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Measuring market power for some industrial sectors in Austria

KARL AIGINGER*‡, PETER BRANDNER*§ and MICHAEL WÜGER*

**Austrian Institute of Economic Research, A-1103 Vienna, PO Box 91, Austria,* ‡*Department of Economics, University of Linz, A-4040 Linz, Austria* and §*Department of Economics, University of Vienna, A-1010 Vienna, Austria*

This paper applies an oligopoly model which parameterizes the degree of market power for two industrial sectors (glass industry, non-electrical machinery) in Austria In contrast all other papers in the New Empirical Industrial Organization literature we account for the non-stationarity characteristics of the data series A dynamic specification procedure which assumes structural long-run equilibrium relationships is therefore applied Since a simultaneous system with non-linear cross-equation restrictions is implied by the economic model, a full information maximum likelihood method is used. The data reveal a higher degree of market power for the glass industry than for non-electrical machinery; this hierarchy is in line with the position of these industries for concentration rates and Herfindahl indices.

I. INTRODUCTION

This paper estimates the degree of market power for two industrial sectors (glass industry, non-electrical machinery) in Austria. The economic model applied is an oligopoly model which parameterizes the degree of price-setting power. Following the NEIO tradition (New Empirical Industrial Organization, see Appelbaum, 1982; Bresnahan, 1982, 1989; Lau, 1982) we use time-series data to reveal the degree of market power by a system of a supply relation, a demand function and a set of factor input-demand functions. To overcome the identification problem we utilize a method proposed by Appelbaum (1982) As usual in NEIO models we need no direct measurement of marginal costs and/or accounting data for profits.

In contrast to other papers in the NEIO literature we account for the non-stationarity characteristics of many data series. We apply a dynamic specification procedure which assumes structural long-run equilibrium relationships which are not holding in each moment of time. In a similar context Sengupta (1992) applied a two-step procedure due to Engle and Granger (1987) for production and cost frontiers We use a different error correction representation recently suggested by Phillips and Loretan (1991). This means including lagged equilibrium relationships rather than lagged differences of the dependent variables as covariates. Since we have a simultaneous system with non-linear cross-equation restrictions implied by the economic model we use a full information maximum likelihood method

The further structure of the paper is as follows. Section II presents the oligopoly model used, Section III its specification to cope with the non-stationarity of the time series. Section IV describes the data, the econometric model estimated and interprets the results, especially the conduct parameter θ and the degree of oligopoly power L for the two industries in Austria. A comparison of the degree of oligopoly power revealed by similar estimates in the literature and with Herfindahl indices and concentration rates estimated is presented. The conclusions are summarized in Section V

II THE TRADITIONAL NEIO MODEL

New empirical industrial organization models infer information about market power without depending on the information about marginal costs and accounting profits. The combination of a demand function and a supply relation reveals in principle how competitive an industry is. The economic reason is that supply reacts differently on demand shifts according to whether it is competitive or monopolistic. The econometric problem is that specific exogenous variables are needed to identify the supply relation (one variable that shifts demand and one which changes its steepness; see Bresnahan (1982); Lau (1982)). This classical identification problem can be mitigated if a block of input-demand functions is included. Then the micro model consists of a demand Equation, 1, a supply relation, 2 and a factor input-demand system, 3.

In a non-competitive industry s firms produce (homogeneous) output y using n inputs, $x = x_1, \ldots, x_n$. Demand is given by

$$y = J(p, z) \tag{1}$$

where p is the output price and z is a vector of exogenous variables. Profit maximization under oligopoly yields the well-known optimality condition that 'perceived marginal revenue equals marginal costs':

$$p(1 - \theta^j \varepsilon) = \partial C^j(y^j, w)/\partial y^j \tag{2}$$

where

$$\theta^j = (\partial y/\partial y^j)(y^j/y)$$

The interesting additional term (the second one in the bracket on the left side of Equation 2) is the product of θ^j and ε.[1] The first term is the conjectural elasticity of total industry output to the output of the jth firm, the second is the inverse (absolute) market elasticity of demand. θ is the crucial conduct parameter which lies between 0 (for competitive behaviour) and 1 (for monopoly). The aggregate degree of monopolistic behaviour of the industry can then be defined as $L = \sum \theta_j s_j \varepsilon$, where $s_j = y_j/y$.[2] The input demand functions can be derived from the cost function according to Shephard's lemma (assuming that all firms face the same input prices) and is given by

$$x^j = \partial C^j(y^j, w)/\partial w \tag{3}$$

The supply relation can be formed into an aggregate one (Equation 6) if we assume $\theta = \theta^j$ implying some kind of 'average industry conduct' (Cowling and Waterson, 1976). The aggregate measure of oligopoly power is therefore $L = \theta\varepsilon$. Equations 4–6 denote the aggregate model

$$y = J(p, z) \tag{4}$$

$$x = y[\partial C(w)/\partial w] + \sum \partial G^j(w)/\partial w \tag{5}$$

$$p(1 - \theta\varepsilon) = C(w) \tag{6}$$

$$\ln y = a + \mu \ln(p/S) + \rho \ln(q/S) \quad \mu = 1/\varepsilon \tag{7}$$

For the input demand function it is convenient to assume linear and parallel expansion paths (Gorman polar form cost functions so that marginal costs are constant and equal across firms). So we obtain Equation 5 for the aggregate costs and then Equation 8 as the empirical specification (if we finally assume costs to follow the generalized Leontieff cost function):

$$c = \sum_i \sum_j b_{ij}(w_i w_j)^{\frac{1}{2}} y + \sum_i b_i w_i \quad i, j = K, L, M \tag{8}$$

where

$$b_{ij} = b_{ji} \quad \text{and} \quad \sum b_i w_i = \sum G^j(w)$$

Factor input demand (Equations 9–11) follows by Shephard's lemma:

$$x_K = b_{KK} y + b_{KL}(w_L/w_K)^{\frac{1}{2}} y + b_{KM}(w_M/w_K)^{\frac{1}{2}} y + b_K \tag{9}$$

$$x_L = b_{LL} y + b_{KL}(w_K/w_L)^{\frac{1}{2}} y + b_{LM}(w_M/w_L)^{\frac{1}{2}} y + b_L \tag{10}$$

$$x_M = b_{MM} y + b_{KM}(w_K/w_M)^{\frac{1}{2}} y + b_{LM}(w_L/w_M)^{\frac{1}{2}} y + b_M \tag{11}$$

The supply relation used for the estimation is derived from the optimality condition, 6, and is given by

$$\begin{aligned} p = [&b_{KK} w_K + b_{LL} w_L + b_{MM} w_M \\ &+ 2b_{KL}(w_K w_L)^{\frac{1}{2}} + 2b_{KM}(w_K w_M)^{\frac{1}{2}} \\ &+ 2b_{LM}(w_L w_M)^{\frac{1}{2}}]/[1 - \theta/\mu] \end{aligned} \tag{12}$$

As empirical specification for the demand function we use the Cobb-Douglas form, Equation 7. The equilibrium conjectural variation is taken to be a function of the input prices $\theta = \theta(w)$. We add import prices (pm) as a proxy for the changing pressure from foreign demand in an open economy (see Equation 13). Competition from abroad is intensive if capacities are underutilized and less in booms. Import prices may represent this cyclical component. European integration progressed between the 1960s and the 1980s, possibly eroding monopoly power over time. Therefore a time trend (t) was also added for the specification of the equilibrium conjectural variation.[3]

$$\theta = \theta(w, pm, t) \tag{13}$$

For the empirical implementation the model has to be imbedded within a stochastic framework.

[1] The product is sometimes labelled as the 'degree of monopoly power of the jth firm'.

[2] There is a relation between this measure L and the Herfindahl index. The Herfindahl index is conceptionally a measure of concentration (the sum of squared market shares). The 'degree of monopoly power' captures explicit conduct. Both measures lie between zero and one, and are equal if $\varepsilon(\delta y/\delta y_j) = 1$. If many firms exist, L becomes larger than H (for m firms of equal size $L = \varepsilon \sum 1/m$, while $H = \sum 1/m^2$). If there are very few suppliers, L becomes smaller than H (for one firm $L = \varepsilon$, where profit maximization implies that $\varepsilon \leqslant 1$; $H = 1$).

[3] Despite our effort to give more economic content to this equation, Equation 13 remains one of the weak points in the NEIO models. The micro model 1–3 disregards business cycles as well as the changing pressure from foreign competition. From the economic point of view the equation corrects for differences in the static micro model and real-world aggregate fluctuations. From the statistical point of view Equation 13 helps to identify the model parameters in a complicated non-linear model.

III THE ECONOMETRIC SPECIFICATION

It has become evident that many economic data series are non-stationary and the conventional techniques of statistical inferences are invalid. As a preliminary exercise we performed unit root tests of the variables of the NEIO model, constructed from our basis data (inputs, outputs, price indices, cost data). We estimated Augmented Dickey–Fuller (ADF) statistics to correct for possible autocorrelation. The relevant t-ratios, constructed both with a constant and with a constant and a time trend, are reported in Table 1. In most cases the null hypothesis of a unit root cannot be rejected at a 5% significance level, only three variables require a 1% significance level to hold the unit root hypothesis. Although some variables seem to contain a second unit root, we attribute this finding to the problem of limited reliability of unit root tests in small samples.

Indirect evidence of unit roots in the data is obtained from the naive estimation of the system Equations 7, 9–12. The coefficients of determination are high, but the low DW-statistics point to the well-known problem of spurious regression (Granger and Newbold, 1974; Phillips, 1986). Taking together the formal and informed evidence we did not estimate the static model but preferred a dynamic specification which is based on structural long-run equilibrium relationships representing the economic model.

Let us define y as any endogenous variable in one of the Equations 7, 9–12 and x as a matrix of exogenous variable

Table 1 *Unit root tests: Augmented Dickey–Fuller*[a]

	Glass		Non-electrical machinery	
Variable	τ_μ	τ_τ	τ_μ	τ_τ
x_K	− 0.69	− 3.02	− 0.94	− 3.40
x_L	− 1.72	− 1.96	− 1.56	− 2.63
x_M	1.35	− 1.24	0.07	− 2.60
$(w_L/w_K)^{\frac{1}{2}}y$	1.63	− 1.47	0.52	− 2.18
$(w_M/w_K)^{\frac{1}{2}}y$	− 0.22	− 3.73	− 0.03	− 2.08
$(w_K/w_L)^{\frac{1}{2}}y$	1.09	− 1.48	− 0.66	− 2.17
$(w_M/w_L)^{\frac{1}{2}}y$	− 0.45	− 3.62	− 0.56	− 1.93
$(w_K/w_M)^{\frac{1}{2}}y$	1.80	− 0.41	− 0.25	− 2.33
$(w_L/w_M)^{\frac{1}{2}}y$	2.10	− 0.28	0.33	− 2.26
y	1.36	− 1.54	− 0.04	− 2.17
$\ln y$	− 0.11	− 3.91	− 1.39	− 1.80
$\ln(p/S)$	0.19	− 2.24	− 2.33	− 2.63
$\ln(q/S)$	− 2.22	− 1.61	− 2.22	− 1.61
w_K	0.69	− 2.89	0.51	− 2.85
w_L	1.39	− 3.05	1.85	− 1.36
w_M	− 1.90	− 1.76	− 0.64	− 2.26
pm	− 0.82	− 1.99	− 0.82	− 1.99

[a]Approximate critical values at 5% are − 2.86 for τ_μ and − 3.41 for τ_τ. One lag was used in computing the ADF statistics, additional lags did not change the results.

and α as their vector of parameters. Equation 15 can be seen as a long-run relation. If both y and x are $I(1)$ (integrated of order one) and a linear combination $y_t - \alpha' x_t$ is $I(0)$ (stationary), y and x are said to be cointegrated and an error-correction representation (Equation 15) exists (Engle and Granger, 1987):

$$y_t = \alpha' x_t + u_{1t} \tag{14}$$

$$\Delta y_t = -\gamma(y_{t-1} - \alpha' x_{t-1}) + \sum_{i=1}^{k} \beta_{1i} \Delta y_{t-i} + \sum_{i=0}^{l} \beta_{2i} \Delta x_{t-i} + u_{2t} \tag{15}$$

u_{it} is a covariance stationary error term. In order to have adequately represented the information set in the past history of Δy_t and present and past history of Δx_t, we have to allow $k, l \to \infty$ as the sample size T runs to infinity.

Recently Phillips and Loretan (1991) argue that one problem with the ECM representation (Equation 15) is that the coefficients, in general, do not decay as the lag increases. Thus, in order to model short-run dynamics using Δy_{t-i} and Δx_{t-i} it is necessary, in general, to include all lags. This happens because the truncation error is non-negligible due to shock persistence. Therefore Phillips and Loretan (1991) strongly suggest the following non-linear representation:

$$y_t = \alpha' x_t + \sum_{j=1}^{\infty} \beta_{0j}(y_{t-j} - \alpha' x_{t-j}) + \sum_{j=0}^{\infty} \beta_{1j} \Delta x_{t-j} + v_t \tag{16}$$

In the general case one has to include leads of Δx_t in the regression to ensure that in the limit v_t is orthogonal to the entire history of Δx_t. This will produce an asymptotically efficient estimator of α.

Another advantage of the representation in Equation 16 – as argued by Phillips and Loretan (1991) – follows from the fact that the error v_t is a martingale difference sequence. Therefore inference can proceed in the usual way with asymptotic normal t-ratios and asymptotic chi-squared criteria constructed in the usual fashion.

This econometric specification maintains all implications of the economic model. The theoretically derived relations between the variables are the steady-state relations, e.g. long-run relationships. A similar procedure that combines integrating processes with the steady state equilibrium notion was recently carried out by Sengupta (1992) for production and cost functions, drawing on the commonly used error correction representation in Equation 15. We, however, formulate all equations according to the representation in Equation 16.

Testing for cointegration in the NEIO model is much more difficult than testing for unit roots. Multivariate tests cannot be applied because too few degrees of freedom are left, and tests of single cointegrating relationships cannot be performed (*ex ante*) because of cross-equation restrictions. However, the successful dynamic specification strategy should provide (*ex post*) indirect evidence of cointegration among the variables.

We simplified the estimation of the whole system by a stepwise procedure, because of numerical problems. First we estimated the block of the three factor input Equations 9–11. To account for the non-linear cross-equation restrictions implied by the model we estimate this subsystem with a full information maximum likelihood method (FIML). Conditional on this estimate we constructed a hypothetical output price under perfect competition. Then we regressed the variables under consideration to explain the degree of monopoly power (see Equation 13), on the relation between the observed output price and the hypothetical output price. Finally to obtain the θ's we combined this result with the price elasticity (μ) estimated from the demand function, Equation 7.

IV. RESULTS

Data from 1960 to 1990 are taken from the WIFO macroeconomic database. Output is gross value-added, which is available in nominal and real terms (giving an implicit price). We have three inputs: capital, employment and materials. Several choices had to be made in accounting input quantity and prices. We choose employment as the labour input (instead of hours), we choose capital services (instead of a stock variable) and had to calculate a crude measure of unit costs (without taxes, keeping depreciation constant). We heroically assumed that the material input could be inferred by the difference between gross and net output and that the implicit price for this difference would be something like a consistently calculated materials price index. Testing some alternatives gives us some confidence that the results should not depend on our choices.

We concentrated on two branches: glass industry and non-electrical machinery. We started from the set of all 20 branches and wanted to include at least one which could be assessed as imperfectly competitive and one which was rather competitive for *a priori* reasons like the number of firms, concentration ratios, etc. *A priori* the glass industry can be considered as monopolistic and non-electrical machinery as competitive. Knowing the problems of the available data involved, we should be careful in interpreting the results.

The glass industry is a relatively small industry producing 2% of industrial output. There are 56 firms, the largest 4 firms producing 85% of industrial output. The non-electrical machinery sector produces 13% of output (718 firms). The largest 4 firms produce only 11%. Import pressure as well as exports have risen considerably in the last decades.

Table 2 *Indicators of oligopoly power 1963–90*

	Glass		Non-electrical machinery	
	θ	L	θ	L
1963	0.54926	0.44817	0.39499	0.32661
1964	0.53202	0.43410	0.38366	0.31725
1965	0.56784	0.46333	0.37065	0.30649
1966	0.54047	0.44100	0.36390	0.30091
1967	0.51976	0.42410	0.34927	0.28881
1968	0.51332	0.41885	0.35370	0.29247
1969	0.49670	0.40529	0.33716	0.27880
1970	0.48993	0.39976	0.31763	0.26264
1971	0.42256	0.34479	0.29457	0.24358
1972	0.39745	0.32430	0.26232	0.21691
1973	0.33346	0.27209	0.25471	0.21062
1974	0.28030	0.22871	0.21722	0.17962
1975	0.33577	0.27397	0.21892	0.18102
1976	0.31128	0.25399	0.22198	0.18355
1977	0.28632	0.23362	0.21041	0.17399
1978	0.28432	0.23199	0.21076	0.17427
1979	0.35366	0.28857	0.20337	0.16816
1980	0.26609	0.21711	0.18525	0.15318
1981	0.25543	0.20842	0.13879	0.11477
1982	0.24312	0.19837	0.15768	0.13038
1983	0.24141	0.19698	0.16256	0.13442
1984	0.26069	0.21271	0.14895	0.12317
1985	0.25704	0.20973	0.15678	0.12964
1986	0.31310	0.25548	0.15081	0.12470
1987	0.29803	0.24318	0.15595	0.12895
1988	0.26490	0.21615	0.13419	0.11096
1989	0.26216	0.21391	0.12106	0.10010
1990	0.24018	0.19597	0.09891	0.08179

The empirical results are structured in the following way. The model estimation results of the system are presented in Appendices A and B. During the specification process we eliminated variables which had no statistical influence. The coefficients of determination are around 0.9; the DW statistics indicate that for most equations there are no considerable problems with autocorrelation.

Table 2 presents the values of θ, the critical parameter indicating the degree of conjectural variation. Following the tradition created by Appelbaum (1982) we also present the 'measure of oligopoly power', L (which is $\theta\varepsilon$), though the information is somewhat redundant.

The values of θ and L are declining over time in both branches, indicating that monopoly power declines over time. Declining market power over time seems an economically plausible result arising from the European integration process. Import and export ratios increased considerably in Austria between 1960 and 1990.[4]

[4]Indicators about the change in the concentration rates are available for a slightly different statistical breakdown than imports. Therefore it is not possible to calculate import adjusted concentration rates. Since the concentration rates in the glass industry and for the majority of the three-digit industries in non-electrical machinery declined between 1976 and 1988 while the imports were increasing, we can conclude that import adjusted concentration rates must have decreased. This is in line with the market power indicator in our calculations.

Table 3. *Oligopoly power revealed by NEIO in comparison to concentration index*[a]

	Average		1963		1990		$CR4_{1983}$ (%)	Rank of $CR4_{1983}$ among 19 industries	$HERF_{1983}$	Rank of $HERF_{1983}$ among 19 industries
	θ	L	θ	L	θ	L				
Glass industry	0.36	0.29	0.55	0.45	0.24	0.20	85	(3)	0.32	(3)
Non-electrical machinery	0.23	0.19	0.39	0.33	0.10	0.08	11	(19)	0.006	(17)

[a] $CR4$ = employment share of the 4 largest enterprises. $HERF$ = Herfindahl index.

Table 4. *Comparison of results for L with the literature (summary of existing empirical work)*

Author	Industry	L
Aiginger–Brandner–Wüger	Glass industry	0.295
Aiginger–Brandner–Wüger	Non-electrical machinery	0.194
Appelbaum (1982)	Electrical machinery	0.198[a]
Appelbaum (1982)	Rubber	0.049[a]
Appelbaum (1982)	Textile	0.072[a]
Appelbaum (1982)	Tobacco	0.648[a]
Bresnahan (1981)	Automobiles (1970s)	0.1/0.34[b]
Lopez (1984)	Food processing	0.504
Porter (1983)	Railroads	0.40[c]
Roberts (1984)	Coffee roasting	0.055/0.025[d]
Slade (1987)	Retail gasoline	0.10
Spiller–Favaro (1984)	Banks 'after'[e]	0.40/0.16[f]
Spiller–Favaro (1984)	Banks 'before'[e]	0.88/0.21[f]
Suslow (1986)	Aluminium (interwar)	0.59

[a] At sample midpoint
[b] Varies by type of car; larger in standard, luxury segment
[c] When cartel was succeeding: 0 in reversionary periods
[d] Largest and second largest firm, respectively
[e] Uruguayan banks before and after entry deregulation
[f] Large firms/small firms.

The competitiveness of the branches differs as expected. The average conduct parameter θ (see Table 3) is 0.23 for non-electrical machinery, but 0.36 for the glass industry. The 'degree of monopoly power' is lower in the first case (L is 0.19 respectively 0.29).

The estimates imply that on the average of the observation period the price in the glass industry is 41% higher than in the competitive case, and 23% for non-electrical machinery.

This relative competitiveness corresponds to the ranking of the branches in the concentration indices. The glass industry is the third most concentrated among Austrian industries according both to concentration rate (share of largest four firms in employment) and to the Herfindahl index; non-electrical machinery ranks 17th or 19th according to these measures.

As expected, the absolute level of the Herfindahl index is pretty close to that of L for the more concentrated industry, but far below for the more competitive non-electrical machinery (0.006).

Table 4 shows the estimates for L from other empirical studies (for a survey and the references in this table see Bresnahan, 1989). Our results for non-electrical machinery are similar to Appelbaum's (1982) results for electrical machinery.

V. TENTATIVE CONCLUSIONS

New empirical industrial organization (NEIO) estimates the actual degree of market power without explicit data on marginal costs and profits. Some dependence of the results on data problems remains since available price data and measures of the factor inputs contain measurement errors and some degree of ambiguity.

The identification problem can be dealt with in different ways. We used a set of input-demand equations and specified a separate equation for the equilibrium rate of conjectural variation. In contrast to all other NEIO papers we are aware of, and explicitly deal with, the non-stationarity of the data. This is crucially important for correct specification and inference.

The results are presented for two industrial sectors in Austria. They conform with the *a priori* notion that the glass industry is rather monopolistic and that the non-electrical machinery is more competitive. The hierarchy is the same as revealed by Herfindahl indices and concentration ratios which, however, only measure structure, while the degree of revealed monopoly power includes actual conduct.

The present paper is an intermediate step towards a complete dynamic approach in new empirical industrial organization. We started from a static economic model and added a dynamic specification procedure which has this static model as a long-run solution. The non-stationarity, the non-linearity and the number of cross-equation restrictions necessitated complex estimation problems which were finally surmounted. The next step is to start with a dynamic economic model. This, however, goes beyond the scope of the paper.

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APPENDIX A: ESTIMATION RESULTS FOR THE OLIGOPOLY MODEL OF THE GLASS INDUSTRY

The following equations have been estimated:

$$x_{Kt} = b_{KK}y_t + b_{KL}(w_{Lt}/w_{Kt})^{\frac{1}{2}}y_t + b_K + \sum_{i=1}^{3} e_{1i}[x_{Kt-i} - b_{KK}y_{t-i} - b_{KL} \times (w_{Lt-i}/w_{Kt-i})^{\frac{1}{2}}y_{t-i} - b_K] + u_{9t} \quad (A9)$$

$$x_{Lt} = b_{LL}y_t + b_{KL}(w_{Kt}/w_{Lt})^{\frac{1}{2}}y_t + b_{LM}(w_{Mt}/w_{Lt})^{\frac{1}{2}}y_t + e_{21}[x_{Lt-1} - b_{LL}y_t - b_{KL}(w_{Kt-1}/w_{Lt-1})^{\frac{1}{2}}y_{t-1} - b_{LM}(w_{Mt-1}/w_{Lt-1})^{\frac{1}{2}}y_{t-1}] + u_{10t} \quad (A10)$$

$$x_{Mt} = b_{MM}y_t + b_{LM}(w_{Lt}/w_{Mt})^{\frac{1}{2}}y_t + \sum_{i=1}^{2} e_{3i}[x_{Mt-i} - b_{MM}y_{t-t} - b_{LM}(w_{Lt-i}/w_{Mt-i})^{\frac{1}{2}}y_{t-i}] + u_{11t} \quad (A11)$$

$$\ln y_t = a + \mu\ln(p_t/S_t) + \rho\ln(q_t/S_t) + \sum_{i=1}^{2} e_{4i}[\ln y_{t-i} - a - \mu\ln(p_{t-i}/S_{t-i}) + \rho\ln(q_{t-i}/S_{t-i})] + d_{41}\Delta\ln(p_t/S_t) + u_{12t} \quad (A12)$$

$$p_t/[b_{KK}w_{Kt} + b_{LL}w_{Lt} + b_{MM}w_{Mt} + 2b_{KL}(w_{Kt}w_{Lt})^{\frac{1}{2}} + 2b_{LM}(w_{Lt}w_{Mt})^{\frac{1}{2}}] = [1 - (\beta_0 + \beta_{trend}t + \beta_1\Delta pm_t + \beta_3\Delta w_{Lt} + \beta_{l1}\Delta pm_{t-1} + \beta_{l2}\Delta w_{Kt-1} + \beta_{13}\Delta w_{Lt-1})]^{-1} + u_{13t} \quad (A13)$$

The results are summarized in Tables A1–A4.

Table A1. *Estimation results of Equations A9–A11*

Parameter	Estimate	SE[a]	*t*-statistics
b_{KK}	−0.569734	0.416951	−1.36643
b_{KL}	0.620456	0.381169	1.62777
b_K	0.688165	0.488996	1.40730
e_{11}	0.742751	0.291162	2.55099
e_{12}	−0.628400	0.228004	−2.75609
e_{13}	0.432237	0.210940	2.04909
b_{LL}	−0.658305	0.395322	−1.66524
b_{LM}	0.251822	0.048132	5.23194
e_{21}	0.953677	0.027400	34.8062
b_{MM}	0.223562	0.055707	4.01318
e_{31}	0.772450	0.362450	2.13119
e_{32}	−0.380190	0.416816	−0.912129

[a]SE is standard error.

Table A2 *Estimation results of Equation A12*

Parameter	Estimate	SE[a]	*t*-statistics
a	−2.47903	1.14815	−2.15915
μ	−1.22556	0.318619	−3.84648
ρ	0.982905	0.247760	3.96716
e_{41}	0.789863	0.193683	4.07813
e_{42}	−0.255698	0.186089	−1.37406
d_{41}	0.322893	0.341552	0.945371

[a]SE is standard error

Table A3 *Estimation results of Equation A13*

Parameter	Estimate	SE[a]	*t*-statistics
β_0	0.641696	0.009437	67.9993
β_1	−0.003367	0.001710	−1.96928
β_3	−0.018883	0.003977	−4.74803
β_{trend}	−0.008013	0.001033	−7.75360
β_{t1}	0.003653	0.002171	1.68287
β_{t2}	−0.013188	0.006695	−1.96991
β_{t3}	−0.011701	0.003990	−2.93244

[a]SE is standard error

APPENDIX B: ESTIMATION RESULTS FOR OLIGOPOLY MODEL FOR NON-ELECTRICAL INDUSTRY

The following equations have been estimated:

$$x_{Kt} = b_{KK} y_t + b_{KL}(w_{Lt}/w_{Kt})^{\frac{1}{2}} y_t + b_{KM}(w_{Mt}/w_{Kt})^{\frac{1}{2}} y_t + \sum_{i=1}^{3} e_{1i}[x_{Kt-i} - b_{KK} y_{t-i} - b_{KL}(w_{Lt-i}/w_{Kt-i})^{\frac{1}{2}} \times y_{t-i} - b_{KM}(w_{Mt-i}/w_{Kt-i})^{\frac{1}{2}} y_{t-i}] + u_{9t} \quad \text{(B9)}$$

$$x_{Lt} = \mathrm{d}b_{LL} y_t + b_{KL}(w_{Kt}/w_{Lt})^{\frac{1}{2}} y_t + b_{LM}(w_{Mt}/w_{Lt})^{\frac{1}{2}} y_t + e_{21}[x_{Lt-1} - b_{LL} y_t - b_{KL}(w_{Kt-1}/w_{Lt-1})^{\frac{1}{2}} y_{t-1} - b_{LM}(w_{Mt-1}/w_{Lt-1})^{\frac{1}{2}} y_{t-1}] + u_{10t} \quad \text{(B10)}$$

$$x_{Mt} = b_{MM} y_t + b_{LM}(w_{Lt}/w_{Mt})^{\frac{1}{2}} y_t + b_M + e_{31}[x_{Mt-1} - b_{MM} y_{t-1} - b_{LM} \times (w_{Lt-1}/w_{Mt-1})^{\frac{1}{2}} y_{t-1} - b_M] + u_{11t} \quad \text{(B11)}$$

$$\ln y_t = a + \mu \ln(p_t/S_t) + \rho \ln(q_t/S_t) + e_{41}[\ln y_{t-1} - a - \mu \ln(p_{t-1}/S_{t-1}) + \rho \ln(q_{t-1}/S_{t-1})] + u_{12t} \quad \text{(B12)}$$

Table A4 *Estimation results of Equations A9–A13*[a]

Equation A9			
Mean of dependent variable	= 0.664058	SE of regression	= 0.151771
SD of dependent variable	= 0.403353	R^2	= 0.856278
Sum of squared residuals	= 0.644967	Durbin-Watson statistic	= 2.10287
Variance of residuals	= 0.023035		
Equation A10			
Mean of dependent variable	= 2.24307	SE of regression	= 0.087504
SD of dependent variable	= 0.377877	R^2	= 0.945275
Sum of squared residuals	= 0.214394	Durbin-Watson statistic	= 2.11901
Variance of residuals	= 0.007657		
Equation A11			
Mean of dependent variable	= 2.43183	SE of regression	= 0.110591
SD of dependent variable	= 1.48424	R^2	= 0.994811
Sum of squared residuals	= 0.342448	Durbin-Watson statistic	= 1.99679
Variance of residuals	= 0.012230		
Equation A12			
Mean of dependent variable	= 1.56915	SE of regression	= 0.055916
SD of dependent variable	= 0.489543	R^2	= 0.989374
Sum of squared residuals	= 0.068786	Adjusted R^2	= 0.986959
Variance of residuals	= 0.003127	Durbin-Watson statistic	= 2.10234
Equation A13			
Mean of dependent variable	= 1.62403	SE of regression	= 0.072546
SD of dependent variable	= 0.341838	R^2	= 0.964976
Sum of squared residuals	= 0.110522	Adjusted R^2	= 0.954969
Variance of residuals	= 0.005263	Durbin-Watson statistic	= 1.70881

[a]SE is standard error, SD standard deviation

$$p_t/[b_{KK}w_{Kt} + b_{LL}w_{Lt} + b_{MM}w_{Mt} + 2b_{KL}(w_{Kt}w_{Lt})^{\frac{1}{2}} + 2b_{KM}(w_{Kt}w_{Mt})^{\frac{1}{2}} + 2b_{LM}(w_{Lt}w_{Mt})^{\frac{1}{2}}]$$
$$= [1 - (\beta_0 + \beta_{trend}t + \beta_1 \Delta pm_t + \beta_3 \Delta w_{Lt} + \beta_4 w_{Mt} + \beta_{t2}\Delta w_{Kt-1} + \beta_{t3}\Delta w_{Lt-1})]^{-1} + u_{13t} \quad \text{(B13)}$$

Estimation results are given in Tables B1–B4.

Table B1 *Estimation results of Equations B9–B11*

Parameter	Estimate	SE[a]	*t*-statistics
b_{KK}	−0.344764	0.150849	−2.28548
b_{KL}	0.287772	0.098358	2.92577
b_{KM}	0.135486	0.081708	1.65818
e_{11}	1.02613	0.296108	3.46540
e_{12}	−0.703735	0.303111	−2.32171
e_{13}	0.546798	0.250736	2.18077
b_{LL}	−0.439041	0.058875	−7.45717
b_{LM}	0.411998	0.123500	3.33601
e_{21}	0.288892	0.451163	0.640327
b_{MM}	−0.039239	0.145768	−0.269188
b_M	4.00440	3.67659	1.08916
e_{31}	0.344899	0.251407	−1.37188

[a]SE is standard error

Table B2 *Estimation results of Equation B12*

Parameter	Estimate	SE[a]	*t*-statistics
a	−1.83356	0.420013	−4.36549
μ	−1.20935	0.296299	−4.08151
ρ	1.35198	0.094882	14.2490
e_{41}	0.595992	0.168610	3.53473

[a]SE is standard error

Table B3 *Estimation results of Equation B13*

Parameter	Estimate	SE[a]	*t*-statistics
β_0	0.446114	0.006088	73.2784
β_1	−0.001451	0.001125	−1.28910
β_2	−0.004497	0.004147	−1.08426
β_4	−0.000991	0.000820	−1.20828
β_{trend}	−0.00873	0.000621	−14.0577
β_{t2}	−0.003552	0.003818	−0.930342
β_{t3}	−0.009089	0.003710	−2.44973

[a]SE is standard error

Table B4 *Estimation results of Equations B9–B13*[a]

Equation B9			
Mean of dependent variable	= 4.33808	SE of regression	= 1.10907
SD of dependent variable	= 2.60283	R^2	= 0.817067
Sum of squared residuals	= 34.4409	Durbin-Watson statistic	= 2.07502
Variance of residuals	= 1.23003		
Equation B10			
Mean of dependent variable	= 19.7128	SE of regression	= 0.844749
SD of dependent variable	= 1.68722	R^2	= 0.816375
Sum of squared residuals	= 19.9808	Durbin-Watson statistic	= 2.44252
Variance of residuals	= 0.713601		
Equation B11			
Mean of dependent variable	= 33.4042	SE of regression	= 1.01462
SD of dependent variable	= 12.0425	R^2	= 0.992649
Sum of squared residuals	= 28.8245	Durbin-Watson statistic	= 2.30154
Variance of residuals	= 1.02945		
Equation B12			
Mean of dependent variable	= 4.03145	SE of regression	= 0.048149
SD of dependent variable	= 0.388655	R^2	= 0.986360
Sum of squared residuals	= 0.055639	Adjusted R^2	= 0.984655
Variance of residuals	= 0.002318	Durbin-Watson statistic	= 1.99084
Equation B13			
Mean of dependent variable	= 1.32646	SE of regression	= 0.026105
SD of dependent variable	= 0.168964	R^2	= 0.981487
Sum of squared residuals	= 0.014311	Adjusted R^2	= 0.976197
Variance of residuals	= 0.000681	Durbin-Watson statistic	= 1.15421

[a]SE is standard error, SD standard deviation