

# Biofuels and Market Power - The Case of Swedish District Heating Plants

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## Abstract

This paper tests for market power on the market for biofuels, employing a statistical model and making use of the idea of Granger causality. We use a panel data set of plant specific input prices and quantities of wood chip covering 91 Swedish district heating plants 1990-1996. If quantity Granger causes price, it is taken as an indication of market power. We find that the Swedish district heating plants to some degree have market power in the market for wood chips.

*Keywords: market power, Granger causality, VAR, biofuel, district heating.*

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## 1 Introduction

The objective of this paper is to test for market power on the market for biofuels used as an input in Swedish heating plants. To achieve our objective we employ a statistical model and make use of the idea of Granger causality. We use a panel data set covering 91 Swedish district heating plants for the period 1990 to 1996.

District heating and the use of biofuels are important parts of the Swedish policy to reduce the use of non-renewable resources, and in the long run, to phase out nuclear power in the production of heat and electricity. According to Lönner et al. (1998), there is a significant potential for increasing the use of wood fuel in Sweden, at a fairly moderate cost. Three reasons to why this potential is not realized is given by Brännlund et al. (2004). The first reason concerns the fact that domestically produced wood fuel may be too expensive relative to other fuels, due to significant costs of production and/or distribution. The second reason is possible market imperfections such as monopsony/oligopsony, and the third reason relates to the fact that potential buyers of wood fuel refrain from increasing its use due to uncertainty about future taxes and technical uncertainty.

In this paper we focus on the second explanation and investigate if the market for wood chips is characterized by imperfect competition. Although district heating and the use of biofuels are important parts of the Swedish policy to reduce the use of non-renewable resources, investigations of possible market power in the district heating sector is, to our knowledge, rare. Brännlund et al. (2004) estimate the shadow price of wood fuel, i.e., the marginal valuation of wood fuel, and compare this to the observed average market price. They argue that a significant positive difference between the shadow price and the observed price would imply market power. This paper addresses essentially the same problem as Brännlund et al (2004), but the data set in this paper contains firm specific input prices and the model is different.

At least two underlying facts provide logical sense for the market for wood chips to be considered as several local monopsonies. The transportation of

wood chips is costly and may cause market friction. Even if long transports of wood chips by train in some cases occur, are they of course limited by the rail road network. Another reason for limited competition is too few potential buyers of wood chips. Besides fuel input in the district heating sector, wood chips are used in the pulp and chipboard industries. The production of these products is concentrated to a few major plants, mostly located at the eastern coast line of Sweden. Although the district heating plants are not as sparsely distributed as the pulp and paper plants and the chipboard plants, the transportation costs, at least to some extent, rule out competition for wood chips between different district heating plants.

To test the hypothesis of market power in the Swedish wood chips market we use the Granger causality methodology, introduced by Granger (1969). A variable  $q$  is said to Granger cause variable  $p$  if the prediction of  $p$ , based on its past history can be improved by incorporating the history of  $q$ . If a market is characterized by full competition, variations in the quantity of a firm's input factor,  $q$ , will have no effect on the price,  $p$ , of that input. If, on the other hand, the firm can affect its input price by varying input quantity, the firm is said to have market power. This makes it possible to use Granger causality as an indicator of market power, as suggested by Brännlund et al. (1999).

Granger causality tests have been used in several papers and the main part concerns the relation between different economic activities and economic growth. For example, Choe (2003) investigates if foreign direct investment and gross domestic investment promote economic growth, Atukeren (1994) tests the relation between exports and economic growth, and Chen (1993) focuses on the relation between defence spending and economic growth.

The rest of this paper is organized as follows. The next section discusses the district heating sector and the market for wood chips. In section 3 we specify the model and the technique for testing market power. Section 4 presents the data and the estimation results. Finally, section 5 offers some concluding remarks.

## 2 District heating and the market for wood chips

District heating was introduced in Sweden in 1948. The main expansion occurred in the period between 1975-1985, mainly as a reaction to the oil crises of 1973 and 1979. At that time, Sweden was to a large extent dependent on oil both for district heating plants and for oil boilers in small houses and apartment blocks. During the most recent decades the use of oil boilers has decreased, and as a result the use of oil as an input in district heating plants has also decreased. In 1970 the district heating sector produced 15 TWh and in 2001 the production was 46,6 TWh. According to the Swedish district heating association the annual growth in the production of district heating will be 2-3 percent until 2010, and the long run production potential is estimated to be 80 TWh, which is about 75 percent of the market for heating today.<sup>1</sup> The future production potential in the district heating sector is, according to the Swedish district heating association, mainly put into action by building small scale district heating<sup>2</sup>, extend the use of waste heat, and by efficiency gains from connecting different district heating pipes and from increased joint production of heat and electricity<sup>3</sup>.

In 1998 almost 1 700 000 apartments and 130 000 small houses used district heating. Naturally, district heating mainly occurs in the bigger cities since the fixed cost for the pipelines and the power plant can be shared by more consumers. In Sweden there are 107 cities with more than 10 000

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<sup>1</sup>According to Statistics Sweden the total market for heating is 106 TWh in 2001. If the population does not grow faster than today, the Swedish district heating association suggests that the total need for heating actually may decrease due to efficiency gains and warmer climate.

<sup>2</sup>Small scale district heating is a smaller power plant and a local system of pipes for distributing the heat.

<sup>3</sup>According to the Swedish district heating association, the use of combined power and heating plants in Sweden is small, while 75 percent of the district heating in Finland and Denmark is produced in combined power and heat plants. By connecting the pipes from district heating in nearby cities the efficiency can be increased. For example both Linköping and Mjölby have district heating plants but the cities are connected with a 30 kilometer pipe which makes it possible for both cities to use the the cheap waste based heat during the summer, which is produced in a combined power and heat plant in Linköping.

inhabitants, and all of these cities are to some extent heated by district heating. Only 18 percent of the smaller cities with 200 to 3 000 inhabitants are partly heated by district heating. Today a typical city in Sweden with district heating is powered by 2-3 boilers for different fuels. In some cases several heating plants are connected in a district heating system. In some plants the production of heat is combined with production of electrical power and district cooling.

Traditionally the district heating sector has been considered as a natural monopoly, as only one firm provides the system of pipes for distributing the heat on a local market, typically the same firm producing the heat. There is an ongoing debate regarding the possibility for more than one firm to be connected to the system of pipes for distributing the heat.<sup>4</sup> In the Nordic countries, only Copenhagen, has competition between firms in a district heating system.<sup>5</sup> Although the district heating sector can be considered as a natural monopoly on the output market, the situation is different in the input market. Different inputs in the district heating sector have different alternative uses. For the case of oil, coal, natural gas, and electricity it is reasonable to assume that district heating power plants are price takers as these factors are traded on a global market in which the district heating plants are small buyers. Apart from the above mentioned inputs, district heating plants use various kinds of biofuels. The most important being various kind of wood fuels, such as residues from the sawmill industry, and logging residues from forestry. In contrast to other fuel inputs, such as oil, it is not as obvious that the district heating plants are price takers in the market for wood chips. This is, as mentioned before, motivated by the fact that the transportation of wood chips is costly<sup>6</sup> in combination with the

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<sup>4</sup>Besides the economic aspect of a deregulation of the district heating market, some technical aspects have to be solved such as who is to be responsible for the pressure level and the temperature level at different nodes in a system of pipes which is used by several firms.

<sup>5</sup>The firm VEK in Copenhagen buys heat from several different plants and then distributes and sells the heat to the consumers.

<sup>6</sup>Although transportation of wood chips generally is costly the combined power and heat plant in Västerås (Sweden) use wood chips which is transported over 600 kilometers

absence of many potential users of wood chips on the local market. This suggests that the district heating plants might have market power, at least locally, in this particular market.

### 3 Methodology for testing market power

Since the introduction of the "new empirical industrial organization", market power has frequently been tested within structural models. Typically, the conduct of a firm or an industry is treated as unknown parameters to be estimated jointly with cost and demand parameters. The determination of price and quantity is based on behavioral equations which are linked to, for instance, the theory of oligopoly, see for instance Appelbaum (1982), Bresnahan (1981), Porter (1983), and Roberts (1984). A survey of empirical papers in this area can be found in Bresnahan (1989). A large number of the empirical market power papers concern monopoly and oligopoly. Examples of studies of market power in input markets are Atkinson and Kerkvliet (1989), and Bergman and Brännlund (1995). An alternative approach is put forward by Brännlund et al. (1999). They use VAR and the Granger causality approach on Swedish price and quantity data for various paper products to test what they label "the small open economy hypothesis". The line of argument is that if quantities do not contribute to the explanation of future prices, the small open economy hypothesis for the Swedish forest sector is supported.

In this paper we follow the latter method and use Granger causality to test for market power. One advantage with this approach is that no restrictive assumptions concerning demand, costs, and market behavior are needed, which is the case when a structural model is used. If a market

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on rail road from Lycksele (Sweden). To make this transportation profitable Mälarenergi had to build rail road tracks to the plant and guarantee to buy all wood chips from the same supplier. In addition the company Green Cargo had to invest in new train sets. The nearby city Eskilstuna also tried to use rail road transported wood chips but this turned out to be unprofitable as the wood chips had to be reloaded and transported by truck between the rail road station and the power plant.

is characterized by perfect competition the firms are price takers. More specifically, if a firm changes its use of an input factor, the price of that factor will essentially remain unchanged. On the other hand, if a firm can systematically affect the price of an input factor by altering the input level, it suggests that the firm to some extent has market power. In this paper, we test the presence of Granger causality between the use of wood chips as an input, at the firm level, and the corresponding firm specific price of wood chips. If we find that quantity Granger cause price, we will treat this as an indicator of market power.

To perform the Granger causality test, we follow Holtz-Eakin et al. (1988) and specify time-series relations, for the price of wood chips and the quantity of wood chips:

$$p_{it} = \alpha_0 + \sum_{l=1}^m \alpha_l p_{it-l} + \sum_{l=1}^m \beta_l q_{it-l} + e_i + u_{it} \quad (1)$$

$$q_{it} = \gamma_0 + \sum_{l=1}^m \gamma_l q_{it-l} + \sum_{l=1}^m \delta_l p_{it-l} + f_i + v_{it} \quad (2)$$

where  $p_{it}$  is the firm specific wood chips price for firm  $i$  in period  $t$ , and  $q_{it}$  is the same firm's input of wood chips. The  $\alpha_l, \beta_l, \gamma_l$ , and  $\delta_l$  are unknown parameters to be estimated. The  $e_i$  and  $f_i$  are firm specific effects. The lag length,  $m$ , is assumed to be long enough to ensure white noise in the error terms  $u_{it}$  and  $v_{it}$ . We simplify the model by using the same number of lags for each right hand side variable. The quantity is said to Granger cause the price if predictions of the price, based on its history, improve by incorporating the quantity. Granger causality is present if  $H_0: \beta_1 = \beta_2 = \dots = \beta_m = 0$  is rejected. To perform the Granger causality test and investigate the presence of market power, we only need to estimate the price equations, as we use the  $\beta_l$  parameters to test whether quantity causes price or not. However, by estimating the price and quantity equations jointly, we may gain efficiency as in any other estimation procedure based on a system of equations.

The introduction of firm specific effects in a panel model with lagged dependent variables cause a problem with correlation between the lagged dependent variables and the disturbances. This problem arises in both a

fixed- and random-effects setting. To avoid this problem, we take the first difference of eqs 1 - 2 and hence eliminate  $e_i$  and  $f_i$ .

$$p_{it} - p_{it-1} = \sum_{l=1}^m \alpha_l (p_{it-l} - p_{it-l-1}) + \sum_{l=1}^m \beta_l (q_{it-l} - q_{it-l-1}) + u_{it} - u_{it-1} \quad (3)$$

$$q_{it} - q_{it-1} = \sum_{l=1}^m \gamma_l (q_{it-l} - q_{it-l-1}) + \sum_{l=1}^m \delta_l (p_{it-l} - p_{it-l-1}) + v_{it} - v_{it-1}, \quad (4)$$

The system of eqs 3 - 4 is estimated using an instrumental variable approach to avoid correlation between the dependent variables and the error terms. To obtain a sufficient number of instrumental variables for identification, the instrumental variables change for each time period. The lag length,  $m$ , is restricted by the need for instrument variables. There are  $2m$  parameters to be estimated in each equation, which implies a need for at least  $2m$  instrumental variables for each time period for identification. To satisfy the orthogonality conditions,  $2(t - 2)$  instrumental variables are available for each time period. It follows that  $t \geq m + 2$ , to ensure at least as many instrumental variables as parameters to be estimated.

As the qualitative outcome of our test of market power will depend on the significance level of the estimates and as the choice of instruments may effect the efficiency of the parameters we use two different instrument sets. Instrument set 1 is the minimum number of instruments required to identify the parameters and instrument set 2 is of the Arellano and Bond (1991) type with additional instruments for the early periods. To obtain some difference between the instrument sets we assume that the maximum lag length,  $m$ , is 2. In addition, we assume stationarity in the first differences of all variables.

The estimation procedure is performed in the following manner. Initially we determine the optimal lag length and in the second step we estimate the restricted and the unrestricted model conditional on the result from the first step. The optimal lag length is determined by estimating the price and quantity equations with lag length  $m = 2$  and  $m = 1$ . The latter will be treated as a restriction of the former and tested by a Wald test. In the

second step we impose the restriction that the quantity parameters in the price equations are zero,  $\beta_l = 0$ . In the second step we will also impose the restriction that price parameters are zero in the quantity equation,  $\delta_l = 0$ . The former will be our test of market power, that is, does quantity contribute significantly to a regression of price on its own history? If this is the case, quantity can be said to Granger cause price, which we will treat as a sign of market power. The latter is to test if price Granger causes quantity.

## 4 Data and results

Our data set is a panel of all 252 Swedish district heating power plants, covering the period between 1990 and 1996. The data are provided by Statistics Sweden. Unfortunately the data set is unbalanced. Only 43 of the 252 plants use wood chips as an input during all the 7 years in the sample, and 114 of the plants do not use wood chips at all during the sample period. In this paper our sub sample contains the plants that used wood fuel as an input during at least 4 years.

The data set contains information on every plant's use of wood chips and the corresponding cost for buying it. This makes it possible for us to calculate firm specific input prices for wood chips. In Table 1 below we present descriptive statistics for the price of wood chips and the quantity for the period 1990 to 1996. The average real price of wood chips is rather stable during the period, while the average use of wood chips has almost doubled. One interesting fact is that the standard deviation for the mean price is quite large, indicating a significant difference between the input price among the plants. The mean of real prices of wood chips over time and plants is 116 SEK/MWh.

The system of equations is estimated using GMM. The parameter estimates for the model with lag length  $m = 2$  are given in Table 2. As can be seen the efficiency of the estimates has increased, as anticipated when additional instruments are used.

In the following we will use the parameter estimates based on instrument set 2. The qualitative result concerning market power is however the same for

Table 1: Descriptive statistics (across plants)

Year	Prices in SEK/MWh		Quantities in GWh	
	Mean	Stdv	Mean	Stdv
1990	117	35.0	48.4	76.4
1991	128	49.2	58.6	95.4
1992	119	29.3	65.0	98.6
1993	115	30.6	69.2	102.5
1994	108	32.0	78.3	124.5
1995	112	35.5	73.2	114.7
1996	115	30.7	81.4	138.0

Table 2: Parameter estimates (p-values in parentheses)

Variable	Instrument set 1		Instrument set 2	
	Price eq.	Quantity eq.	Price eq.	Quantity eq.
$\Delta p_{t-1}$	-0.160 (0.005)	0.213 (<0.001)	-0.163 (<0.001)	0.170 (<0.001)
$\Delta p_{t-2}$	-0.090 (0.373)	-0.014 (0.558)	-0.016 (0.426)	-0.037 (0.006)
$\Delta q_{t-1}$	0.101 (0.127)	-0.071 (0.688)	0.006 (0.991)	-0.390 (<0.001)
$\Delta q_{t-2}$	-0.204 (<0.001)	0.341 (<0.001)	-0.128 (<0.001)	0.294 (<0.001)
Test of overidentifying restrictions for instrument set 1: 30.41 (0.016)				
Test of overidentifying restrictions for instrument set 2: 36.6 (0.128)				

Table 3: Test of parameter restrictions (p-values in parentheses)

Type of test	$\chi^2$ value	Rejection
Lag length $m = 2$	115.6 (<0.001)	NO
Granger causality $q \rightarrow p$	71.9 (<0.001)	NO
Granger causality $p \rightarrow q$	45.5 (<0.001)	NO

the estimates based on instrument set 1, although the test of overidentifying restrictions are rejected when instrument set 1 is used. The signs of the significant estimates should be interpreted with care. The reason to this is that the effect on price and quantity is the result of changes emerging from both the demand and supply side. To interpret the signs and magnitudes of the parameter estimates we would then need a structural model in order to identify shifts in both demand and supply. However, since the basic idea here is to avoid structural modelling, we refrain from any interpretation of the magnitudes of the parameters, and instead focus on statistical significance.

In the test procedure we first impose the restriction that all parameters corresponding to the second lag is zero, which means that the model will have lag length  $m = 1$ . To test this, and the following restrictions we use an ordinary Wald test. As can be seen from Table 3 below, the hypothesis of lag length  $m = 1$  is rejected and in the following we will use the model with lag length  $m = 2$ . The second step concerns market power and hence the Granger causality between quantity and price. In this test we impose the restriction that the parameters corresponding to lagged quantities in the price equation jointly are zero, that is  $\beta_1 = \beta_2 = 0$ . According to our test this restriction is rejected and hence we can not reject Granger causality between quantity and price. In the last step we check if price Granger causes quantity. This is done by testing if the parameters corresponding to lagged prices are jointly zero in the quantity equations, that is  $\delta_1 = \delta_2 = 0$ . Also this restriction is rejected which implies that price Granger causes quantity.

## 5 Concluding comments

In this paper we have used the concept of Granger causality to investigate possible market power in the Swedish district heating input market of wood chips. According to our findings the history of quantities is important when explaining the price by its own history, that is, the quantity of wood chips Granger cause the price of wood chips. This result indicates that the Swedish district heating sector may have market power in the market for wood chips. The district heating power plants may have local monopsony due to the combination of significant transportation cost of wood chips and few or no competing users of wood chips in the local market. For short distance transports of wood chips ordinary trucks are used. For long distance transportation this is too expensive and special sets of trains is used. The use of rail road transportation may imply two reloads of wood chips (from truck to train and from train to truck) which, of course, may be expensive. As a consequence it is reasonable to assume that the transportation cost of wood chips will dampen the competition between potential users that are not located in the same area. However, as pulp and paper and chipboard is produced at few major plants, and in most cases far from a district heating plant, the competition over wood chips in the local market is small. In the future, competition in the local market may increase as the use of district heating increase in combination with an increase in the use of wood chips as an input in the district heating sector. In addition, the use of wood chips in the production of ethanol used in cars may lead to more intense competition.

The hypothesis that the Swedish market for wood chips can be considered as a local monopsony is also supported in Brännlund et al. (2004). In addition, they conclude that the market power seems to have decreased over time. Unfortunately our analysis can not capture the degree of market power and as a consequence our results can neither reject nor support decreasing market power over time.

One shortcoming with this paper is the fact that we have no information in this data set about the different plants' location. Such information would make it possible to investigate possible market power for different plant

clusters.

Interesting extensions to this paper would be to investigate at least three issues: (1) Is market power present in this particular market all over Sweden? A few more observations for every plant in combination with information about the plants' location would make it possible to investigate possible market power for geographical subgroups. (2) What is the source to market power in this particular market? (3) What is the relation between the structure of the market and the fact that 110 of the 252 plants did not use wood chips at all during the sample period. In addition, it would be interesting to investigate why 95 of the plants entered the market for wood chips during only some of the years in the sample.

## References

- Appelbaum, E., 1982 , The Estimation of the Degree of Oligopoly Power, *Journal of Econometrics* 19, 287-299.
- Arellano, M and S. Bond, 1991, Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *Review of Economic Studies*, 58, 277-297.
- Atkinson, S. E. and J. Kerkvliet, 1989, Dual Measures of Monopoly and Monopsony Power: An Application to Regulated Electric Utilities, *Review of Economics and Statistics*, 71, 250-257.
- Aturkeren, E., 1994, A Note on the Tests of Granger-Causality Between Exports and Economic Growth, *Applied Economics Letters*, 1, 207-209.
- Bergman, M. and R. Brännlund, 1995, Measuring Oligopsony Power: An Application to the Swedish Pulp and Paper Industry, *Review of Industrial Organization* 10, 307-321.
- Bresnahan, T.F., 1981, Departures from Marginal-Cost Pricing in the American Automobile Industry: Estimates for 1977-1978, *Journal of Econometrics*, 11, 201-227.

- Bresnahan, T.F., 1989, Empirical Studies of Industries with Market Power in R. Schmalensee and R. Willig , eds, *Handbook of Industrial Organization*, Elsevier Science Publishing Company, Amsterdam.
- Brännlund, R., P-O. Marklund and M. Sjöström, 2004, Evaluating Market Efficiency without Price Data: The Swedish Market for Wood Fuel, *Applied Economics*, 36, 31-39.
- Brännlund, R., K-G. Löfgren and S. Sjöstedt, 1999, Forecasting Prices of Paper Products: Focusing on the Relation Between Autocorrelation Structure and Economic Theory, *Journal of Forest Economics* 5, 23-44.
- Chen, C-H., 1993, Causality Between Defence Spending and Economic Growth: The Case of Mainland China, *Journal of Economic Studies* 20, 37-43.
- Choe, J., 2003, Do Foreign Direct Investment and Gross Domestic Investment Promote Economic Growth?, *Review of Development Economics* 7, 44-57.
- Granger, C.W.J., 1969, Investigating Causal Relations by Econometric Models and Cross-Spectral Methods, *Econometrica* 37, 424-438.
- Holtz-Eakin, D., W. Newey and H. Rosen, 1988, Estimating Vector Autoregressions with Panel Data, *Econometrica* 56, 1371-1395.
- Lönner, G., B-O. Danielsson, B. Vikinge, M. Parikka, B. Hektor, and P. O. Nilsson, 1998, Kostnader och tillgänglighet för trädbränslen på medellång sikt, Rapport från Vattenfall AB.
- Porter, R.H., 1983, A Study of Cartel Stability: the Joint Executive Committee, 1880-1886, *Bell Journal of Economics* 14, 301-314.
- Roberts, J., 1984, Testing Oligopolistic Behavior, *International Journal of Industrial Organization* 2, 367-383.
- Swedish district heating association, 2004a , Fjärrvärmens och Miljön, <http://www.fjarrvarme.org>
- Swedish district heating association, 2004b, Fjärrvärme i Framtiden: Prognos och Potential för Fjärrvärmens Fortsatta Utveckling i Sverige, <http://www.fjarrvarme.org>