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Does vertical integration have an effect on load factor? – A test on coal-fired plants in England and Wales [*]

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Abstract

Today in the British electricity industry, most electricity suppliers hedge a large proportion of their residential customer base requirements by owning their own plant. The non-storability of electricity and the corresponding need for an instantaneous matching of generation and consumption creates a business need for integration. From a sample of half-hour data on load factor for coal-fired power plants in England and Wales, this paper tests the hypothesis that vertical integration with retail businesses affects the extent to which producers utilize their capacity. We also pay attention to this potential effect during periods of peak demand.

Keywords: panel data, vertical integration, electricity supply.

JEL Classification:C51, L22, Q41.

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1 Introduction

Today, most electricity retailers hedge their supply by owning their own plant. Thus most electricity retailers face a trade-off between the cost of dealing with market uncertainty and the cost of managing production units. The non-storability of electricity and the corresponding need for an instantaneous matching of generation and consumption creates a need for integration (Kahn, 2002: 46). A supplier that owns physical production capacity can bypass the volatile and often illiquid electricity exchanges in order to hedge its customer base. Unlike Industrial & Commercial customers, who often are offered contracts indexed to electricity exchange related prices, residential customers are charged (for the time being) with prices that do not reflect real-time conditions. [1]

Electricity is a basic good thus nearly all electricity customers must be given some assurance against energy shortages and rationing. As mentioned in the previous paragraph electricity retailers supply electricity to domestic customers at prices that are not forcibly linked to real-time wholesale prices. Like for any non-storable good, retailers must respond to uncertain demand in the short term by sourcing from capacity that is inflexible in the short-term. [2] The fact that in the short-term to mid-term the electricity supply curve is inelastic can thus lead to significant wholesale price spikes. [3] Note that in general off-peak, prices yield insufficient income to pure generators, which implies that peak profit maximisation strategies may seek to balance off-peak losses (Fitoussi, 2003: 43)

The California experience has made it clear that market system design can have negative consequences for consumers and other stakeholders in the well functioning of

[1] Furthermore there are logistical constraints on the number of times per year that a large supplier can adjust its prices, on top of regulated notice periods of notice (currently 28 days in the British electricity market).

[2] Maintenance, repairs, equipment failures of power plants and primary input price fluctuation (coal in coal-fired plants, etc.) add to this uncertainty.

[3] In fact some economists have asked themselves the question, why spikes are not observed more frequently and with more intensity, probably the result of some sort of self-restraint.

the physical electricity system. Agents in the electricity sector are dependent on each other since failures in any part of the system can affect other firms' costs in the short term [4] (Delmas and Tokat, 2003: 8). These constraints are compounded by the fact that in the short term residential demand is not contingent on prices, particularly because of the political and logistic difficulty of confronting them with the wide fluctuation in marginal supply costs on a real-time basis (see Kahn, 2000: 46).

The industry structure of the mid-merit coal-fired generation sector in the UK is the result of several mandatory and voluntary plant divestments and subsequent re-concentration. Before 1990 each regional supplier (ex-Regional Electricity Company) was vertically integrated with a distribution network, whilst National Power and Powergen owned most of the thermal generation assets (78%). [5] Plant divestments along with new entry took place, thus reducing both National Power and Powergen's share of generation capacity and fragmenting the electricity generation industry.

Though some market power remains under the New Electricity Trading Arrangement (NETA) (Bower, 2002: 11-12), estimates suggest the "pivotal player strategy" is less often used in the wholesale energy market in England and Wales as a result of the increasing fragmentation of capacity ownership (Frontier Economics, 2003). [6] Plant divestment was accompanied with a rapid move to vertical integration (VI) of generation businesses with supply businesses (once initial regulatory barriers had been lifted). Today's present market structure is marked by the dominance of the residential supply market by six large vertically integrated firms (albeit the degree of vertical integration varies amongst them, there is a tendency to converge upon a similar business model).

Vertically integrated retailers are less exposed to price volatility as they can internally adjust production (supply) to their load (demand) requirements (Delmas and Tokat, 2003: 9) at a lower cost than the one they might face in the wholesale markets. This

[4] Notably the failure of ENRON and other energy traders subsequently increased the amounts of collateral requested by most electricity traders from remaining counter parties to cover credit-risk.

[5] Whilst nuclear remained in the hands of British Energy and BNFL.

[6] The exercise of market power as a result of capacity withholding by multi-plant producers seems to have been more extreme in California than elsewhere (Kahn, 2002: 47).

efficiency may be passed on to customers. Among other authors Kahn (2002: 49) believes that continued ownership of generation by suppliers in California would have protected them but they accepted the obligation to freeze their retail rates and subsequently found themselves in great financial penuries as wholesale prices spiked persistently.

By monitoring the performance of their generators, integrated retailers can improve supply reliability and accordingly earn returns from alleviating moral hazard problems. It is thus expected that VI is related to the extent to which producers utilize their available capacity, especially in periods of peak demand. Whilst, at the same time VI may raise policy concerns as it increases market concentration and may reinforce the dominant position of an incumbent.

The main question raised in this project is whether VI plays a significant role in explaining the distribution of load factor (LF). LF can be defined as the ratio of the output produced by a plant in a certain period and the theoretical maximum that it could have produced. If LFs were higher for vertically integrated firms, more particularly, during peak times then we could conclude that VI has a role to play in limiting gaming in the wholesale electricity production market. Obviously LFs may be influenced by several other determinants such as seasonality, plant vintage, and plant scale. We essentially address these issues from a multivariate statistical approach applied to data on ten coal-fired power plants in England & Wales in a typical day.

The plan is as follows. In section 2 we suggest a few rationales underlying VI of generators with retail businesses. It is also suggested that the incentive to merge is higher for electricity retailers than for producers who still may have an incentive to "game" the market. Section 3 explores the distribution of LFs in more detail and sets up a multivariate model to test whether it is influenced by VI, particularly during peak times. We are also enable to measure the marginal effect on LFs of the size of plants, which indirectly gives precious information about the technology that relates supply to owned capacity. Section 4 presents the results. Section 5 concludes.

2. Vertical integration as a natural structure in an industry subject to particularities

2.1 Fragmentation of coal-fired electricity generation capacity

The coal-fired generation duopoly of National Power and Powergen was able to exercise a considerable amount of market power in the Pool, especially after March 1993 when the vesting coal contracts expired. As privatisation began, reduction in industry concentration in the generation sector was effective in reducing market power thus lowering prices (Green, 2004; Bower, 2002). Specifically by the time the New Electricity Trading Arrangements (NETA) were implemented, the coal-fired generation sector had become fragmented amongst over eight firms. Overall capacity concentration fell by 3856 points over the period April 1990-March 2002 as measured by the HHI index (Bower, 2002: 30).

In July 1998 Powergen was allowed to vertically reintegrate its generation business with the supply business of East Midlands Electricity in return for further divestment. Similarly National Power bought the retail business of Midlands Electricity Board in June 1999. [7] In a subsequent voluntary round of divestment, Powergen divested plant to British Energy and London Electricity (today EDF Energy) before in turn being itself taken over by E.ON in July 2002. National Power reduced its coal-fired capacity too and was later taken over by RWE in May 2002. New entrants invested in combined cycle gas turbines (CCGT) plant that initially enjoyed a cost advantage due to coal vesting contracts and low wholesale gas prices.

2.2 Drivers behind vertical integration

Retailers face uncertainty about the cost of sourcing the electricity they are to supply to their customer base. This economic uncertainty is a source of market transaction costs (Spulber, 1999: 236-). Following the transaction costs literature, VI may be

[7] Powergen sold Fiddlers Ferry (1960 MW) and Ferrybridge (1956MW) to Edision Mission energy whilst National Power sold Drax (3870MW) to AES.

economically founded as it is sometimes cost effective to internalize some transactions, organising and coordinating them within a hierarchical firm (Grossman, 2003: 23). According to Bower (2002), the NETA gave large consumers and suppliers an incentive to undertake active load and price risk management. Consequently they can alleviate the costs of dealing with market uncertainty (the amounts of electricity they purchase) (Spulber, 1999: 270) through VI and control over generation, which may increase reliability of input supplies. [8]

2.2.1 Hedging customers

Residential end-customers do not contract directly with generators. The social cost of a decentralised matching market would be certainly higher than transacting with electricity retailers. Basically these latter act as market makers (they interface end-customers and producers who ship electricity via the grid and distribution networks). It is worth noting that long term contracts may decrease the transaction cost gains from VI. Although long term contracts have the virtue they can reduce wholesale electricity prices (Green, 2003), vertically integrated retailers can handle information asymmetries more effectively in the short term. Also long-term contracts present risks for the retailer (counter party credit risk, lack of flexibility, amongst others).

In the E&W market coal plant sometimes runs during periods of high demand. During peak demand, opportunistic gaming behaviour can be more profitable for independent generators and the importance of appropriately hedging domestic customers becomes even bigger. VI may alleviate opportunistic behaviour (plant capacity withdrawal) by otherwise pivotal generators and thus increase LF. The most obvious reason is that being a retailer may give producers, particularly pivotal generators, an incentive to increase supply as they have contractual obligations vis-à-vis their customers at a fixed price. These generators could otherwise have benefited from withholding capacity (López, 2002; Bower, 2002). Finally since generators learn about the amount of their resource stock one period before the market clears, retailers may seek to acquire more

[8] Kahn (2002: 46) emphasizes the high degree of interdependence between investments and operation at the transmission and generation levels presumably taken into account internally by the several vertically integrated franchised monopolists that used to dominate the US electric industry. VI provides incentives for undertaking investments at one horizontal level necessary for the success of operations at another.

than one generation units, thereby eliminating uncertainty about the total amount of available supply. [9]

2.2.2 Ensuring plant dispatch during peak demand periods

In general power plants find it profitable to produce electricity during peak time when whole sale prices are higher than average. By calling their peaking plant, there is certainly a trade off between withholding capacity until price reaches a certain level and producing hence making money now (Green, 2004). Today capacity withholding is however less often observed as stated in section 2.1. VI may thus allow generators to dispatch their peak-load plants with lower coordination costs. This assertion will be tested econometrically.

The existence of a link between LF and VI would thus be informative about the extent to which producers may be attempting to “game” the market (by withholding load at peak demand periods for example). A positive relationship between VI and LF would suggest that vertically integrated producers seek rents in a less opportunistic way than independent producers.

3 Does vertical integration have an effect on load factor?

3.1 Technical definition of load factor

Traditionally LF is a measure linked to a theoretical maximum output capacity measure and it can be defined as the ratio of the output produced by a plant in a certain period and the theoretical maximum that it could have produced. Thus a yearly LF would equal the total output of a plant in a year divided by the maximum possible output of that plant also in a year. LFs can be measured in hours, days, weeks, or whatever other time period one deems appropriate.

[9] Demand seasonality gives an incentive to acquire generation plants of different capacity to operate near full capacity for a greater amount of time thus reducing average costs. It is worth noting that a retailer holding all installed capacity in the sector would still face uncertain demand.

It is different from the availability factor (AF) that is the ratio of gross electric output over a given period of time to the amount of electricity that could be produced if the plant were operating at capacity for the entire time, excluding scheduled downtime periods. [10] AF gives higher values than LF when used to assess the performance of any particular plant (Virdis and Rieber, 1991). LF is a key indicator as it is the relevant concept for generation costs estimates. The higher the LF the lower the generation cost per kWh, as the greater total fixed costs of plant are distributed over a larger power output. This negative relation exists in a stronger form for nuclear plants. In the late 80s, a LF for U.S. coal plants could be estimated at above 60%.

Finally, the level of LF might be driven by technical efficiency in that firms that use lower amounts of capacity for a given amount of supply are thus more efficient. Given VI is often a rationale for being more efficient throughout larger scales of production, thus supporting the potential link between VI and the level of LF. A network with a high LF may be more cost-efficient otherwise, a low LF would suggest that the same level of supply could be obtained with less installed capacity. It is generally accepted that a firm that can obtain more output without changing the level of inputs is more technically efficient (Delmas and Tokat, 2003). When transposed to our case these firms achieve higher economies of scale. The data of summarised in **Table 1**

3.2 Distribution of load factor

This study is preliminary as we restrict to coal-fired generation plants and consider a typical day (an average of all days throughout the year). [11] The data range from 1st January 2003 to 31st December 2003. LFs are collected for 10 coal-fired power plants in E & W. This latter restriction has the advantage that marginal cost must be similar

[10] For nuclear plant, downtime is required for schedules maintenance, or for refuelling once in twelve to eighteen months, reducing its output.

[11] As seasonality is not removed we are aware this may create aggregation problems and therefore biased estimation. The rationale is that all generators face the same seasonality of demand.

across producers. [12] LF is measured each half hour for 14 coal-fired generation units that supply in that day.

We can see in **Figure 1** that LF is less dispersed at times when the demand presses on capacity that is in the interval 8am–7pm. In **Figure 2** we compute the standard deviation of LF across plants over time (the thick line). Two remarks that concern the properties of the data deserve to be mentioned here:

(*i*) LF looks clearly non stationary in its first two moments;
(*ii*) the standard deviation seems clearly negatively correlated with the mean. [13]

The thin line in **Figure 2** represents the mean across plants.

In a preliminary analysis, we look at the unconditional distribution of LF in order to find out whether we have two populations with distinct means, one for vertically integrated and the other for independent producers (our sample has 50% of each type). A preliminary visual analysis shows that load throughout the day follows an asymmetric distribution with a mode about 75% of capacity for both types of producers. As shown in **Figure 3** the mode corresponds to a higher value for LF in vertically integrated firms.

3.3 Conditional model for load factor

It seems that we actually have two distinct populations according to whether power plant is vertically integrated or not. We build now a conditional model with potential determinants that are supposed to explain this difference. We estimate the following conditional linear model for LF:

[12] For economic reasons, coal-plants are generally used for base-load as well as cycling and peak loads, when load following becomes necessary (Virdis and Rieber, 1991). The reasons are a low capital cost of coal plants and a high variable cost of each extra kWh. This cost is about €35/MWh.

[13] A linear fit of the apparent relationship between the two variables gives a coefficient of determination of 0.938. The corresponding equation is *standard deviation* = –0,259 × *mean* + 0,316.

$$\frac{q_{it}}{k_i} = \beta_0 + \beta_1 d_i + \beta_2 v_i + \beta_3 k_i^* + u_{it} \qquad (1)$$

$$u_{it} = \mu_i + \lambda_t + v_{it} \qquad (2)$$

where $t = 1,\dots,T(\equiv 48)$ half hours, $i = 1,\dots,N(\equiv 10)$ denotes the different generation units, q_{it} is the supply for plant i during period t, k_i is its installed capacity. $LF_{it} \equiv q_{it}/k_i$ is thus the load factor for plant i during period t. $k_i^* = 10^{-4}k_i$ is introduced as a means to capture the effect that larger plants may have on the level of load factor. [14] Its relevance will be discussed later.

In addition to the constant term β_0, we have introduced a dummy variable d that equals one if i is vertically integrated and 0 otherwise. Delmas and Tokat (2003) use a different proxy for VI. VI for an electric utility is captured using the proportion of electricity sold that is generated by the utility. Their dependent variable is however different than ours; it captures productive efficiency using input and output measures. [15] v is vintage of plant i; the age of the plant at 2003. μ_i accounts for unobservable plant-specific effect that are not included in the regression, λ_t is the unobservable time effect and v_{it} is the remainder disturbance.

We notice if one estimates the model as a one-way error component one with fixed-individual effects we cannot estimate a coefficient on any time-invariant regressor (Baltagi, 2005: 13). The Least Squares Dummy estimator measures individual observations as deviations from time means. But given the obvious trend in the variable *LF* in a typical day (see remarks (*i*)-(*ii*) at p. 9 and **Figure 1**) we should prefer a method that averages the observations across individuals for each half-hour and therefore ignore estimators that average observations over time. We thus propose to estimate the model as a one-way error component with fixed time effects. [16]

[14] We thank L. Nesta for motivating the insertion of that variable.

[15] They use Data Envelopment Analysis to convert multiple input and output measures into a single ratio for US electric utilities (details in Delmas and Tokat, 2003: 13-14).

[16] One may want to estimate the model as a one-way with random-individual or a two-way with fixed-time and random-individual effects but these would produce the same estimates for the coefficients as but

4 Results

Results are given in **Table 2**. As expected, the coefficient multiplying the VI variable is positive (0.0459) and significantly different from zero (a 95% confidence interval for this coefficient is [0.0261, 0.0656]). Notice that total capacity for vertically integrated plants is about 200MW lower than that for independent plants, which could have as consequence that producers with less capacity use on average a higher fraction of it relative to independent producers ceteris paribus the other factors. Our model corrects for this potential 'capacity effect' since we inserted capacity through k_i^*. Put other way, our result suggests that for similar levels of installed capacity, vertically integrated producers use a higher fraction of that capacity than independent producers.

The individual effect of capacity is positive. If we combine this result with the previous result, these are clearly an argument in favour of concentration in the hand of independent producers as vertically integrated producers can achieve similar levels for LF with less capacity. The negative vintage effect (– 0.0255) may be explained as follows: older plants are certainly less cost-efficient and are more likely to be used only when demand is the highest while younger plants are used more often base-load. **Figure 4** supports this result. It shows the cumulated values of *LF* for two categories of plants, those built in the period 1966-1969 (dashed curve) and those built in the period 1970-1974 (continuous) curve.

We also ran a test that VI has no effect on the relationship between load factor and peak demand against the alternative that either VI alone or the interaction variable or both have an effect (see **Table 3**). To avoid multicollinearity we estimated (1) including a dummy for half hours between 17 and 35 inclusive in addition to an interaction variable between this dummy and the VI dummy. The coefficient on the interaction variable will allow us to test whether customers hedging during peak times increases with VI (or VI may give producers a further incentive to increase supply, especially during periods of peak demand). The *f*- statistic equals 2.903, which is lower although close to the

higher standard errors. Moreover, in random-individual models, it is preferable that *N* be large, a condition which our sample does not satisfy.

95% critical value $F(2,475)$ of 3.00. Consequently VI has no effect on the relationship between load factor and peak demand.

5 Conclusion

Transaction and contractual theories of the firm as well as the achievement of economies of scale provide a rationale for vertical integration of electricity businesses with supply businesses. Today in the British electricity sector, the majority of retailers hedge their residential customer base using their own plants. This preliminary paper investigated this potential link between vertical integration and the fraction used of available capacity (the load factor) from data on ten coal-fired power plants in England and Wales.

As suggested the effect on load factors of vertical integration corrected for both the size of plant and its age, is positive and significant. Vertically integrated producers would use an extra 4.6% of their installed capacity. This effect is however not significant when demand presses on capacity that is in the period 8am-7pm. Interestingly, the greater the plant capacity the higher that is the load factor. This is clearly an argument in favour of increasing returns to scale in power plants and possibly concentration more particularly for independent producers as our main result shows vertically integrated producers use a higher fraction of their capacity. The reason could be that retailers holding a high number of plants are better equipped to dispatch them efficiently to hedge their customers.

Regulation authorities would do well in keeping an open mind regarding vertical integration, as it may serve to limit the exercise of market power by pivotal generators. Although vertically integrated firms may be slow to adapt to changing regulatory environments (Delmas and Tokat, 2003). Indeed, "deintegrated" firms may adapt more rapidly as they do not have to coordinate new regulatory information among different steps of the value chain. The idea that firms with high load factors are more technically efficient can be mitigated.

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APPENDICES

APPENDIX 1

TABLES

Table 1. Characteristics of coal-fired power plants in 2003

Plant Name	Capacity (MW)	Load factor %		Onwer	Vintage
		Min	Max		
Independent					
Drax	3870	57	78	Drax Power Ltd	1974
Rugeley	1006	38	73	International Power	1972
Ferrybridge C [(a)]	1955	10	59	AEP	1966
Fiddler's Ferry [(a)]	1961	11	72	AEP	1971
Eggborough	1960	21	52	British Energy	1967
Total	10752				
Vertically integrated					
Ratcliffe	2000	47	75	E.On UK	1968
Ironbridge	970	18	51	E.On UK	1970
Cottam	2008	26	75	EDF Energy	1969
West Burton	1972	13	64	EDF Energy	1967
Aberthaw B	1455	43	58	RWE Npower Plc	1971
Total	8405				

[(a)]. Includes Biomass.

Table 2. Results for the model with fixed-time effects

	Fixed-time effects	
Variables	Coefficient	Standard Error
Vertical integration	0.0459 ***	0.0101
Vintage	– 0.0255 ***	0.0020
Capacity	0.6016 ***	0.0674
Constant	1.0945 ***	0.0816
$\bar{R}^2$	0.703	

*** = "1% significance level"

Table 3. Results from OLS

	Unrestricted		Restricted	
Variables	Coefficient	Standard Error	Coefficient	Standard error
Vertical integration	0.0615 ***	0.0172		
Peak	0.2232 ***	0.0187	0.2034 ***	0.0133
Vertical integration×Peak	– 0.0395 *	0.0264		
Vintage	– 0.0255 ***	0.0028	– 0.0243 ***	0.0028
Capacity	0.6016 ***	0.0916	0.5191 ***	0.0893
Constant	1.1728 ***	0.1020	1.1754 ***	0.1030
$\overline{R}^2$	0.451			0.437
F-test	$79.73 > F_{0.01}(5,474) = 3.05$		$125.41 > F_{0.01}(3,476) = 3.82$	

*** = "1% significance level", * = "20%".

APPENDIX 2

FIGURES

Figure 1. Load factors

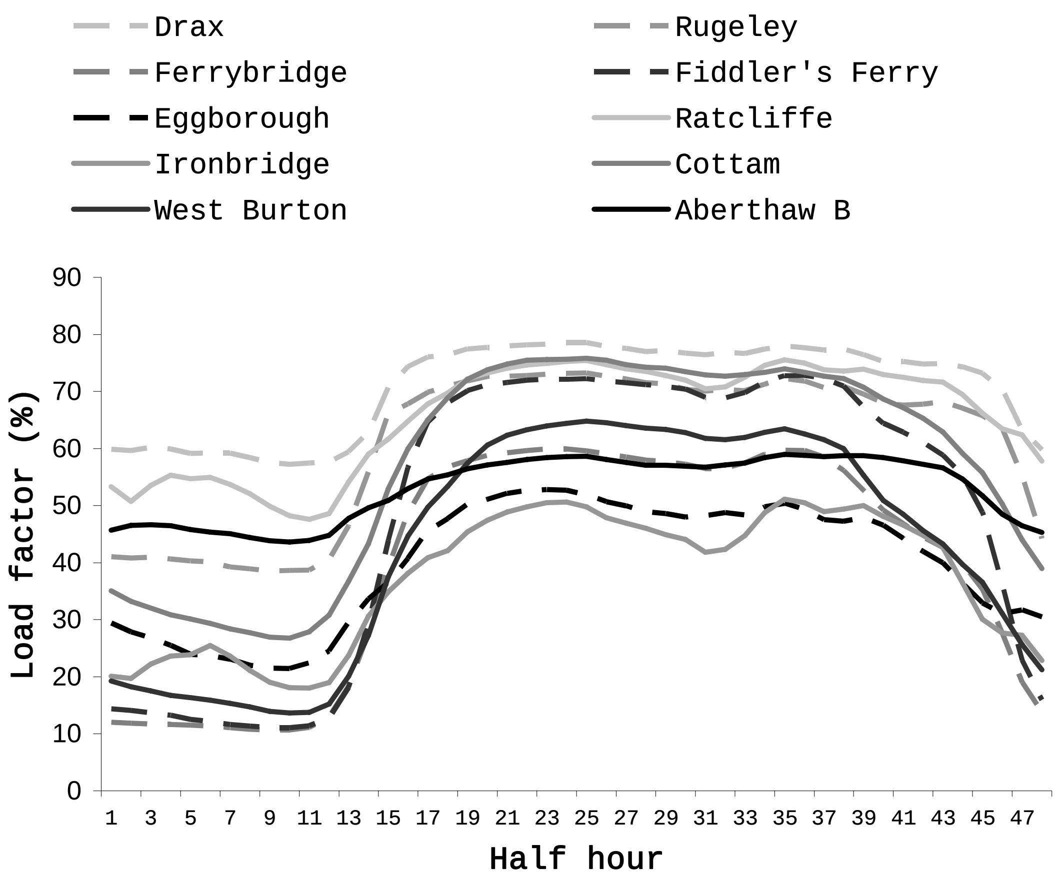

Figure 2. **Spread of load factors for independent and integrated generating plants**

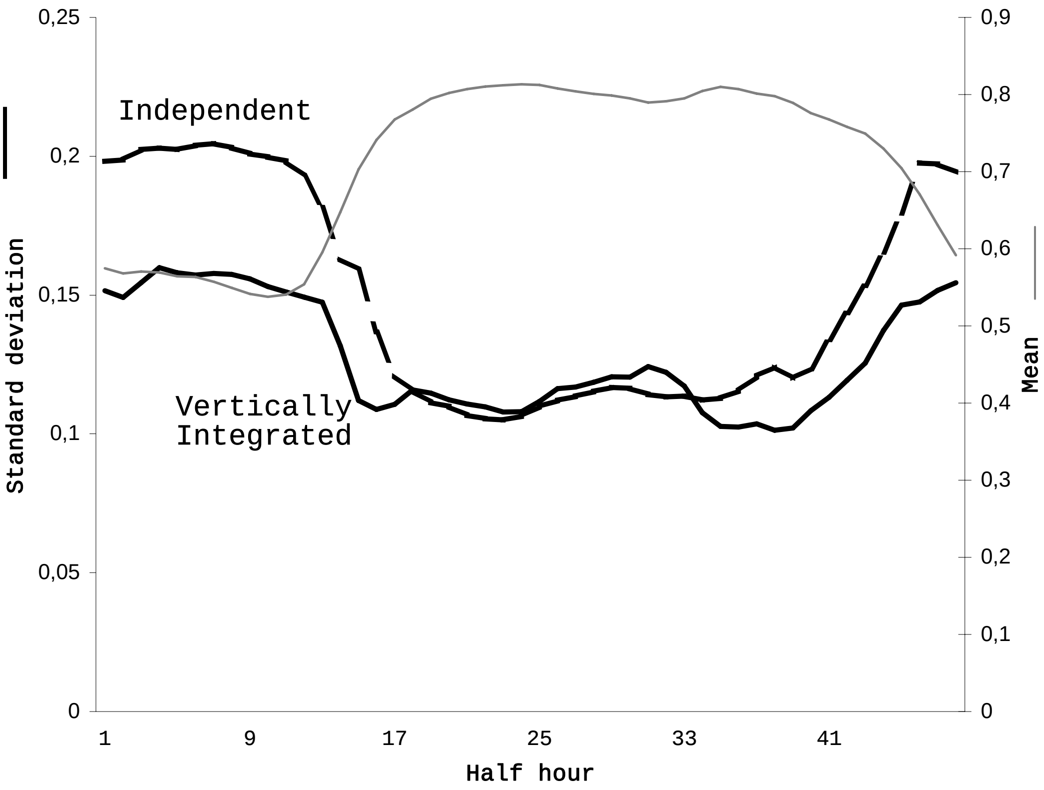

Figure 3. The frequency distribution of load factors for independent and integrated generating plants

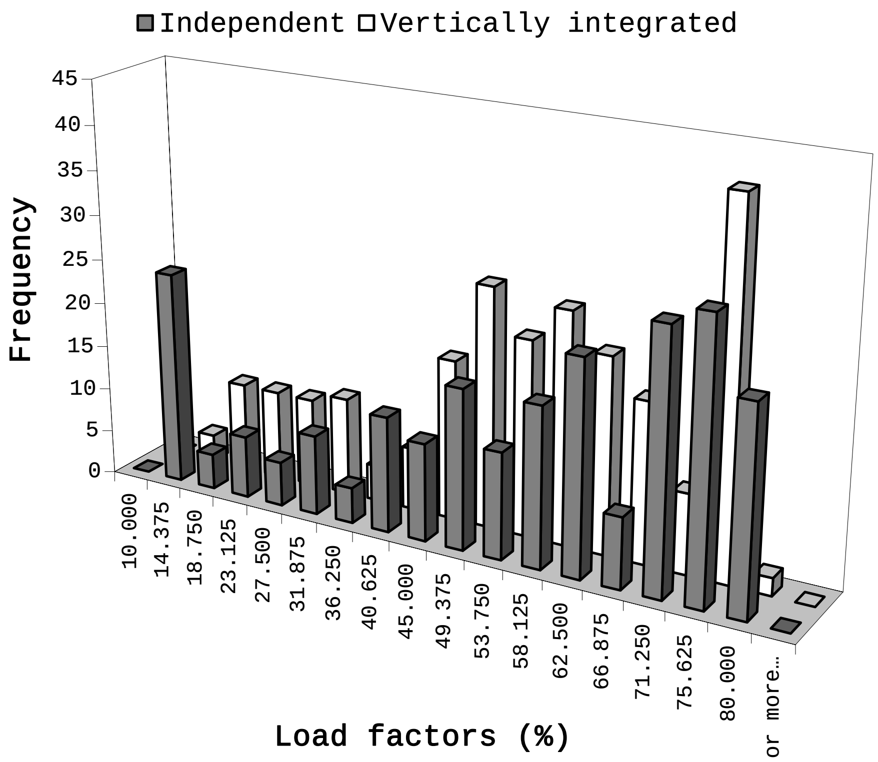

Figure 4. Cumulated load factor and plant vintage