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LIFE EXPECTANCY OF INTERNATIONAL CARTELS: AN EMPIRICAL ANALYSIS

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ABSTRACT

This paper examines the empirical relation between market structure and life expectancy for cartels that were active in international commodity markets throughout this century. I consider two alternative empirical formulations and estimate their parameters recognizing that durability cannot take negative values. Both formulations predict that increases in either market shares or intercartel concentration prolong life expectancy but disagree in the relative importance of these two factors. The application of tests to discriminate among the two formulations does not support constant-elasticity models.

Life Expectancy of International Cartels: An Empirical Analysis

Jaime Marquez[1]

1. Introduction

That cartels are short-lived is one of the most robust predictions of economic theory. Cheating is too great a temptation to resist and the ensuing price instability brings the coalition to an end. But why is it that some cartels last longer than others? Can cartels prolong their existence by increasing their share of the market and if so by how much? How important is cartel concentration in determining cartel durability? I address these questions using Griffin's data (Griffin, 1989) matching durability with indicators of market structure for international cartels.

The analysis begins in section 2 with a description of the data. Section 3 models a cartel's life expectancy as a function of its performance which is then linked to cartel concentration and market share. Section 4 describes the method for parameter estimation and offers an alternative specification to assess the sensitivity of the results. The evidence, shown in section 5, suggests that increases in market shares and cartel concentration prolong a cartel's life expectancy. The relative importance of these two factors is model dependent but test results do not support constant-elasticity models.

These findings are of interest because very little is known about the relation between market structure and life expectancy. Indeed the reviews of

[1] The calculations in this paper use LIMDEP version 5.0. I am grateful to William Greene for clarifying some of the functions of his software; to participants in seminars at the Federal Reserve Board and the U.S. International Trade Commission; to Paul Streaker for research assistance; and to Jon Faust, Michael Gibson, James Griffin, William Helkie, Dale Henderson, Doug Irwin, Michael Leahy, Matthew Pritsker, Stephen Salant, and Janice Shack-Marquez for several suggestions. The author is a staff economist in the Division of International Finance. The views expressed in this paper are solely the responsibility of the author and should not be interpreted as reflecting those of the Board of Governors of the Federal Reserve System or other members of its staff.

performance. First, advances in telecommunications could reduce cartels' operational costs by facilitating the coordination of international activities. Second, United Nations' programs stabilizing export revenues of developing countries could enhance cartel profitability by either controlling production (Adams and Behrman, 1978) or inducing free-rider effects.

Many of the historical cartel collapses shown in table 1 are followed by the emergence of another cartel in the same market. This phenomenon raises the question of whether cartels can improve their performance by avoiding previous mistakes made in their line of activity. Finally, the sample includes cartels that ended their operations in 1939 raising the question of whether the onset of worldwide hostilities, besides raising transportation costs and operational risks, brought a premature ending to these cartels.

To examine the role of these cartel-specific attributes, I add four dummy variables to the data set: DR which equals one for renewable products; DWII which equals one for cartels that initiated their operations before 1945; D39 which equals one for cartels expiring in 1939; and REPEAT, which equals K-1 for cartels with K previous episodes of cartelization.[4]

Taking the dates of cartel activity as given, table 2 offers summary statistics for the full sample and the sub-groups mentioned above. On average, cartels last seven years but, as the moments of the distribution of durability indicate, this estimate is not representative of life expectancy. Cartels also differ in their performance and market structure. For example, the Lerner index varies from *minus* twelve percent to eighty percent with a mean of twenty-nine percent. Similarly, the average market share is sixty-one percent and varies from nine percent to one-hundred percent. Finally, the Herfindahl index varies from twenty-nine percent to one-hundred percent.

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[4] The first observation of REPEAT is set to zero to treat uniformly the first episode across cartels regardless of their number of cartelization efforts.

3. Empirical Formulation

I assume that cartels' incentives to remain active are directly related to the gap between their profitability and the return on an alternative activity. Thus I postulate that

$$\text{(1)} \qquad E\,\delta_i = \beta_0 + \beta_1\,E\,(\pi_i - R_i) \geq 0,$$

where E denotes the expectation operator, δ_i is the number of years of activity for the ith cartel, $\beta_1 > 0$, π_i is the Lerner index of profitability, and R_i is the rate of return of an alternative activity. I measure R_i as the 4-6 month rate for U.S. commercial paper (see table 1), a choice based on the availability of 19th-century data. In all but five cases, the cartels listed in table 1 have Lerner indexes exceeding the alternative rate of return; for the five exceptions, durability is below its sample mean.[5]

Ideally, equation (1) should relate life expectancy to the expected excess return over the life of the association -- that is, a lifetime analogue to π-R. The absence of such data precludes testing directly the validity of (1). As a result, appendix A develops testable assumptions showing a link between the ideal lifetime excess return and the observable excess return π-R.

Even in the absence of these complications, estimating the parameters of (1) is difficult because no agreement exists on how to measure π (Weiss, 1971; Griffin, 1989; Schmalensee, 1989); the presence of cartels in table 1 with *negative* Lerner indexes underscores these measurement difficulties. To bypass them, I follow the work initiated by Bain (1951) and assume that a cartel's performance depends linearly on its ability to coordinate production, its price elasticity of demand, and idiosyncratic attributes:

$$\text{(2)} \qquad E\,\pi_i = \alpha_0 + \alpha_1 H_i^{1/2} + \alpha_2 \epsilon_i + \alpha_3 \text{DWII} + \alpha_4 \text{DR} + \alpha_5 \text{REPEAT} + \alpha_6 \text{D39},$$

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[5] Investing in financial assets and earning R_i is not the only alternative to cartel members. For example, they might abandon the association and keep their line of business active. The rate of return in that alternative activity, however, should not be less than R_i systematically.

where H_i is the degree of cartel concentration (Herfindahl index) and ϵ_i is the cartel's demand price elasticity measured in absolute terms (see Geroski, 1988; Scherer and Ross, 1990). Greater cartel concentration facilitates coordinating the production levels needed to increase prices above marginal costs ($\alpha_1>0$). Increases in ϵ_i, stemming from either the entrance of new firms or the introduction of substitute products, force cartel members to lower their prices and induce a decline in their profitability ($\alpha_2<0$).

Substituting (2) into (1) yields

$$(3)\quad E\,\delta_i = \theta_0 + \theta_1 H_i^{1/2} + \theta_2 \epsilon_i + \theta_3 DWII + \theta_4 DR + \theta_5 REPEAT + \theta_6 D39 - \beta_1 R_i,$$

which links life expectancy to market structure: If increases in cartel concentration or declines in price elasticity prolong life expectancy, then $\theta_1>0$ and $\theta_2<0$. If developments in the postwar period expand cartel longevity, then $\theta_3<0$. If having exploitation rights to sites of non-renewable products extends life expectancy, then $\theta_4<0$. If learning from previous cartel failures prolongs life expectancy, then $\theta_5>0$. Finally, if the onset of hostilities in 1939 forced cartels to end their operations, then $\theta_6<0$.

Estimating the parameters of (3) requires data on *cartels'* demand price elasticities, which are either unavailable or measured very imprecisely. Recognizing that a cartel's price elasticity is inversely related to its share of the market, S_i, and that data on market shares are easier to obtain than data on price elasticities, I assume that $\epsilon_i = 100/S_i$. This formulation allows ϵ_i to be large for small cartels ($S_i \rightarrow 0$) and unity for large cartels ($S_i \rightarrow 100$). Substituting this assumption into (3) gives

$$(4)\quad E\,\delta_i = \theta_0 + \theta_1 H_i^{1/2} + \theta_2 100/S_i + \theta_3 DWII + \theta_4 DR + \theta_5 REPEAT + \theta_6 D39 - \beta_1 R_i.$$

Increases in market shares, by lowering the cartel's demand price elasticity, widen the gap between prices and marginal costs enhancing the cartel's incentives to remain active ($\theta_2<0$). The elasticities of life-expectancy with respect to market share and cartel concentration are $-\theta_2 100/(\delta_i S_i)$ and

$(\theta_1/2)(H_i^{1/2}/\delta_i)$, respectively. Because these elasticities vary with durability and market structure, I report percentiles from their empirical distributions.

4. *Econometric Estimation*

Given that durability cannot be negative, I estimate the parameters of (4) using Amemiya's maximum likelihood estimator for truncated samples (Amemiya, 1973). This estimator rests on three assumptions. First, the conditional life expectancy is a linear function of its determinants:

$$(5)\quad E(\delta_i|X_i) = \Theta' X_i = \theta_0 + \theta_1 H_i^{1/2} + \theta_2 100/S_i + \theta_3 \mathrm{DWII} + \theta_4 \mathrm{DR} + \theta_5 \mathrm{REPEAT} + \theta_6 \mathrm{D39} - \beta_1 R_i,$$

where X_i is the vector of explanatory variables and $\Theta' = (\theta_0 \ \ldots \ \theta_6 \ -\beta_1)$ is a vector of unknown parameters.

Second, the dispersion of durability increases with life expectancy:

$$(6)\qquad \mathrm{Var}(\delta_i|X_i) = [\exp(\sigma^2) - 1]\ [\Theta' X_i]^2,$$

where σ^2 is an unknown parameter. Third, the conditional distribution of durability is

$$(7)\qquad \ln\delta_i \sim N(\mu_i, \sigma^2),$$

where $\mu_i = \ln(\Theta' X_i) - \frac{1}{2}\sigma^2$. Other distributions are available (see Amemiya, 1973), but the log-normal has a tractable likelihood function that facilitates testing whether the estimation residuals are normal (Jarque and Bera, 1980), and it ensures that estimates of life expectancy are positive:

$$\hat{E}(\delta_i|X_i) = \exp(\hat{\mu}_i + \tfrac{1}{2}\hat{\sigma}^2) = \exp[\ln(\hat{\Theta}' X_i)] = \hat{\Theta}' X_i > 0.$$

To examine the robustness of the results to model formulation, I use

$$(8)\quad \ln\delta_i = \eta_0 + \eta_1 \ln H_i^{1/2} + \eta_2 \ln(100/S_i) + \eta_3 \mathrm{DWII} + \eta_4 \mathrm{DR} + \eta_5 \mathrm{REPEAT} + \eta_6 \mathrm{D39} + \eta_7 \ln R_i + v_i,$$

where $v_i \sim N(0, \sigma_v^2)$. Equation (8) retains the assumed normality of the logarithm of durability to avoid negative estimates of life expectancy. But, in contrast to the log-normal formulation, (8) assumes constant elasticities. I estimate the parameters of (8) with ordinary least squares (OLS).

5. Empirical Results

The coefficient estimates from the log-normal formulation (eqs. 5-7) reveal several features. First, increases in market shares and cartel concentration have positive, significant, and robust effects on cartels' life expectancy (table 3); increases in the interest rate lower life expectancy but this effect is not very significant. Second, life expectancy is significantly shorter for cartels that initiated their operations before 1945 than for those that initiated operations afterwards. Similarly, life expectancy is shorter for cartels in renewable products than for those in non-renewable products; other cartel-specific attributes are not significant. Third, the estimation residuals are consistent with normality. Finally, predicting life expectancy using only the mean of durability (model 6) entails a loss of information relative to models allowing a role for economic theory. But as found before (Weiss, 1971), the models' explanatory power is low; model 3 has the largest $\bar{R}^2$ (0.29) and the smallest number of parameters supported by the data.

The OLS estimates from (8) suggest that increases in market shares have positive and significant effects on life expectancy (table 4), which is consistent with the evidence from the log-normal formulation. Increases in cartel concentration also increase life expectancy, but this effect is not very significant. Similarly, increases in interest rates do not have a significant effect on life-expectancy. The postwar dummy DWII has a negative sign and is the only cartel-specific attribute with a significant effect. The estimation residuals are consistent with normality but the $\bar{R}^2$s are lower than those of the log-normal specification; model 4 has the largest $\bar{R}^2$ (0.18) and the smallest number of parameters consistent with the data.

The evidence shown thus far indicates that both formulations predict a direct association between life expectancy and either market share or cartel concentration. Stated in terms of elasticities, however, the results suggest that market shares are relatively more important in the log-linear case than in the log-normal formulation (table 5). Moreover, the log-linear specification suggests that the relation between life-expectancy and

Table 3
Maximum Likelihood Estimates for Log-Normal Formulation[1]
(t-statistics in parentheses)

$$E(\delta_i|X_i) = \theta'X_i = \theta_0 + \theta_1 H_i^{1/2} + \theta_2 100/S_i + \theta_3 DWII + \theta_4 DR + \theta_5 REPEAT + \theta_6 D39 - \beta_1 R_i$$

$$Var(\delta_i|X_i) = [\exp(\sigma^2) - 1]\,[\theta'X_i]^2$$

$$\ln\delta_i \sim N[\ln(\theta'X_i) - \sigma^2/2,\ \sigma^2]$$

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	10.500 (2.73)	10.105 (2.71)	10.513 (3.39)	8.779 (3.20)	4.413 (1.57)	7.065 (7.43)
$H_i^{1/2}$	0.113 (2.49)	0.108 (3.02)	0.104 (2.96)	0.094 (2.54)	0.074 (1.53)	
$(100/S_i)$	-1.145 (-2.49)	-1.068 (-2.24)	-1.043 (-2.23)	-0.951 (-2.17)	-0.942 (-1.83)	
R_i	-0.616 (-1.66)	-0.486 (-1.42)	-0.473 (-1.46)	-0.424 (-1.40)	0.070 (0.22)	
DWII	-6.692 (-1.45)	-6.708 (-2.72)	-6.877 (-3.22)	-5.332 (-2.81)		
DR	-2.452 (-1.45)	-2.317 (-1.47)	-2.289 (-1.48)			
REPEAT	0.379 (0.47)	0.132 (0.17)				
D39	-2.013 (-0.73)					
$\hat{\sigma}$	0.754 (5.56)	0.763 (5.48)	0.764 (5.56)	0.791 (5.27)	0.868 (6.56)	0.973 (6.24)
$\bar{R}^2$	0.273	0.271	0.285	0.249	0.125	
log-likelihood	-53.036	-53.548	-53.589	-55.038	-58.772	-63.236
Normality[2]	1.094	1.219	1.344	1.651	0.492	

[1] The $\bar{R}^2$s are calculated using $1-[(T-1)/(T-K)](1-R^2)$, where K is the number of regressors and T = 52. The R^2s are computed following Baxter and Cragg (1970):

$$R^2 = (1 - \exp[2(L_6 - L_i)/T]) \,/\, (1 - \exp(2L_i/T)),$$

where L_i is the log-likelihood of model i.

[2] Test for normality of residuals; test-statistic is distributed as χ^2 with two degrees of freedom and the value for the 5% significance level is 5.991.

Table 4
Ordinary Least Squares for Log-linear Specification
(t-statistics in parentheses)

$$\ln\delta_i = \eta_0 + \eta_1 \ln H_i^{1/2} + \eta_2 \ln(100/S_i) + \eta_3 DWII + \eta_4 DR + \eta_5 REPEAT + \eta_6 D39 + \eta_7 \ln R_i + v_i$$

$$v_i \sim N(0,\ \sigma_v^2)$$

	Model 1	Model 2	Model 3	Model 4	Model 5
Intercept	0.096 (0.06)	0.058 (0.03)	0.092 (0.01)	-0.207 (-0.15)	0.444 (0.31)
$\ln H_i^{1/2}$	0.648 (1.59)	0.649 (1.61)	0.658 (1.80)	0.696 (1.93)	0.370 (1.07)
$\ln(100/S_i)$	-0.666 (-2.74)	-0.660 (-2.76)	-0.663 (-2.85)	-0.678 (-2.96)	-0.701 (-2.92)
$\ln R_i$	-0.111 (-0.67)	-0.090 (-0.61)	-0.088 (-0.62)	-0.076 (-0.54)	0.084 (0.66)
DWII	-0.731 (-2.18)	-0.737 (-2.23)	-0.730 (-2.40)	-0.675 (-2.37)	
DR	-0.147 (-0.58)	-0.135 (-0.54)	-0.134 (-0.55)		
REPEAT	0.001 (0.01)	-0.005 (-0.06)			
D39	-0.109 (-0.28)				
$\hat{\sigma}_v$	0.767	0.759	0.751	0.745	0.786
$\bar{R}^2$	0.134	0.152	0.170	0.183	0.104
log-likelihood	-55.647	-55.694	-55.696	-55.863	-58.801
Normality[1]	1.231	1.364	1.393	1.637	0.642

[1] Test for normality of residuals; test-statistic is distributed as χ^2 with two degrees of freedom and the value for the 5% significance level is 5.991.

Table 5
Life-Expectancy Elasticities

	Log-linear	Log-normal 25%	Log-normal Median	Log-normal 75%
Market Share	0.678	0.177	0.354	0.863
cartel concentration	0.348	0.351	0.519	1.090
Degree of Homogeneity	1.026	0.528	0.873	1.953

Source: model 4 for log-linear (table 4) and model 3 for log-normal (table 3).

its determinants is homogeneous of degree one whereas the degree of homogeneity for the log-normal case varies from 0.53 to 1.95.

Choosing between log-normal and log-linear formulations needs to recognize that the models do not nest each other because the logarithm of a sum (log-normal) is not equal to the sum of the logarithms (log-linear). Thus I apply MacKinnon's method (MacKinnon, 1983) to

$$(9) \qquad (\delta_i - \hat{\delta}_{i0}) = \psi_{10}\,(\hat{\delta}_{i0} - \hat{\delta}_{i1}) + \hat{F}'_{i0}\,\psi_{20} + r_{i0}\,,$$

$$(10) \qquad (\delta_i - \hat{\delta}_{i1}) = \psi_{11}\,(\hat{\delta}_{i0} - \hat{\delta}_{i1}) + \hat{F}'_{i1}\,\psi_{21} + r_{i1}\,,$$

where $\hat{\delta}_{ij}$ is the prediction from the jth formulation (j=0 for the log-normal, j=1 for the log-linear); $\hat{F}_{ij}$ is a vector of partial derivatives of δ_{ij} with respect to θ_j evaluated at $\hat{\theta}_j$; and r_{ij} is a disturbance.

MacKinnon's method focuses on the informational content of each formulation. Thus if the log-linear specification adds information to that already embodied in the log-normal formulation, then $\psi_{10} \neq 0$. Alternatively, if the log-normal formulation adds information to that already present in the log-linear specification, then $\psi_{11} \neq 0$. Based on least squares, the t-statistic for the null hypothesis that $\psi_{10} = 0$ is 0.5 which means that the log-linear specification does not add information to that already contained in the log-normal formulation. The t-statistic for the null hypothesis that $\psi_{11} = 0$ is 1.8 which indicates that the log-normal formulation has information not contained in the log-linear specification. This result suggests against explaining life expectancy with a constant-elasticity model.

6. *Summary*

This paper offers an empirical analysis of the relation between life expectancy and market structure for a sample of cartels operating in international commodity markets throughout the last one-hundred years. The evidence suggests that increasing market shares and cartel concentration prolongs life expectancy, a finding robust to model specification. The relative importance of these two factors is model dependent, but the evidence does not support constant-elasticity models.

Appendix A: Derivation of Equation (1)

I assume that cartels are active for as long as they perceive the association to be profitable:

$$\text{(A1)} \qquad E\,\delta_i = \beta_0 + \tilde{\beta}_1\, E\,\Pi_i\ ,$$

where E denotes the expectation operator, δ_i is the number of years of activity for the ith cartel, and Π_i is the associated present, discounted value of excess profits per unit of output (excess relative to the return of an alternative activity). By being an ex-ante and lifetime measure of excess profitability, Π is hard to measure and data for it are not publicly available. Thus what is needed is a list of testable assumptions that allow linking the ideal Π to the observable excess return used in equation (1), π-R.

To this end, let P be the present, discounted value of the stream of excess profits over time:

$$\text{(A2)} \qquad P = \sum_{t=0}^{\infty} Q_t(p - mc - oc)_t/(1+\varphi)^t\ ,$$

where Q_t is the quantity of output sold at time t, p_t is the price charged by the cartel, mc_t is the cartel's aggregate marginal cost, oc_t is the opportunity cost per unit of output, and φ is the constant discount rate. To simplify the analysis, I express (A2) as

$$\text{(A3)} \quad P = \sum_{t=0}^{\infty} Q_t\ mc_t[(p_t - mc_t)/mc_t - oc_t/mc_t]/(1+\varphi)^t = \sum_{t=0}^{\infty} Q_t\ mc_t(\pi\text{-}R)_t/(1+\varphi)^t,$$

where $\pi_t = (p_t - mc_t)/mc_t$ and $R_t = oc_t/mc_t$. I also assume that the cartel's aggregate production function exhibits constant returns to scale, implying that marginal costs are constant and equal to mc. Moreover, I assume that

$$\text{(A4)} \qquad P = mc \sum_{t=0}^{\infty} [(EQ + u_t)(E(\pi - R) + e_t)]/(1+\varphi)^t,$$

where EQ is the per-period, expected level of sales, $E(\pi - R)$ is the expected excess profit rate per period; and both u_t and e_t are random disturbances with the following properties:

$$E(u_j\ e_t) = 0\ \forall j\neq t;\quad E(e_j\ e_t) = 0\ \forall j\neq t;\quad E(u_j\ u_t) = 0\ \forall j\neq t;$$
$$E(u_t\ e_t) = \rho;\qquad E(e_t\ e_t) = \sigma_e\ ;\qquad E(u_t\ u_t) = \sigma_u.$$

Both the nature of the cartel's aggregate production function and the assumptions about the time series of output and prices can be tested although I do not have the necessary data.

Given these assumptions, the expected value of P equals

$$\text{(A5)}\quad E(P) = mc\ E\{\sum_{t=0}^{\infty} EQ\ E(\pi-R)/(1+\varphi)^t + \sum_{t=0}^{\infty} EQ\ e_t/(1+\varphi)^t +$$

$$+ \sum_{t=0}^{\infty} u_t E(\pi - R)/(1+\varphi)^t + \sum_{t=0}^{\infty} u_t e_t/(1+\varphi)^t\}$$

$$= mc \quad \sum_{t=0}^{\infty} EQ\ E(\pi-R)/(1+\varphi)^t + \sum_{t=0}^{\infty} E(u_t e_t)/(1+\varphi)^t$$

$$= mc\ [(1+\varphi)/\varphi]\ EQ\ [E(\pi-R) + \rho/EQ].$$

The expected, present discounted value of excess profits per unit of output is

$$\text{(A6)}\qquad E(P)/EQ = E\ \Pi = mc\ [(1+\varphi)/\varphi]\ [E(\pi-R) + \rho/EQ].$$

If ρ/EQ is close to zero, then

$$\text{(A7)}\qquad E\ \Pi = mc\ [(1+\varphi)/\varphi]\ E(\pi-R).$$

Substituting (A7) into (A1) yields

$$\text{(A8)}\qquad E\ \delta_i = \beta_0 + \tilde{\beta}_1\ mc\ [(1+\varphi)/\varphi]\ E\ (\pi_i - R_i) = \beta_0 + \beta_1\ E\ (\pi_i - R_i),$$

which is equation (1).

To assess the extent to which the data in table 1 support the view that $\beta_1 > 0$, I apply Amemiya's maximum likelihood method for truncated samples (see section 4) to (A8) and find that $\hat{\beta}_1 = 0.088$ with a t-statistic of 2.03, which is statistically significant.

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