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Collusion and Market Structure : The Japanese Automobile Industry 1956-1979

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This paper examines the oligopolistic state of the Japanese automobile market, from 1956 to 1979. The use of a Bayesian approach enables us to predict exact years of structural change and values of conjectural variations. We found three change points:1958, 1962 and 1973. The former two change points seem to be related to internal entry/exit activities and external trade liberalization pressures. The third change point is associated with the satiated demand for automobiles just after the *High Rapid Growth* period.

Keywords : Bayesian approach, collusion index, Markov chain Monte Carlo (MCMC), oil crisis, structural change, trade liberalization

1. Introduction

The Japanese automobile industry is often referred to as a "ten percent industry," meaning that its total sales and the number of employees related to it account for over ten percent of all manufacturing industries' sales and employment.[1] In addition to its economic importance, it is believed that the Japanese automobile industry is a typical oligopoly. Market concentration is one of the most common indices to measure the state of market competition. In particular, two automakers, *Toyota* and *Nissan*, are dominant firms. The combined market shares of these two firms exceeded sixty percent in1970's.[2] The period of 1970's is characterized as one where the Japanese automakers were engaged in export activities (see Nakamura [11], Ono [12] and Shimokawa [14]).

The purpose of this paper is to investigate collusion in and the market structure of the Japanese automobile industry during its evolutionary growth pe-

1) In 1995, the Japanese automobile industry produced 39.5 trillion yen in sales, which amounts to 12.9% of all manufacturing industries. The Japanese automobile related industries provided 7.1million job opportunities, which corresponds to 11.7% of the manufacturing jobs.

2) In 1970, the combined market share of *Toyota* and *Nissan* was about 61%, exceeding 70% in 1975 and falling to 60% in 1980.

riod from 1956 to 1979.[3] The Japanese automobile industry was in an infant industry stage after the World War II. Japan produced only 32 thousand motor vehicles in 1956. In contrast to this, she produced more than six million motor vehicles in 1979, half of which were exported. However, the growing process of the Japanese automobile industry after the war was not smooth. Early 1955, the MITI launched *the National Car Plan* and adopted a policy of subsidizing domestic automakers. There was a drama of entry and/or exit from late 1950's to early 1960's.[4] In this period, the Japanese automobile industry is considered to be competitive even given the oligopolistic state. There were also constant pressures from outside to reduce the rate of tariffs on automobiles and parts. Until the late 1960's the Japanese government charged a 40% tariff on imported motor vehicles in an attempt to make domestic automakers competitive enough internationally.

As already stated above, the Japanese automobile market has been typically oligopolistic. According to the theory of industrial organization, if there are a few firms in the market, firms' collusion matters (see Scherer [13]). Notably, Bain [2] argued that a concentrated market facilitates collusion among firms. While collusive behavior is commonly observed in imperfectly competitive markets, there are at least two different viewpoints in explaining them. The performance approach predicts industry profitability to be positively correlated with the level of concentration (see Cowling and Waterson [6]). As its variant, Clarke and Davies [5] advocated a joint determination of profitability and concentration. In contrast to this, the efficiency approach emphasizes that an industrial structure is determined by the efficiency requirement of equilibrium (see Demsetz [7]).

These approaches, however, assume away structural changes. They implicitly assume that structural equations remain the same during the sample period. In considering the Japanese automobile industry during the period of 1956-1979, we anticipate that the industry had experienced both internal and external shocks so as to change its structure. In order to prepare for outside pressures to liberate trade in late 1950's, the MITI encouraged the domestic automakers to expand their production, which induced entry/exit activities in the domestic market. Furthermore, after the end of *High Rapid Growth*, the demand for motor vehicles reached its reflection point and decreased around 1971 and 1973 even before the first oil crisis. Of course, the oil crises in 1970's

3) As is well known, the Japanese automobile industry practiced voluntary export restraints in 1981 and continued to do so until 1994. Therefore, we excluded this particular period.

4) *Suzuki* entered into the automobile industry in 1955. *Fuji, Daihatsu* and *Mazda* followed this in 1958. Finally, *Honda* entered in 1963. In contrast to these movements, *Tokyu Kurogane* quietly receded from the automobile industry in 1961.

also seem to affect market structure.

There are few studies that measure the collusiveness of the Japanese automobile industry.[5] In this paper, using the methodology developed by Chib [4], we measure collusiveness in the Japanese automobile industry and investigate the structural change of the Japanese automakers' behavior. Chib [4] proposed the Bayesian approach for models with multiple change points, in which the estimation is conducted by Markov chain Monte Carlo (MCMC) methods. His procedure is quite applicable to detect the change points of firms' collusive behavior.

The outline of the paper is as follows. In section 2, we introduce the theoretical model. In section 3, we explain the Bayesian framework and estimate the model described in section 2 by using the data of the Japanese automobile industry from 1956 to 1979. Also, we determine the change points of the Japanese automakers' behavior. Lastly, brief concluding remarks are given in section 4.

2. Theoretical Framework

In this section, following Clarke and Davies [5], we introduce the theoretical model used to investigate the Japanese automakers' behavior. Using the conjectural variation model developed by Clarke and Davies [5], we can examine the firms' collusive behavior by estimating a simple regression model.

According to Clarke and Davis [5], we assume that there are N firms in the market, which produce a homogeneous good, X_i, and maximize their profits π_i. That is,

$$\pi_i = pX_i - \varepsilon_i(X_i), \tag{1}$$

Where p and $\varepsilon_i(X_i)$ respectively stand for price and cost functions.

We define the degree of collusion, α, as follows:

$$\frac{dX_j}{X_j} = \alpha \frac{dX_i}{X_i}.$$

Note that the inverse demand function be of the form :

$$p = p\left(X_i + \sum_{j \neq i} X_j\right).$$

5) Alley [1] measured the rate of collusion (α) in relation to partial ownership arrangement. He dealt with the period of 1980-1995 and assumed away any structural change. Ono [12] investigated collusiveness in the Japanese automobile industry, 1955-1972. He estimated α and used a piece-wise F test to check structural change. While it is difficult to find the exact change point, he found that 1963 is a candidate for the change point.

The profit maximizing behavior of each firm yields the following equation (see equation (9) in Clarke and Davies [5]),

$$p\left[1-\frac{1}{\eta}\left(\frac{X_i}{X}-\alpha\frac{X_i}{X}+\alpha\right)\right]=c_i, \tag{2}$$

where η and c_i respectively denote the price elasticity of demand and marginal cost, and $X=\sum_i X_i$. Equation (2) will easily be transformed into

$$\frac{\pi_i}{R_i}=a+bMS_i, \tag{3}$$

where R_i and MS_i respectively represent revenue and market share of firm i. Comparing equation (2) with equation (3), we can derive

$$a=\frac{\alpha}{\eta}\text{ and } b=\frac{1-\alpha}{\eta}.$$

3. Econometric Analyses

This section provides a Bayesian approach to specify change points. We choose the sample period of 1956-79 and assume at most four change points during the sample period.

3.1 The Model

Let us consider the following Markov switching regression model

$$y_{it}=x_{it}'\beta(s_t)+u_{it},\ u_{it}\sim \mathrm{N}(0,\sigma^2),\ i=1,\dots,n_t,\ t=1,\dots,T, \tag{4}$$

where y_{it} is a dependent variable, x_{it} is a $p\times 1$ vector of covariates, $\beta(s_t)$ is the corresponding regression parameter, which depends on the outcome of the latent state variable $s_t\in\{1,\dots,K\}$ It is assumed that

$$\beta(s_t)=\beta_k \quad \text{if} \quad s_t=k,(k=1,\dots,K) \tag{5}$$

and that the latent state variable s_t evolves a Markov chain with the one-step ahead transition probability matrix P. Following Chib [4], we assume that this transition probability matrix is represented as

$$P=\begin{pmatrix} p_{11} & p_{12} & 0 & \cdots & 0 \\ 0 & p_{22} & p_{23} & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \cdots & \cdots & 0 & p_{K-1,K-1} & p_{K-1,K} \\ 0 & 0 & \cdots & 0 & 1 \end{pmatrix} \tag{6}$$

and $s_1 = 1$ and $s_T = K$.

As discussed in Chib [4], the model defined by equations (4) - (6) can be viewed as a generalized change-point model, and the transitions of the state identify the change points (*e. g.*, the ith change point can be detected at τ if $s_\tau = i$ and $s_{\tau+1} = i+1$).

Denote that $Y = \{y_{it}\}$, $S = \{s_t\}$ and $\Theta = \{\beta_k, \sigma^2\}$. Then, the density function of Y conditional on Θ and S is written as

$$f(Y \mid \Theta, S) \propto \prod_{t=1}^{T} \prod_{i=1}^{n_t} \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{-\frac{(y_{it} - x_{it}'\beta(s_t))^2}{2\sigma^2}\right\}. \tag{7}$$

In order to derive the likelihood function of Θ, we need to marginalize equation (7) with respect to $\{s_t\}$. However, since marginalization of (7) involves summations over all possible state sequence of s_t, the likelihood function of Θ is not available in a simple form. Therefore, we employ a Bayesian approach and use a Markov chain Monte Carlo (MCMC) method, which requires sampling $\{s_t\}$ from their complete conditional distributions. For a review of MCMC methods, see Gelfand and Smith [10], Tierney [15], Gamerman [9] and the references therein. Among existing algorithms we used the algorithm due to Chib [3, 4], and a brief explanation of it is given in Appendix.

3.2 Empirical Results

Before stating our empirical results, we briefly touch upon our data source. The profit margins are defined as

(sales-raw materials-wages)/sales.

We may alternatively define the profit margins as equivalent to

current profit/sales,

which reflects the use of average cost, rather than marginal cost. *Security Report*, published biannually by each automaker, provides all the necessary figures to calculate both the profit margins and market shares. In the case of later comers such as *Honda*, *Mazda* and so on, their figures are, naturally, included after their entry.

Since we adopted a Bayesian approach, we need to specify prior distributions for the parameters. The prior distributions used in the later analyses are as follows :

$$\beta_k = [a_k, b_k]' \sim \mathrm{N}(0,\ 1000 \times I)(k = 1, \ldots, K)$$

$$\frac{1}{\sigma^2} \sim \mathrm{Ga}(5, 0.01),$$

$$p_{kk} \sim \mathrm{Be}(5, 0.5)(k=1, \ldots, K).$$

For posterior inference, the MCMC simulation was run for 12,000 iterations and the first 2,000 sample was discarded as a burn-in period. All results reported here are generated using *Ox* version 2.00 (see Doornik [8])

We estimated four models with a single change point, two, three and four change points. Table 1 shows the logarithm of marginal likelihood for each model. Based on the Bayes factor, the models with three and four change points might be selected, and the model with four change points is a little bit better than the one with three change points. Figures 1 and 2 show the posterior probability mass function of τ_i (i th change point) for the models with three and four change points, respectively. From these figures, the model with three change points detects the change points clearly, while the one with four change points does not. Therefore, we adopt the model with three change points and only report the results of it to save space. Table 2 shows the summary of estimation. Figure 3 shows the posterior probability of $s_t = k$, which visualizes the determination of change points. From this figure, we may specify three change points as 1958, 1962, and 1973. Figure 4 shows the posterior means of the collusion index and their 5% and 95% points at each year. From this figure, the variations of α are large before the second change point and after the third change point.

1955 is the year when Japan became a member of the GATT and at the same time the year when the MITI launched the *National Car Plan*, which supported national automakers to produce small-sized cars through subsidization. From late 1950's to early 1960's, there were entry/exit activities in the automobile industry (see footnote 4). The pressures for trade liberalization also caused entry/exit activities in the Japanese automobile industry. Therefore, it is reasonable to specify the change points as later 1950's and early 1960's. The state of the market may be more fully observed by looking at Figure 4. Figure 4 indicates changes in the index of collusion and its variance.

It is interesting to observe a hump around 1960. Because of a government policy for raising a domestic automobile industry, entry was very active and the variance of the collusion index fluctuated widely. This means that automakers behaved quite differently; some of them behaved collusively and others competitively. The first structural change occurred around 1958; this seems to be the result of outside pressure for trade liberalization forcing domestic automakers to collude more on average, even if the variance fluctuated widely. The second structural change occurred around 1962 when entry was essentially finished. Although *Honda* entered in 1963, its move was fully anticipated in the market.

During 1960's, two big makers, *Toyota* and *Nissan*, represented the automobile industry. The rates of collusion are more stable with small variations. However, around the end of the 1960's Japan was near to the end of *High Rapid Growth* period and there was a depression in 1968. Therefore, the demand for automobiles was believed to be near its satiation point. It should be noted that around 1972 the collusion index started moving upward and at the same time the variance began fluctuating. The automakers behaved differently like in late 1950's. Amplified moves in variances of the collusion index in Figure 4 suggest the third change point. While we imagine 1973 as the year of the first oil crisis, it may be safe to say that the structural change in the automobile industry started around 1970 and that the change point was coincident with the first oil crisis by chance. In early 1970's just after the end of *High Rapid Growth* in Japan, it was argued that the Japanese automobile industry had become matured and that the demand would fall down. There was severe market share competition at this time. Therefore, the seed of the third structural change seems to start in early 1970's and to strengthen competition among firms before the first oil crisis.

4. Concluding Remarks

We may summarize our results as follows.

(1) Based on recently progressed Bayesian approach, we found three change points, 1958, 1962 and 1973.

(2) We predicted not only the change points but also the movement of the collusion index. The latter seems to characterize the economic configuration of the change points.

(3) Before the second change point of 1962, the variance of the collusion index fluctuates widely, implying that the Japanese automakers behaved sporadic. Around 1958, there were both external pressure (trade liberalization) and internal pressure (entry/exit) in the automobile industry, which might make some firms behave collusively and others competitively.

(4) Around the second change point of 1962, entry and/or exit activities finished. Then the Japanese automobile industry was dominated by two automakers, *Toyota* and *Nissan*, which induced others to behave collusively. This causes both the stable movements of the collusion index and the small changes in the variances.

(5) After establishing the solid oligopolistic state of the market, the third structural change was created by the unavoidable fact that automobiles as durable goods reached their satiation point near the end of the *High Rapid Growth* period. Therefore, in early1970' s automakers responded to

this change. We stress our finding that the third change point occurred just before the first oil crisis.

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Appendix : The MCMC Scheme

In order to implement the MCMC algorithm, it is necessary to sample from

(1) $\Theta \mid Y,S,P,$

(2) $S \mid Y,\Theta,P,$

(3) $P \mid Y,\Theta,S.$

Since sampling of Θ is similar to those in a linear regression model, we only explain how to sample S and P from their complete conditional distributions.

Sampling S_t: As shown in Chib [3], the joint distribution of S is factorized as

$$p(S \mid Y,\Theta,P) \propto p(s_{T-1} \mid Y,s_T,\Theta,P) \times \cdots \times p(s_t \mid Y,S^{t+1},\Theta,P) \times \cdots \times p(s_1 \mid Y,S^2,\Theta,P), \tag{8}$$

where $S_t = (s_1, \cdots, s_t)$ and $S^{t+1} = (s_{t+1}, \cdots, s_T)$ denote the state history up to time t and the future from $t+1$ to T, respectively. Hereafter, we employ a similar convention for Y_t and Y^{t+1}. It should be noted that the last term of (8) is degenerated at $s_1 = 1$. Thus, we confine ourselves to sampling S_t from $p(s_t \mid Y,S^{t+1},\Theta,P)$. Chib [3] showed that each term of (8) is expressed as

$$p(s_t \mid Y,S^{t+1},\Theta,P) \propto p(s_t \mid Y,\Theta,P)\,p(s_{t+1} \mid s_t,P), \tag{9}$$

where $p(s_{t+1} \mid s_t,P)$ is just the transition probability. The quantity $p(s_t \mid Y,\Theta,P)$ is recursively obtained from the following two equations:

$$p(s_t = k \mid Y_t,\Theta,P) \propto p(s_t = k \mid Y_{t-1},\Theta,P) \times f(y_t \mid \Theta,s_t = k), \tag{10}$$

$$p(s_t = k \mid Y_{t-1},\Theta,P) = \sum_{l=k-1}^{k} p_{lk} \times p(s_{t-1} = l \mid Y_{t-1},\Theta,P), \tag{11}$$

where $y_t = (y_{1t}, \cdots y_{m_t t})$ and $f(y_t \mid \Theta,s_t = k)$ is the density of y_t conditional on $s_t = k$. Using the fact that $p(s_1 \mid Y_0,\Theta)$ is concentrated at 1, the quantity $p(s_t \mid Y,\Theta,P)$ can be initialized at $t = 1$.

Sampling p_{kk}: Since the prior distribution for p_{kk} is a Beta distribution, *i.e.*,

$$p_{kk} \sim \text{Be}\ (a, b)$$

it can be shown that the complete conditional distribution of p_{kk} is also a Beta distribution

$$p_{kk} \mid Y,S,\Theta \sim \text{Be}(a + n_{kk}, b + 1)$$

Where n_{kk} is the number of one-step transition from state k to state k.

Table 1: Log Marginal Likelihood

Number of change points	1	2	3	4
Log $m(Y)$	246.50	252.36	254.60	254.67

Table 2: Posterior Means and Standard Deviations[a]

	$k=1$	$k=2$	$k=3$	$k=4$
a_k	0.12549	0.20785	0.24386	0.20090
	(0.036236)	(0.030151)	(0.022115)	(0.014091)
b_k	0.32806	0.22829	0.33853	0.25273
	(0.18497)	(0.15303)	(0.10679)	(0.094632)
p_{kk}	0.81250	0.83610	0.90042	
	(0.13213)	(0.12115)	(0.084250)	
τ_k	2.6963	6.8346	17.407	
	(1.1942)	(3.1886)	(1.2321)	
σ^2	0.0065910			
	(0.00062471)			

[a]Standard deviations are in parentheses. τ_k denotes the k-th change point.

Figure 1 . Posterior Probability Mass Function of τ_k : Three Change Points.

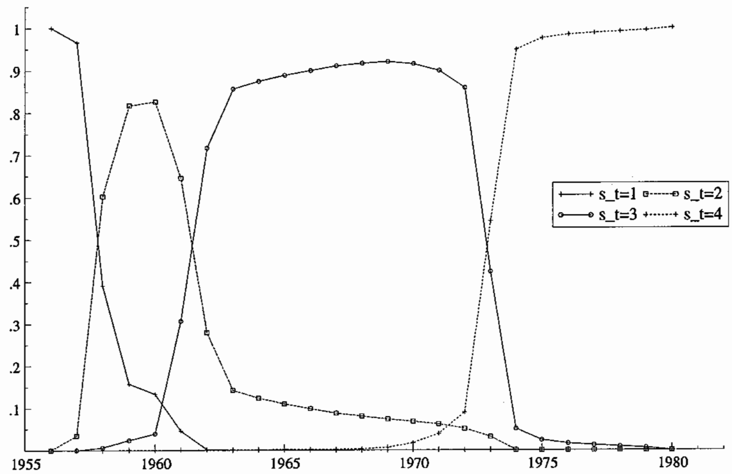

Figure 2 . Posterior Probability Mass Function of τ_k : Four Change Points.

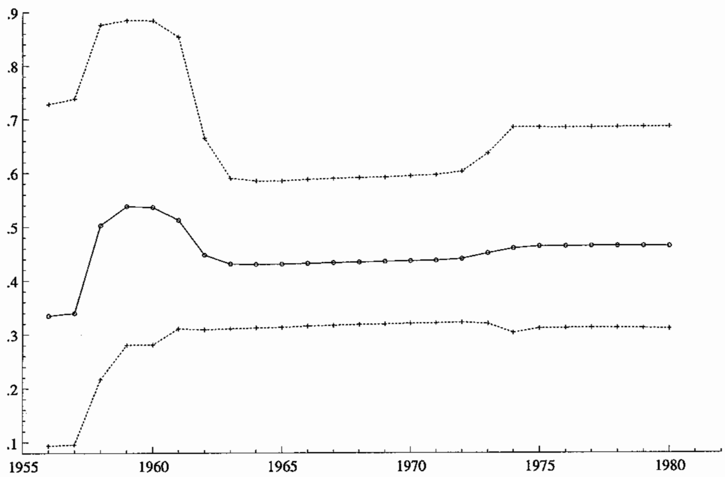

Figure 3 . Posterior Probability of $s_t = k$.

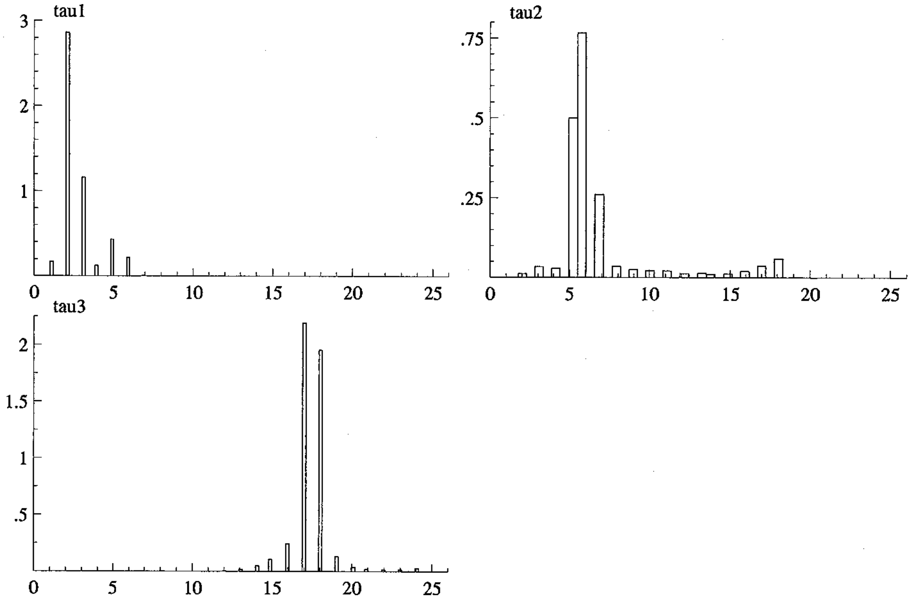

Figure 4 . The Posterior Means of the Collusion Index α (solid line) and Their 5 % and 95% Bands (dotted lines).