within the 'Own-3' category (see Appendix A for more details).

The original PIW data as described above has been checked for internal consistency across different years and adjusted where necessary. All companies and their home countries have been given unique identifiers over time.[10] The exact percentage of state (voting) ownership has been added and all entries have been grouped according to four distinct ownership types:

- 'Own-1': fully state-owned NOCs, i.e. public ownership of no less than 100%;
- 'Own-2': majority state-owned companies, i.e. public voting ownership in excess of 50%[11];
- 'Own-3': minority state-owned companies; and
- 'Own-4': fully private companies.

Overall, the dataset has 1001 observations (20 years of 50 observations each, plus in 2003 two firms were tied for 50th place): of these, 406 observations are of fully state-owned companies, 127 of majority state-owned companies, 67 of minority state-owned companies, and 401 observations are of fully private firms. Overall, 87 different companies feature in the dataset, but the industry's structural stability is reflected in the fact that 27 companies made the Top 50 in every single year.[12] Of the 87 companies, 23 have always been under full and exclusive state control, 35 firms have always belonged to the private sector, and 28 have seen changes in ownership, i.e. they have been partially or fully privatised.[13] Comparing the years 1987 and 2006, the number of fully private companies in the ranking has remained virtually constant (20 vs. 21), whereas the number of fully state-owned firms has dropped from 26 to 18, and the number of firms with mixed ownership has increased from 4 to 11.

Table 1 highlights the changes in the typical firm size by ownership type. The compound annual growth rates (CAGR) for the Top 50 can be compared to the global sector growth (across all firms and ownership types) over the same period: 2.1% CAGR in proven oil and gas reserves, 1.9% CAGR in oil and gas production, and 0.9% CAGR in refining capacity (BP, 2008). The figures confirm an ongoing consolidation trend in the upstream, with the Top 50 firms growing reserves and production significantly more than the industry average. In terms of production, fully state-owned NOCs grew at more than double the rate of fully private IOCs, who still outperformed the sector average. In the downstream, fully state-owned firms are the only category to have clearly grown refining capacity over the past 20 years.

More generally, the dataset allows a rare firm-level perspective on longer-term sector trends. Figs. 2 and 3 plot the evolution of aggregate state ownership in the upstream and downstream,

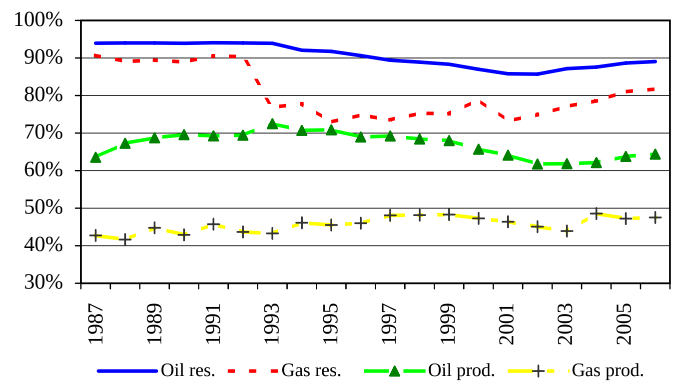

Fig. 2. Weighted state ownership: upstream.

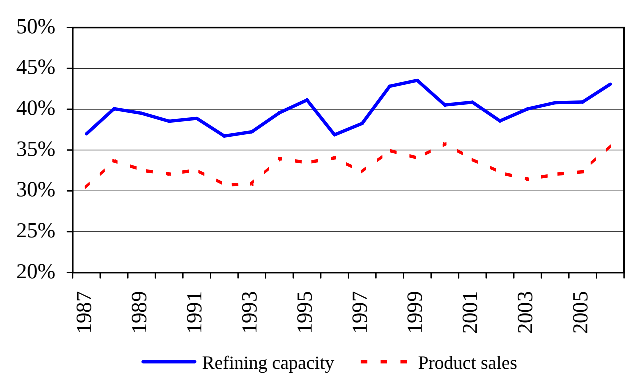

Fig. 3. Weighted state ownership: downstream.

[10] In the case of acquisitions (or mergers) only the identifier of the surviving company (or of the higher-ranked company in the year prior to the merger) is carried forward for the combined entity.

[11] In 2000, Brazil reduced its economic ownership in Petrobras to below 50%, but retained a voting majority. Russia's Gazprom is considered to have always been majority state-controlled post-1993 due to the peculiar share voting and transfer stipulations.

[12] Of those 27 firms, 15 are fully state-owned and 8 are fully private.

[13] Ten privatised firms are from the Former Soviet Union and three from the P.R.C.

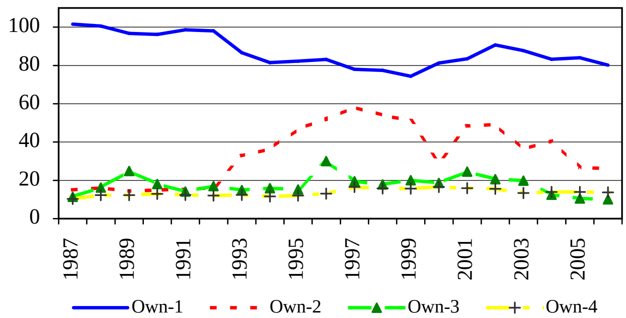

Fig. 4. R/P ratio (years) by ownership type.

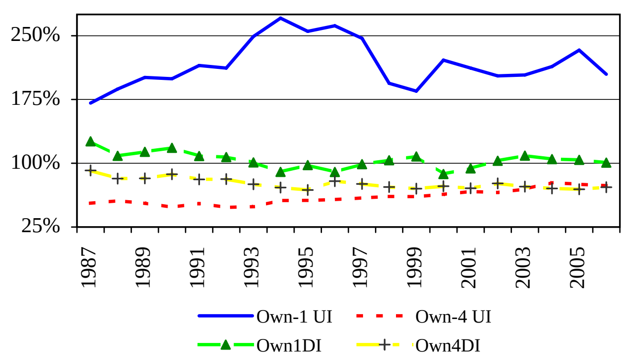

Fig. 5. Upstream ('UI') and downstream ('DI') integration.

respectively, where the percentage of state ownership in each firm is weighted by that firm's relative contribution to aggregate output. For oil reserves and production, state ownership was gradually reduced since the early 1990s, but this has been reversed since 2002. For gas the picture is slightly different: since the mid-1990s (after the part-privatisation of Gazprom) the NOCs' share in gas reserves and production has risen gradually as these companies now make an increased effort to find and to possibly exploit an increasingly valuable resource.

The picture with regard to reserves-to-production ratios (R/P, Fig. 4) is, unsurprisingly, most favourable to the fully state-owned NOCs. More interestingly, all other ownership categories show a marked decline in R/P ratios since the oil price crash in 1998. In its wake private companies cut back on capital spending and introduced severe economic hurdle rates for the development of new reserves, contributing to the shortfall of new supplies in recent years. The data confirms this to be true for all companies listed on public stock markets. Fig. 5 shows the degree of vertical business integration of the business, i.e. the ratios of oil production to oil refining (upstream integration, UI) and refining to product sales (downstream integration, DI). Fully state-owned NOCs are still heavily biased towards the upstream, but balanced in the downstream. Fully private firms as a group have over time improved their upstream exposure (to 74%) and are long in downstream retail vs. refining.[14]

In addition to the PIW dataset as described above, my analysis uses as further data inputs the IMF's annual consumer price indices; the annual average real-terms crude oil price and global refining margin, sourced from the BP Statistical Review of World Energy; a dummy variable for countries with OPEC membership; and annual data on domestic fuel prices (blended value of diesel and super gasoline, in US$ per litre)[15] and per-capita GDP (PPP), both sourced from the World Bank's World Development Indicators database.

5. Methodology

Multivariate regression analysis based on a panel dataset allows different generic estimators to be used, namely the *total*, *between*, *within*, and *random-effects* estimators. Following Petersen (2004), these different models can be interpreted as "different ways of describing the data, each yielding relevant insight in its own right" (p. 334). In the following I will focus on total and within estimators. The between estimator compares average outcomes of individual units, but in the PIW dataset both time-distribution and frequency of observation varies between firms, which can lead to serious estimation bias. Random-effects models are theoretically superior to within estimation[16] and are more efficient in their use of information, but also make the strong assumption that the unmeasured time-constant variables are independent of the measured variables (Wooldridge, 2002). Hausman tests have been conducted on all of the models described in the following, indicating a violation of this assumption and warranting the within specification instead.

$$y_{it} = \alpha + \beta' x_{it} + \varepsilon_{it} \quad (1)$$

Eq. (1) shows the total estimator (or pooled or ordinary least squares estimator), where x_{it} is a K-dimensional vector of explanatory variables and α is a non-unit-specific intercept. It ignores the grouped nature of the data and roughly corresponds to the estimator obtained in standard cross-sectional analysis, except that individual firms may contribute with more than one observation (Petersen, 2004). In the context of this paper the total estimator yields the performance differential between companies of different ownership structure, controlling for a given set of other independent variables. There is no inherent bias in the results relative to this question posed, but the estimated effect of ownership might still in part reflect other, unobserved variables.

$$y_{it} = \alpha + \delta_i D_i + \beta' x_{it} + \varepsilon_{it} \quad (2)$$

The within estimator (or fixed effects or least squares dummy variable estimator) as set out in (2) includes a firm-specific dummy variable D_i, which changes the intercept for each company to capture *all* (observed and unobserved) time-constant variables. Importantly, it estimates the within-individual changes over time, i.e. the effect of a change in ownership on performance and efficiency, rather than the total difference between two types of ownership status. In fact, the within estimator *requires* changes in independent variables to properly interpret their contribution—otherwise they become additional time-constant factors included in the unit-specific intercept. One, therefore, has to accept a fundamental trade-off between the total estimator, which uses all available information but cannot account for unobserved variables, and the within estimator, which implicitly controls for all time-constant variables but is unable (or, in the case of slowly moving variables, inefficient) to estimate their specific contribution (Beck, 2001; Wilson and Butler, 2007). This limitation of the fixed-effects methodology is important because our key variable

[14] See Wolf (2008) and Appendix A for additional details and descriptive statistics on the dataset.

[15] The price of transport fuels for the final customer is treated as an inverse proxy for the extent of fuel subsidies (Eller et al., 2007), although this admittedly does not take into account any differences in taxation, which might be just as substantial.

[16] They can interpret time-variant and time-constant variables.

of interest is state ownership, and to quantify its impact the within estimator only draws on companies with changing ownership over time, leaving to one side valuable information on other firms.

Section 3 set out many of the key structural variables in oil company comparisons. Where possible they are directly included in the multivariate regression (e.g. commodity prices, the proxy for fuel subsidies, operational profile of the firm). As to the unobserved variables, many can be reasonably hypothesised to remain stable over time (e.g. geological properties, reserves entitlement, fiscal regime) and thus will be captured by the fixed-effects model. This is a simplifying assumption in some cases, but a distinct advancement over previous studies in the control for exogenous factors. Furthermore, any arising differences between the two estimators can often be rationalised and thus contribute to a fuller understanding of the subject matter.

The choice of dependent and independent regression variables is motivated by the industry model set out in Fig. 1, as well as by the previous oil and gas studies discussed in Section 2. In addition to the continuous variable of state ownership, every econometric model also includes the binary variable for OPEC membership. Another binary variable for state majority control was initially included as well, but did not prove significant over and above the percentage of state ownership. The industry literature provides a wide range of potentially important control variables; given the lack of precedent multivariate studies on state ownership in the petroleum sector, my main criteria for model selection are goodness of fit and, other things being equal, parsimony. In practice, I start with a deliberately wide selection of possible control variables to minimise the risk of omitted variable bias, and then gradually eliminate – separately for each performance metric – any non-significant variables (Baum 2006).[17]

6. Results

Following the stylised input–output relationships depicted in Fig. 1, Tables 2–5 report the regression results for (1) upstream production and depletion policy, (2) total output efficiency, (3) revenue generation per unit of output, and (4) profitability.

6.1. Upstream production

Table 2 reports the impact of state ownership on the conversion of petroleum reserves and total assets into upstream oil and gas production, controlling for the stage of national development and (one-year lagged) oil prices. Employment is not found to be significant in explaining upstream production. Reserves, on the other hand, are confirmed as a fundamental driver of upstream production with a coefficient (elasticity) of 0.64 in the pooled OLS model (total estimator).[18] The reserves coefficient is noticeably lower if estimated in a within-model, implying that reserve levels are more important to determine production differences between companies than changes within companies over time—an indication of varying depletion policies between firms.

[17] This approach is usually known as general-to-specific modeling (Hendry, 1993). The empirical analysis starts with a general statistical model that captures the essential characteristics of the underlying dataset. Then, "that general model is reduced in complexity by eliminating statistically insignificant variables, checking the validity of the reductions at every stage to ensure congruence of the finally selected model" (Campos et al., 2005, p. 3).

[18] When estimating oil reserves and gas reserves separately, both are significant, but in line with global P/R ratios the elasticity for oil reserves is significantly higher.

Table 2
Regression result for log of oil and gas production.

	Total estimator		Within estimator	
	Coeff.	*t-test*	*Coeff.*	*t-test*
lgResOG	0.6414	20.10***	0.4119	6.67***
lgAssets	0.2506	7.90***	0.2806	6.98***
State	−0.2794	−6.27***	−0.4772	−6.95***
OPEC	−0.4419	−4.63***	–	
lgGDPcap	−0.0151	−0.49	0.5005	3.86***
lag.lgOil	−0.0784	−1.79*	−0.0754	−1.56
Constant	−1.6267	−4.28***	−4.9988	−4.40***
N	645		645	
F-test	848.3		142.8	
R-sq (total/within)	0.90		0.75	

Notes: */**/***: Significant at 10%/5%/1% level, respectively.
Dependent variable: logarithm of annual oil and gas production (mmboe). Independent variables: please see notes to Table 3.
Total estimator calculated with robust standard errors (HC3) as suggested in Long and Ervin (2000). Within estimator: calculated with cluster-robust standard errors (individual firms as clusters); constant term reflects average of unit-specific intercepts; *F*-test shows joint significance of listed variables, excluding fixed unit effects.

Table 3
Regression result for log of total output.

	Total estimator		Within estimator	
	Coeff.	*t-test*	*Coeff.*	*t-test*
LgResOG	0.3394	15.34***	0.2292	4.67***
LgAssets	0.4716	17.82***	0.2755	8.26***
LgEmp	0.0501	2.37**	0.1180	2.77***
State	−0.3036	−7.61***	−0.2392	−2.28**
OPEC	0.0945	1.44	–	
ResBalOG	0.4707	7.26***	0.2437	1.28
UpInt	−1.7202	−17.91***	−0.8154	−2.66***
DwInt	−1.3248	−11.32***	−0.6598	−3.50***
lgGDPcap	−0.1376	−5.77***	0.5841	3.88***
lgOil	−0.1086	−3.13***	−0.0701	−2.29**
Constant	1.8118	5.23***	−3.8244	−2.46**
N	552		552	
F-test	800.0		36.4	
R-sq (total/within)	0.93		0.77	

Notes: */**/***: Significant at 10%/5%/1% level, respectively.
Dependent variable: logarithm of annual total output (sum of oil and gas production, refining capacity and oil product sales) (mmboe). Independent variables in Tables 2 and 3. 'lgResOG': logarithm of sum of oil and gas reserves (mmboe); 'lgAssets': logarithm of real-terms total assets (US$m); 'State': state voting ownership (%); 'OPEC': binary variable with value = 1 for membership; 'lgGDPcap': logarithm of GDP per capita (PPP, constant 2005 $); 'lag.lgOil'/'lgOil': (one-year lagged) logarithm of real-terms oil price (US$); 'lgEmp': logarithm of total number of employees; 'ResBalOG': ratio of oil reserves to sum of oil and gas reserves; 'UpInt': ratio of oil production to sum of oil production and refining capacity; 'DwInt': ratio of refining capacity to sum of refining capacity and product sales.
Total estimator calculated with robust standard errors (HC3) as suggested in Long and Ervin (2000). Within estimator: calculated with cluster-robust standard errors (individual firms as clusters); constant term reflects average of unit-specific intercepts; *F*-test shows joint significance of listed variables, excluding fixed unit effects.

The impact of both state ownership and OPEC membership is significantly negative for upstream production, with the OPEC effect being incremental to fully state-owned NOCs in these countries. Based on the point estimators of the pooled model, and assuming a real-terms oil price of US$50 per barrel and median sample values for all other variables, a fully state-owned NOC is predicted to produce 24% less than fully private firms, and OPEC NOCs 51% less—in terms of production rate this translates to

Table 4
Regression result for log of revenues.

	Total estimator		Within estimator	
	Coeff.	*t-test*	*Coeff.*	*t-test*
lgTotOut	0.3398	4.82***	0.2686	1.98*
State	0.0428	0.61	0.1386	0.73
OPEC	0.2261	1.85*	–	
lgAssets	0.6880	10.55***	0.4032	4.19***
lgEmp	0.0275	0.92	0.2204	2.97***
ProdBalOG	0.6264	4.57***	0.8776	2.74***
UpInt	−1.0575	−8.03***	−0.0610	−0.18
DwInt	−0.9644	−3.73***	−0.2742	−1.14
lgFuel	0.1218	3.88***	0.0011	0.02
lgGDPcap	0.2210	5.60***	0.9054	2.97***
lgOil	0.2904	6.11***	0.4422	5.46***
Constant	−2.2723	−4.20***	−9.2710	−3.15***
N	374		374	
F-test	432.6		96.3	
R-sq (total/within)	0.94		0.84	

Notes: */**/***: Significant at 10%/5%/1% level, respectively.
Dependent variable: logarithm of annual real-terms revenues (US$m). Independent variables: please see notes to Table 5.
Total estimator calculated with robust standard errors (HC3) as suggested in Long and Ervin (2000). Within estimator: calculated with cluster-robust standard errors (individual firms as clusters); constant term reflects average of unit-specific intercepts; *F*-test shows joint significance of listed variables, excluding fixed unit effects.

Table 5
Regression result for log of net income.

	Total estimator		Within estimator	
	Coeff.	*t-test*	*Coeff.*	*t-test*
lgRev	0.9496	17.01***	0.5382	3.37***
State	−0.2492	−1.75*	−1.0957	−2.95***
OPEC	−0.2012	−0.90	–	
ProdBalOG	−0.6852	−2.55**	0.5820	0.63
UpInt	2.2202	7.51***	0.1582	0.16
DwInt	0.7056	1.45	−0.9054	−1.36
lgGDPcap	−0.3068	−4.16***	1.1828	2.78***
lgOil	0.9732	7.90***	1.1347	6.91***
Constant	−3.3941	−3.64***	−13.4860	−3.71***
N	530		530	
F-test	106.0		68.1	
R-sq (total/within)	0.64		0.48	

Notes: */**/***: Significant at 10%/5%/1% level, respectively.
Dependent variable: logarithm of annual real-terms net income (US$m). Independent variables in Tables 4 and 5. 'lgTotOut': logarithm of annual total output (mmboe); 'State': state voting ownership (%); 'OPEC': binary variable with value = 1 for membership; 'lgAssets': logarithm of real-terms total assets (US$m); 'lgEmp': logarithm of total number of employees; 'ProdBalOG': ratio of oil production to sum of oil and gas production; 'UpInt': ratio of oil production to sum of oil production and refining capacity; 'DwInt': ratio of refining capacity to sum of refining capacity and product sales; 'lgFuel': logarithm of annual real-terms fuel prices(US$); 'lgGDPcap': logarithm of GDP per capita (PPP, constant 2005 $); 'lgOil': logarithm of real-terms oil price (US$); 'lgRev': logarithm of annual real terms revenues ((US$m).
Total estimator calculated with robust standard errors (HC3) as suggested in Long and Ervin (2000). Within estimator: calculated with cluster-robust standard errors (individual firms as clusters); constant term reflects average of unit-specific intercepts; *F*-test shows joint significance of listed variables, excluding fixed unit effects.

annual production of 6.1% of reserves for private firms, 4.6% for non-OPEC NOCs, and 2.9% for OPEC firms.[19] The production effect of state ownership indicated by the fixed-effects model, which controls for many unobserved structural variables, is more negative still (6.0% private vs. 3.7% non-OPEC NOC), and strongly supports the notion that depletion policies change when ownership changes, e.g. in the context of a formal privatisation. The within estimator is unable to produce a point estimate for OPEC membership as this rarely changes over time—in fact, it does not at all within our dataset.

These calculations assume that the underlying reserve numbers are "true", i.e. no systematic overstatement has occurred. If NOC reserves were overstated, actual NOC production rates would be higher and the differences between private and state-owned firms less pronounced. But unless *all* of the differences can be explained by reserves overstatement, NOCs are still producing their reserves more cautiously. As set out earlier, this might be due to technical and managerial deficiencies, but it might equally be due to deliberate policy, and in itself is therefore no conclusive proof of lower NOC efficiency.

6.2. Output efficiency

Moving beyond the upstream to a corporate perspective, Table 3 summarises the empirical relationship between total physical output (defined as the sum of upstream production, refining capacity and product sales) and various input factors. As shown in the literature review, the metrics of capital, labour and reserves efficiency have previously been investigated for petroleum firms, but not usually in a joint estimation model and without adequate control for exogenous determinants of performance. Whilst reserve numbers should not be the sole basis for efficiency measurement, they carry some information and thus are initially retained as joint explanatory variables.

All three of these inputs prove statistically significant in explaining physical output, but the differences between the pooled and fixed-effects models imply (just as the unit-specific effects do) the presence and importance of time-constant unobserved variables. For both models a number of control variables also prove significant, such as the relative upstream/downstream exposure, the stage of national economic development, and global oil prices. State ownership is a very significant drag on the aggregate efficiency of input–output conversion: based on the point estimates of the total estimator and the same assumptions as before, a fully state-owned non-OPEC is predicted to produce 26% less output from the same set of inputs compared to a fully private player. Based on the within estimator this difference amounts to 21%. The differences between OPEC and non-OPEC NOCs are insignificant in the pooled model.

Not explicitly reported here is an alternative model that excludes both independent variables linked to petroleum reserves, lgResOG and ResBalOG. Its results for non-OPEC state ownership of NOCs are very much in line with the above, at 28–30% below the output efficiency of fully private firms. The implications for OPEC firms seem much more positive, though: ignoring their huge reserve bases makes them 49% (pooled model) more efficient than the private sector (all results significant at 1%-level). But whilst naïve measures of reserves efficiency are likely to underestimate NOC performance relative to IOCs, asset-based comparisons can be hypothesised to have a contrary bias due to differences in geographical/geological settings and historic inflation rates.[20] Within-estimation controls for one-off 'distortions' of asset

[19] Due to the constant and the logarithmic form this result will differ for other assumed values.

[20] Both affect the carrying value of assets on the balance sheet. The capitalised upstream expenditure required to develop one barrel of reserves varies greatly between countries and might often be favourable for NOCs. State ownership is more common in developing countries, which also tend to have higher inflation rates.

values, but unfortunately is not available for OPEC countries, where they might be most prevalent.

6.3. Revenue generation

Table 4 reports the regression estimates for revenue generation, i.e. the ability to translate physical output into operating revenues, and shows no statistically significant impact of state ownership. This result, however, is quite sensitive to the choice of control variables used and thus provides scope for further analysis. First, standard diagnostics support both the model shown in Table 4 and an alternative model which excludes firm size (lgAssets) and employment (lgEmp) as control variables,[21] and which indicates a significantly *positive* impact of state ownership. On the other hand there is an argument that the control for national economic development (lgGDPcap), which is used as a proxy for state capacity in regulation and administration (Kaufmann et al., 2005), "soaks up" some of the negative effects caused by state ownership, which consequently is portrayed in an overly favourable light. Indeed, dropping lgGDPcap from the model specifications presented in Tables 2, 3 and 5 generally yields more negative results for state ownership, but it does not change the overall conclusions of these models. In the case of revenue generation, however, its omission results in the estimator for state ownership becoming significantly *negative*, at least in the pooled model. In the absence of a satisfactory resolution of these issues I conclude that there is no unambiguous evidence of state ownership affecting revenue generation per unit of output. For a commodities business, this might not be a particularly surprising finding if quality differentials, price subsidies etc. are effectively controlled for.

6.4. Profitability

The final performance metric set out in Fig. 1 is the link between revenues and profits, the return on sales (RoS). The total and within estimators of the elasticity between revenues and profits vary once again to a considerable degree, implying that important variables are still unobserved in the pooled model—underlying asset quality, production cost or taxation are plausible candidates. The profitability differences between state and private firms are statistically significant in both models, but particularly strong using fixed effects: based on the same assumptions as earlier on oil prices and median sample values for other variables, the pooled model predicts RoS of private firms at 11.9% vs. 9.3% for non-OPEC NOCs. The fixed-effects model, based on actually observed profitability changes during ownership change and controlling for all time-constant structural variables, predicts private-sector RoS of 10.0% vs. state-sector RoS of 3.4%.

An interesting observation pertains to the evolution of profitability differences over time. Calculating average annual, unadjusted RoS ratios for each of the four ownership groups, fully state-owned NOCs seem to outperform the other groups up to the year 1997, but in the period since the oil price crash 1998 they have been the *least* profitable. Formal testing in the regression models provides some support, but is not conclusive: state ownership in the pooled model is insignificantly positive for the years prior to 1998, but significantly negative thereafter; the fixed-effects model indicates a strongly negative influence of the state for both periods, albeit more pronounced post-1998. Likely explanations for this shift include the value-based restructuring at IOCs after the oil price crash of that year, the efforts of IOCs to strengthen their upstream portfolio relative to refining and petrochemicals, and the much improved returns on refining and marketing after 2001.

7. Conclusion

The past years have seen a re-emergence of a fundamental debate between State Oil and Private Oil, which to some extent reflects broader shifts in global economic balance and policy approaches. To analyse the economic consequences of different ownership structures within the industry, this paper has compiled a comprehensive global dataset covering the largest public and private oil firms over the years 1987–2006. It then performs econometric comparisons between NOCs and IOCs in terms of upstream production, output efficiency, revenue generation and profitability. The size and panel nature of the dataset allow for significantly better control of structural differences between firms than in previous empirical oil and gas studies.

NOCs, and OPEC NOCs in particular, are found to produce a much lower annual percentage of their upstream reserves than the private sector. This might be caused by a more conservative depletion policy (intentional or not), a systematic overstatement of reserves, or by a combination of the two. Intentionally low production rates might well be justified on national welfare grounds and do not necessarily indicate lower productivity or efficiency at state-controlled firms, as had been argued by other studies. Measuring the aggregate efficiency of input-to-output conversion, though, state-owned firms have been significantly underperforming their private counterparts, by between 21% and 30%, whereas the efficiency of OPEC firms is sensitive to the inclusion of petroleum reserves as a dependent variable. The evidence on revenue generation per unit of output does not indicate a consistent advantage of either ownership form. In terms of profitability private firms are again significantly ahead, with particularly strong evidence from the within estimator of actual ownership changes.

The findings are generally supportive of the hypothesis that "ownership matters" in the sense that private ownership encourages better performance and greater efficiency than state ownership does. Several issues nevertheless require further study and critical examination, two of which will be discussed in the following. First, the results for OPEC NOCs are not as robust as for other state firms; this is due to a lack of data as well as methodological shortcomings. Despite the generally good scope and depth of the PIW dataset, financial data on OPEC NOCs still is very sketchy.[22] Methodologically, the within estimator can implicitly control for time-constant variables by aggregating them into unit-specific intercepts, but it cannot explicitly estimate their impact on performance and efficiency; hence fixed-effects model cannot estimate the impact of OPEC membership, which is an important limitation. It should be noted, though, that the development of improved methods for panel-data analysis is ongoing: political scientists in particular have recently paid increased attention to the estimation of time-constant or slowly moving variables (Beck and Katz, 2001; Green et al., 2001; Pluemper and Troeger, 2007), which over time might allow for better analysis of existing datasets. Second, there might be questions about the longer-term sustainability of the private sector advantage. Part of the current profitability gap seems to have materialised after the oil price crash in 1998, when private

[21] Although both variables are strongly correlated with total output (r^2 of 0.79 and 0.74), multicollinearity is not a major issue when including them.

[22] For example, out of the total 231 OPEC firm-years in the dataset there are only 47 observations on total assets, with only 5 member countries contributing more than 5 observations each. No asset data at all is available for important members such as Saudi Arabia, Iraq or the UAE.

firms under-invested in new production capacity. It has also been suggested that in a high energy price environment the resource-holding nations will be at greater liberty to chose like-minded partners, and that therefore Western IOCs might struggle to access new reserves as NOC–NOC cooperation becomes the norm. These future concerns notwithstanding, the findings in this paper suggest that ownership effects exist in the oil and gas industry, and that a political preference for State Oil usually comes at an economic cost.

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Appendix A. Supplementary Materials

The online version of this article contains additional supplementary data. Please visit doi:10.1016/j.enpol.2009.02.041.

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