Efficiency and Vertical Integration: The Case of Mine-Mouth Electric Generating Plants,
by Joe Kerkvliet,
presented by Fatma Ozgu Serttas
This paper’s aim is to test 4 propositions about vertically integrated (from now on VI) and vertically non-integrated (from now on NVI) firms:

• VI and NVI firms allocate inputs with equal efficiency.
• Achieve equal technical efficiency.
• Upstream transaction-specific investments provide monopsony power.
• Monopsony behavior is not different for VI and NVI firms.

Some facts first:
Problems of Coordination vs. Contracting Costs

• Previously, it has been shown that a VI firm will have greater adaptability to unanticipated events, reductions in opportunistic behavior in bilateral exchange (like monopoly / monopsony), yet problems of coordination and other managerial diseconomies might exist (Williamson
(1979) and Klein et al. (1978)). Whereas, a NVI firm, through contracting, can produce efficient economic behavior, and reduce the problems of coordination (Blair and Kaserman (1983) and Hart and Holmstrom (1987)).

- The transaction (contracting) costs vary directly with the amount of transaction-specific investments incurred. This in turn, might induce the market to become a bilateral monopoly / monopsony.

Choice between integrating and contracting (allowing for market exchange) is determined by the trade-off between managerial diseconomies and contracting costs.

In this paper, the author seeks to test the 4 propositions mentioned above. Basically, he seeks to find out how different is the performance of vertically integrated and non-integrated firms by looking at allocative efficiencies. He questions whether there are economies or diseconomies of internal organization (VI)? He
also tries to determine the importance of transaction-specific investments in input production on the exercise of monopsony power by the input user and searches for the differences in the usage of that monopsony power by the VI and NVI firms.

For estimation, he uses a behavioral cost function that depends on shadow input prices, following previous works.

Sample:

- US electric utilities operate at least 23 mine-mouth plants with a capacity of over 29 gigawatts (which forms 10% of the US coal-fired generating capacity). One third of these firms are VI, and own the regulated electric utility (the plant that consume the steam coal and produce electricity) and operate the adjacent coal mine. Remaining NVI firms use 20 to 50 year contracts to govern the coal sales.

- 20 of VI and NVI coal-fired, mine-mouth, electric generating plants are used for esti-
mation, in total 149 observations over the sample period 1979-87. 7 are VI and 13 are NVI.

- Utility ownership of more than one plant is common so as the ownership of more than one adjacent mines. For ex. Utah Power and Light operate 3 plants and owns 2 of three adjacent mines.

Theory

3 major problems that can affect cost inefficiency for mine-mouth plants

- Potential monopsony behavior of the electric generating plant due to transactional failures. Because coal sales to the plant are complex, uncertain and involves small numbers of trading hence requires transaction-specific investments.

There are various types of coals including BTU, moisture and chemical content. To reduce maintenance costs, utilities custom-build plants that burn a design coal with specific features. The use of a different type coal will require high
costs. (Potential opportunistic behavior / monopsony by the plant).

Coal suppliers make substantial investments to supply the plant with a design coal, like reserves, mine pits, haul roads. To undertake these investments the mine has to make a choice between integration or a long-term contract. Since the number of potential buyers are limited by the type of the coal, mine is subject to potential opportunistic behavior by the plant. This paper focuses on the possibility of monopsony behavior by the plant.

- **Economies of internal production.** VI can induce technical efficiency by promoting coordination, however, if the utility is inexperienced and/or less skilled at mine operation then independent firms will lower the costs.

- **Existence of a regulatory environment.** As an example, Fuel Adjustment Clause (FAC) is given. It might reduce the efficiency of fuel use relative to non-fuel inputs by affect-
ing the price of fuel differently than other fuels in case of a change in the output price.

The Model

• Operator of the electric generating plant is assumed to min. the constrained costs, which depend on vertical arrangement and regulatory environment. Plant produces electricity, \( Q \), via a well behaved production function.

\[
Q = Q(X_C, X_A, X_L; M) \quad \text{(1)}
\]

\( M \): Fixed plant capacity in megawatts
\( X_C \): Coal input
\( X_A \): Fuel input other than coal
\( X_L \): Labor input

• Plant is a price-taker in labor and other fuel markets, \( P_L \) and \( P_A \) are the respective input prices. Another fuel can be oil or natural gas.

• \( g(X_C) \): Total cost of procuring coal for both VI and NVI
firms. Let \( h(X_C) \) and \( h'(X_C) \) be the total and marginal cost of coal production and let \( P_C \) be the observed price of coal. Then for a VI firm,

\[
g(X_C) = h(X_C) \tag{2}
\]

and for a NVI firm,

\[
g(X_C) = h'(X_C) \cdot X_C \tag{3}
\]

where \( h'(X_C) > 0 \).

Since this is a regulated plant, it faces regulatory and environmental constraints. The constraint is a general one and assumed to directly affect the fuel inputs, but not labor,

\[
\bar{B} = R(X_C, X_A) \tag{4}
\]

where \( R(.) \) is twice differentiable. In the case of FAC, if both fuels are treated symmetrically then \( \partial R / \partial X_A = \partial R / \partial X_C \). If not, then \( \partial R / \partial X_A \neq \partial R / \partial X_C \) for VI plants.

Plant’s constrained cost minimization problem is given by,
\[
\text{MIN}_{X_C, X_A, X_L, \lambda_1, \lambda_2} \quad L = g(X_C) + P_A X_A + P_L X_L \\
+ \lambda_1 (\bar{Q} - Q(.)) - \lambda_2 R(X_C, X_A)
\]

(5)

where \(\lambda_1 \geq 0\) and \(\lambda_2 \geq 0\) are Lagrangian Multipliers. FOC of an interior minimum will give,

\[
\frac{\partial L}{\partial X_C} = g'(X_C) - \lambda_1 \frac{\partial Q}{\partial X_C} - \lambda_2 \frac{\partial R}{\partial X_C} = 0
\]

(6a)

\[
\frac{\partial L}{\partial X_A} = P_A - \lambda_1 \frac{\partial Q}{\partial X_A} - \lambda_2 \frac{\partial R}{\partial X_A} = 0
\]

(6b)

\[
\frac{\partial L}{\partial X_L} = P_L - \lambda_1 \frac{\partial Q}{\partial X_L} = 0
\]

(6c)

where \(\frac{\partial Q}{\partial X_i} > 0\), \(i = C, A, L\). First, consider the VI plant without the FAC. Equating for the \(\lambda_1\)s in Equation 6 will give the MRS ratios between inputs.
\[
\frac{\partial Q}{\partial X_C} = \frac{h'(X_C) - \lambda_2 \partial R/\partial X_C}{P_A - \lambda_2 \partial R/\partial X_A} \quad (7a)
\]

\[
\frac{\partial Q}{\partial X_A} = \frac{h'(X_C) - \lambda_2 \partial R/\partial X_C}{P_L} \quad (7b)
\]

\[
\frac{\partial Q}{\partial X_A} = \frac{P_A - \lambda_2 \partial R/\partial X_A}{P_L} \quad (7c)
\]

Since the MRS are not equal to the ratios of prices and/or coal production cost, VI plant is not allocatively efficient. If FAC regulation is symmetric when coal is internally produced, then fuel inputs are used efficiently. Also if labor is not included in the regulation constraint, it is not employed efficiently relative to either fuel. Following FOCs belong to the NVI plant with regulation,

\[
\frac{\partial Q}{\partial X_C} = \frac{h'(X_C) + h''(X_C)X_C - \lambda_2 \partial R/\partial X_C}{P_A - \lambda_2 \partial R/\partial X_A} \quad (8a)
\]
\[
\frac{\partial Q/\partial X_C}{\partial Q/\partial X_L} = \frac{h'(X_C) + h''(X_C)X_C - \lambda_2 \partial R/\partial X_C}{P_L}
\] (8b)

\[
\frac{\partial Q/\partial X_A}{\partial Q/\partial X_L} = \frac{P_A - \lambda_2 \partial R/\partial X_A}{P_L}
\] (8c)

As can be seen regulated NVI plant does not employ inputs efficiently. Even under the non-existence of FAC regulation when \(\lambda_2\) is zero, monopsony power makes the NVI plant underemploy coal relative to the other fuel. All regulation induced distortions disappear if the regulation is symmetric wr. to the fuel inputs. However, both distortions remain for the fuel/labor proportions.

Above model does not provide us with the mixed effects of vertical arrangement and regulation on cost efficiency. From this model one can misspecify the bias. Instead, consider that firm minimizes behavioral costs, subject to fixed output, fixed capacity with shadow input prices given by,
\[ \hat{P}_i = \Psi_i P_i \quad i = C, A, L \]  \hspace{1cm} (9)

\( \Psi_i \) is the divergence of shadow price from actual price. If \( \Psi_i > 1 \) then input is inefficiently underemployed, if \( \Psi_i < 1 \) then input is inefficiently overemployed. The case of its being unity corresponds to allocative efficiency.

Solving for the input demands from Equation 6, the behavioral cost function is,

\[ C^B(\Psi_i P_i; Q, M) = \Psi_C P_C X_C^\ast + \Psi_A P_A X_A^\ast + \Psi_L P_L X_L^\ast \] \hspace{1cm} (10)

By Shephard’s Lemma;

\[ X_h^\ast = \frac{\partial C^B}{\partial \Psi_h P_h} = \frac{1}{\Psi_h} \frac{\partial C^B}{P_h} \quad h = C, A \] \hspace{1cm} (11)

Equation (11) is not observable thus not estimable, Actual Costs are observable and estimable;

\[ C^A = P_C X_C^\ast + P_A X_A^\ast + P_L X_L^\ast \] \hspace{1cm} (12)
In (12) substitute for $X^*_L$ from (10) and substitute $X^*_h$ from (11):

\[
C^A = \frac{\partial C^B}{\Psi_L} + \frac{\partial C^B}{P_C} P_C \left( \frac{1}{\Psi_C} - \frac{1}{\Psi_L} \right) + \frac{\partial C^B}{P_A} P_A \left( \frac{1}{\Psi_A} - \frac{1}{\Psi_L} \right)
\]

If $\Psi_i = 1$ for all $i$ then cost efficiency is achieved since actual cost equals behavioral cost. Equation 12 shows that $C^B$ can be written in terms of $C^A$. Author approximates behavioral cost function with the translog behavioral cost function,

\[
\ln C^B = \delta_0 + \alpha_q (\ln Q) + \alpha_m (\ln M) + \sum \alpha_i (\ln \Psi_i P_i)
\]

\[
+ \frac{1}{2} \gamma_{qq} (\ln Q)^2 + \frac{1}{2} \gamma_{mm} (\ln M)^2 + \frac{1}{2} \gamma_{qm} (\ln Q)(\ln M)
\]

\[
+ \frac{1}{2} \sum \sum \gamma_{ij} (\ln \Psi_i P_i)(\ln \Psi_j P_j)
\]

\[
+ \sum \gamma_{iq} (\ln \Psi_i P_i)(\ln Q)
\]
\[ + \sum_i \gamma_{im}(\ln \Psi_i P_i)(\ln M) \]  

\[ \text{i,j=C,A,L and } \gamma_{ij} = \gamma_{ji} \]

Take exponential of (14) and substitute into (13),

\[
\frac{\partial C^B}{\partial P_i} = \frac{C^B}{P_i} \left[ \alpha_i + \sum_j \gamma_{ij}(\ln \Psi_j P_j) \right] + \frac{C^B}{P_i} [\gamma_{iq}(\ln Q) + \gamma_{im}(\ln M)] 
\]

\[ = \frac{C^B}{P_i} [d_i] \quad i = C, A \quad (15) \]

Substitute (15) in exponential of (14), it will give actual costs in terms of shadow prices,

\[ \ln C^A = \ln C^B + \ln \frac{1}{\Psi_L} + \left( \frac{1}{\Psi_C} - \frac{1}{\Psi_L} \right) d_C + \left( \frac{1}{\Psi_L} - \frac{1}{\Psi_L} \right) d_A \quad (16) \]

\[ M_i^B = \frac{\Psi_i P_i X_i^*}{C^B} = [d_i] \quad (17) \]
\[
M_i^A = \frac{P_i X_i^*}{C^A} = \frac{\Psi_i^{-1}[d_i]}{\left[ \frac{1}{\Psi_L} + \left( \frac{1}{\Psi_C} - \frac{1}{\Psi_L} \right) d_C + \left( \frac{1}{\Psi_A} - \frac{1}{\Psi_L} \right) d_A \right]}
\]

(18)

For incorporating information about allocative inefficiency, the author modifies Equations 16 and 18 and specify the shadow prices as:

\[
\Psi_C P_C = \exp (\rho_C + \rho_{NVI} D_{NVI} + \rho_F F + \rho_S S + \rho_W W + \rho_{NVI,W} W \times D_{NVI}) P_C
\]

(19a)

\[
\Psi_A P_A = \exp (\rho_A + \rho_F D_F) P_A
\]

(19b)

\[
\Psi_L P_L = P_L
\]

(19c)

\(D_{NVI}\): Binary variable, if the plant is NVI then it is 1, o.w. 0.

\(F\): Binary Variable, which incorporates changes in fuel costs under FAC. If FAC, F=1, o.w. 0.

\(S\): Accounts for excessive mark-ups of the transfer price of coal by VI integrated plants,
for NVI plants S=0.

\[ W = \max(0, 10000 - \text{BTUC}) \], where BTUC is the average annual BTUs per pound of coal delivered to the plant (high BTUC, high quality of coal). \( W \) measures the importance of transaction-specific investments to the plant and thus potential of monopsony power. If BTUC > 10000, \( W = 0 \), less potential of monopsony power. If BTUC < 10000, \( W > 0 \) (low quality of coal), transfer-specific inv. has to be incurred then high potential of monopsony power.

Also the intercept in (14) is modified as below to allow for differences in technical efficiency;

\[ \delta_0 = \beta_0 + \beta_E E + \beta_W W + \beta_M MP + \beta_{NVI} D_{NVI} \]

(20)

E: Total years plant has been in operation.

MP: Number of mine-mouth plants operated.
Estimated Parameters
(Absolute Value of asymptotic t-ratios are in parantheses)

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Conclusions

• After accounting for regulations, the results provide evidence for significant differences in allocative efficiency of VI vs. NVI firms.

• There are significant differences in technical efficiency of VI and NVI firms. VI increases technical efficiency.

• Transaction-specific invs. in coal mines are a source of monopsony power.

• This monopsony power is exercised by NVI plants only.