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DISECONOMIES OF SCALE FOR PLANT UTILISATION IN ELECTRICITY GENERATION

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Using data on electricity generation in the Netherlands it is shown that diseconomies of scale for plant utilisation occur. It is plausible that these diseconomies even offset economies of scale for capacity costs.

1. Introduction

The influence of the utilisation rate is frequently neglected in the discussion on economies of scale in, for instance, electricity generation. However, when investigating these economies of scale, one should carefully distinguish between cost reduction resulting from decreasing average capacity costs and cost reduction resulting from increases in the average utilisation rate. The traditional scale influence, capacity costs, might be enforced or countered by the influence of the utilisation rate. Using US-data Stewart (1979, p. 564) concludes, for instance, that 'The major source of cost reduction at the unit level comes from increases in the plant utilisation factor, not from increases in the size of the unit ... given that larger plants are generally operated at higher plant factors'. Contrary to this conclusion, however, we shall argue below that, at least for the Netherlands, possible economies of scale in unit size have been offset by diseconomies of scale in the utilisation rate.

2. Steam electric power generation

Average costs in steam electric power generation consist of variable fuel costs and fixed capital costs (including complementary labour costs). Since fuel efficiency does not vary significantly with plant capacity, at least for units larger than 150 MW, [1] economies of scale will not occur in average variable costs. Hence we concentrate on average fixed costs.

The average fixed costs of electricity production are defined by

$$C/X = C/V \cdot 1/b, \tag{1}$$

where C stands for total yearly fixed costs, X for the yearly production in MWh, V for the capacity of the turbine in MW $\times$ 8760 hours (which is the maximum number of hours per year) and where b stands for the utilisation rate. Let the average fixed costs of capacity decline exponentially with capacity (the traditional scale effect), hence its scale-elasticity, α, is negative. Moreover, let the utilisation rate increase exponentially with capacity, hence its scale-elasticity, κ, is positive. Then the scale-elasticity of average fixed costs of production, ϵ, is given by [2]

$$\epsilon = \alpha - \kappa. \tag{2}$$

This elucidates our point that economies of scale will have two sources: the costs of a unit and its utilisation, represented by the scale elasticities α and κ, respectively. When instead of increasing with capacity the utilisation rate decreases, economies of scale in average fixed costs of production ($\epsilon < 0$) are no longer certain.

3. Economies of scale in utilisation?

Whereas economies of scale in average fixed costs of capacity have been studied extensively, those in the utilisation rate have only had very rare attention. [3] In the technical literature one finds that larger plants tend to have lower utilisation rates [e.g., Knudsen (1976)]. Abdulkarim and Lucas (1977) argue that this is plausible since larger units will be more complex and therefore will have a larger number of modes of failure. Moreover, they will be more difficult to operate.

[1] Van Helden and Muysken (1981). Possible differences in fuel prices are neglected.

[2] Let $C = \kappa_1 \cdot V^{1+\alpha}$, $\alpha < 0$, and $b = \kappa_2 \cdot V^{\kappa}$, $\kappa > 0$, then from (1) we have $C/X = \kappa_3 \cdot V^{\epsilon} = (\kappa_1/\kappa_2) \cdot V^{\alpha-\kappa}$.

[3] Stewart's conclusion of economies of scale in plant utilisation is arrived at only indirectly: by concluding that $\epsilon = -0.19$ and $\alpha = -0.02$. Cf. Stewart (1977, p. 563).

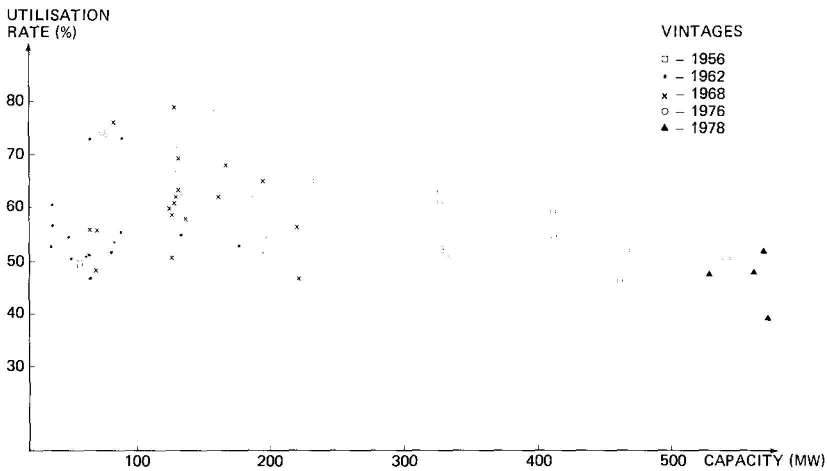

Fig. 1. Utilisation rate, size and vintage of steam turbines in the Netherlands.

In exploring the relationship between the utilisation rate and capacity we use data on 62 steam turbines in the Netherlands, installed in the period 1955–1978 [cf. Van Helden and Muysken (1982)]. The capacities vary from 24 MW to 640 MW. To each turbine a normal rate of utilisation is alotted by taking the average utilisation of the turbine in the three years following the year of installation [e.g., Knudsen (1976, p. 13)]. [4]

From fig. 1 one sees that the relationship between the normal utilisation rate of a turbine and its capacity appears to be negative; the opposite holds for the relation with its vintage. This impression is confirmed by analysis of variance: both capacity and vintage have a significant influence on the utilisation rate [Van Helden and Muysken (1982, p. 6)].

The separate effects of capacity and vintage can be identified by means of multiple classification analysis. It turns out that larger capacities induce a lower utilisation rate, whereas younger vintages bring about a higher utilisation rate [Van Helden and Muysken (1982, pp. 6–7)].

[4] Of course evidently exceptional observations have been excluded. Cf. Van Helden and Muysken (1982, app.).

These results are also found by means of regression analysis (t-values in parentheses): [5]

$$b = -\underset{(5.06)}{0.00050}\,V + \underset{(4.18)}{0.010}\,T - \underset{(0.07)}{0.011}, \qquad R^2 = 0.29, \tag{3}$$

where T stands for the vintage, b for the utilisation rate and V for the capacity (in MW) of a turbine. If we confine ourselves to production units with a capacity above 150 MW, the vintage effect becomes insignificant. Then the scale elasticity, κ, can be estimated directly:

$$\ln b = -\underset{(3.67)}{0.18}\ln V + \underset{(1.55)}{0.422}, \qquad R^2 = 0.35. \tag{4}$$

From these results one can conclude that there is a negative relation between the capacity of a turbine and its utilisation rate, which agrees with the technical studies mentioned above. Moreover, at least for capacities above 150 MW, the scale elasticty of the utilisation rate, κ, is about -0.18 in the Netherlands.

4. Conclusion

Economies of scale in electricity generation only occur in average fixed costs. However, when considering average fixed costs one should distinguish between the costs of capacity and the utilisation of capacity. We found that in the Netherlands the scale elasticity of utilisation is negative, about -0.18. Since economies of scale for fuel input are absent, this implies that economies of scale in electricity generation will only occur when the scale elasticity of capacity costs lies below -0.18, cf. eq. (2). Hence the traditional economies of scale should exceed 18%, whereas estimates in the literature vary from 0% to 20% [Van Helden and Muysken (1982, p. 9)].

This implies that due to diseconomies of scale in capacity utilisation, the occurrence of overall economies of scale in electricity generation is implausible.

[5] The relation between b, V and T was estimated in several forms; the linear form showed the best fit.

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