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ESTIMATING MARKET STRUCTURE AND TAX INCIDENCE:
THE JAPANESE TELEVISION MARKET

by

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The tax incidence falling on consumers depends on the market structure. While the effect of market structure on tax incidence has been examined theoretically, we are unaware of any empirical research in this area.[1] This paper estimates market structure and tax incidence in the Japanese television market.

We believe there are four reasons why this research is useful. First, we demonstrate theoretically and empirically that tax incidences on consumers can and do exceed 100% in oligopolistic industries.

Second, that tax incidences exceed 100% is of practical importance as well as academic interest, since tax incidence is important in determining whether dumping has occurred under U. S. law. Current law requires that the U. S. price be raised to reflect the incidence of the tax that falls on consumers in the foreign market before comparing the U.S. and foreign prices.[2] Since dump-

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[1]See Robert L. Bishop (1968), Davidson and Martin (1985), Seade (1985), and Wright (1987).

[2]Section 772(d)(1)(C) of the Tariff Act of 1920, as amended, 19 U.S.C. Section 1677a(d)(1)(C), and Section 353.10 of the antidumping regulations provide that, in calculating dumping margins, the Department of Commerce, International Trade Administration (ITA) shall increase the U.S. price of the import in question by:
> "...the amount of any taxes imposed in the country of exportation directly upon the exported merchandise...which have been rebated, or which have not been collected, by reason of the exportation of the merchandise to the United States, but only to the extent that such taxes are added to or included in the price of such or similar merchandise when sold in the country of exportation..."

ing is only plausible in markets that are not perfectly competitive, estima-
tion techniques that ignore market structure are biased.[3] This paper examines
the size of the biases inherent in such an analysis.

Third, the incidence of the tax determines whether it pays for a firm to
export substantial quantities. Since Japan's 15% ad valorem tax on luxury
consumer durables is forgiven when they are exported, the higher the tax
incidence falling on firms, the more firms would export, all else the same.

Fourth, we derive measures of market structure and test whether the Japa-
nese television market is competitive, Nash-Cournot, or collusive. Our theo-
retical approach differs in some details from earlier approaches and this
study is the first empirical examination of the Japanese television market.
Earlier empirical papers have either estimated market structure based on
aggregate data (e.g., Appelbaum (1979, 1982), Just and Chern (1980), Sumner
(1981)) or on fully disaggregated data (e.g., Iwata (1974) and Gallop and
Roberts (1979)). We use data on some but not all firms and industry aggregate
data to estimate market structure.

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[3]In a number of recent cases, studies of tax incidences have assumed perfectly
competitive, linear models. For example in a recent television case, George-
town Economic Services, "The Economic Theory of Commodity Tax Passthrough and
Absorption in Home Market Sales of Japanese, Korean, and Taiwanese CTV's (sub-
mitted by Collier, Shannon, Rill & Scott on August 18, 1986 to the Department
of Commerce) claims that tax incidence can be correctly calculated using a
linear supply and demand framework. They note that this technique was used in
a Korean piano case (apparently Grand and Upright Pianos from the Republic of
Korea; Final Determination of Sales at Not Less Than Fair Value; 50 Fed.
37,561 (September 16, 1985)).

The standard approach to estimating tax incidence is to assume a competitive market structure, estimate supply and demand elasticities, ω and η, and then locally approximate the tax incidence as $\omega/(\omega + \eta)$ where the elasticities are measured at the equilibrium in the absence of a tax.[4]

Such an approach cannot be used in noncompetitive markets since the meaning of a supply elasticity is ambiguous. In our approach, a general model is estimated that allows for either competitive or noncompetitive behavior. The tax incidence is then calculated based on the relevant market structure.

We start our discussion by using an oligopolistic model to illustrate the bias that results when tax incidence is incorrectly calculated under the maintained hypothesis of competitive behavior. In the second section, we discuss how data availability determined our implementation of the theoretical model. In the third section, we present two variants of our theoretical model: the "aggregate" and the "disaggregate" models. Each of these models is then applied to estimate the market structure and the tax incidence in the subsequent sections. The results are summarized and conclusions drawn in the last section. The data are discussed in an appendix.

Biases Caused by Inappropriately Assuming Competition

To motivate our approach that estimates market structure, we use a standard conjectural varations model to illustrate the biases from inappropriately assuming competition. For now, we assume that there are n identical firms collectively producing Q units of a homogeneous product that sells for price

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[4]The approximation is exact if the supply and demand curves are linear.

$p(Q)$.[5] In the symmetric equilibrium, each firm produces $q = Q/n$ units at a variable cost of $C(q)$. If an ad valorem tax rate of t is imposed, firm i's profits are

$$\pi^i = (1 - t)p(Q)q_i - c(q_i) \tag{1}$$

The firm maximizes its profits by choosing q_i such that,

$$(1 - t)[p(Q) + (1 + \lambda)q_i p'(Q)] - c'(q_i) = 0, \tag{2}$$

where $1 + \lambda = dQ/dq_i$ is firm i's constant conjectural variation. Equation (2) says that each firm sets after-tax marginal revenue equal to marginal cost. Those readers who dislike the conjectural variation concept may prefer to interpret λ as an index of market structure. The values of λ of -1, 0, and $n-1$ determine, respectively, the competitive, Nash-Cournot, and collusive equilibria.

If t varies during the sample period, it would be possible to estimate the tax incidence using a reduced form model. Unfortunately, in most empirical investigations, there is little variation in the tax. Thus, it is necessary to estimate a structural model and then simulate the effect of the tax.

An economist inappropriately assuming competition estimates a supply equation using the first-order condition:

$$(1 - t)p(Q) - k'(q_i) = 0, \tag{2'}$$

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[5] In our estimations below, we drop the assumption that all firms are identical.

where k' is an individual firm's marginal cost. Equation (2') says that after-tax price equals marginal cost. Due to the assumed lack of variation in t, the economist mistakes k' for c'. Given the historical t and the constant λ,

$$k'(q) = c'(q) - (1 - t)(1 + \lambda)qp'(nq) \equiv h(q,t), \qquad (3)$$

where the identity is in q. That is, due to falsely assuming competition, the economist estimates a marginal cost curve that is too high: k'(q) is higher than c'(q), since demand curves slope down (p' < 0).

The effect of a change in t on q and p obviously differs depending upon whether the correct model or the competitive model is estimated. In the correct model, by totally differentiating (2), we obtain,

$$\frac{dq}{dt} = \frac{p + h_t}{h^*(q,t)}, \qquad (4)$$

where $h^*(q,t) \equiv (1-t)np' - h_q < 0$ for stability; $h_q = c'' - (1-t)[Qp'' + p'](1+\lambda)$; and $h_t = (1+\lambda)qp' \leq 0$, where equality holds only if the market is competitive ($\lambda = -1$). From (3), the estimate of dq/dt obtained under the competitive assumption is p/h^*, which is greater in absolute value than the true value given by (4).

Let p_λ be the predicted price at a tax rate of 0 under the oligopolistic model where λ is correctly estimated and p_c be the comparable price where competition is assumed so that $\lambda = -1$. Since demand slopes downward, $p_\lambda > p_c$ for $\lambda > -1$. If the observed price is p, the estimated incidence borne by consumers is

$$I_i = \frac{p - p_i}{tp} \, , \tag{5}$$

for i = λ (the correct model) or i = c (the competitive model with λ = -1).

From these definitions and the inequality in prices,

$$I_c = I_\lambda + \frac{p_\lambda - p_c}{tp} > I_\lambda. \tag{6}$$

for λ > -1.[6] That is, the maintained assumption of competitive behavior gives an upwardly biased estimate of tax incidence when the assumption is false.[7]

In a dumping case, were the tax incidence to be incorrectly estimated under the competitive assumption, a finding of dumping would be less likely than if the correct model were used. Since dumping is only profitable in the presence of market power, the assumption of competition in such cases is bizarre.

The Choice of Models

Since failure to properly model market structure leads to biased estimates of tax incidence, we estimate market structure and tax incidence based on a flexible model. Using data on a firm's input levels, input prices, and output, and aggregate data on demand variables, we jointly estimate parameters for demand, technology (cost), and market structures. These estimates are

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[6]A simple graphical illustration of this result is shown in Perloff (1987) for the collusion.

[7]Seade (1985) and Wright (1987) show that under oligopoly the tax incidence borne by consumers may exceed 100%. A necessary condition for this result is that $h_q < 0$. This inequality and the assumption that λ = -1 (perfect competition) imply concave costs (see equation (3)), which is inconsistent with the assumption of perfect competition.

used to calculate equilibrium prices for different tax rates and tax inci-
dence. This indirect approach to estimating tax incidence is used, since
there was not variation in tax rates during our sample period.

Our approach to estimation is determined by two data deficiencies. First,
the detailed data necessary to estimate costs functions were only available
for firms representing half the total market.[8] Second, industry-wide data by
type of color or black and white television sets are not available. Only data
for total color and total black and white televisions are reported (details on
the data set are presented in the appendix). Given this limited data set,
market structure and tax incidence can only be estimated if strong assumptions
are made.

We use two similar models to estimate tax incidence: the "aggregate" model
and the "disaggregate" model. In the aggregate model, we assume that all
color televisions are identical as are all black and white sets.[9] That is, we
aggregate across types of televisions, though not across firms. We simultane-
ously estimate four equations: the demand for color sets, the demand for black
and white sets, the cost function for color sets, and the cost function for
black and white sets. While this aggregation assumption is probably unrealis-
tic, this model is simple and does not require strong additional assumptions
in order to estimate tax incidence.

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[8]The data used in this study were obtained by the Commerce Department for use
in their investigation of possible dumping by Japanese television firms. In
the following, we purposefully do not name the firms nor supply enough infor-
mation so that one could infer which firm is which. Similarly, we do not list
raw data. The studies reported here are part of the public record so that
interested parties can check our work.

[9]As reported in more detail below, we were unable to reject the hypothesis that
the cross-price elasticities between color and black and white sets are zero.
Therefore, we model the black and white and the color markets as separate.

In the disaggregate model, we recognize that there are various types of television sets. Our data set divides televisions by size (small, medium, and large color and black and white sets) and differentiates color sets by style ("plain" and "fancy"), so there are six types of color sets and three types of black and white sets.[10] This model is more complex than the aggregate model since more equations must be simultaneously estimated and stronger assumptions must be made in order to calculate tax incidence.

Thus the aggregate model uses weaker assumptions and is easier to model, but its estimates may be incorrect if all sets are not identical in both production and consumption. The disaggregate model allows for cost technology differences across types of sets, but the estimate of tax incidence depends more heavily on how we have modeled and estimated market structure. While we believe the disaggregate model is richer and more reasonable, we present both models so that readers may draw their own conclusions.

Theory

Both our aggregate and disaggregate models are based on the conjectural variation model described above, but we now allow for nonidentical firms. Each assumes a firm maximizes its profits, equation (1), by choosing its output according to the first-order condition, equation (2). Both models assume the same log-linear functional form for demand and cost functions.

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[10]Small sets are less than 13" (diagonal measure), medium are 13 to 18", and large are 19" and above, but not including projection televisions. Fancy sets have stereo, remote control, or electronic tuning.

If we had data for all firms and types of televisions, we could estimate a complete set of equations including separate conjectural variations for each pair of firms. Our data set includes data for only some firms and industry aggregates. Thus, in both our approaches, we assume symmetric assumptions across firms. As a result, we can estimate market structure and incidence using data from only one firm and the industry aggregates.

The Aggregate Model

In the aggregate model, we use the same approach in analyzing both the color and black and white television markets, so in the following discussion, we only refer to televisions. For each market, we estimate a demand equation, a cost equation, and then use the behavioral assumption to determine the market structure and the tax incidence.

We can rewrite the first-order condition, equation (2), as

$$\frac{(1 - t)p(Q) - c'(q)}{s\varepsilon(1 - t)p(Q)} = -(1 + \lambda), \tag{7}$$

where $s = q/Q$ is the firm's share of the market and ε is the price elasticity of inverse demand (see equation (8) below).

As mentioned above, the parameter λ can be simply interpreted as an index of the markup of price over marginal cost. This model allows for competitive behavior ($\lambda = -1$), oligopolistic ($-1 < \lambda < [1 - s]/s$) and cartel behavior ($\lambda = [1 - s]/s$).[11]

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[11]Since we have not assumed that all firms are identical, the tests on λ provide necessary but not sufficient tests for market structure.

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In order to calculate tax incidence we require

Assumption 1: The share, s, is independent of Q.

Assumption 2: The conjecture (or measure of market power), λ,

is independent of Q.

Assumption 1 states that the aggregate behavior of other firms parallels that

of a given firm. This assumption is weaker than assuming all firms are iden-

tical or behave identically. Given assumption 1, assumption 2 can be replaced

by the assumption that the markup is invariant to the tax.

The equilibrium price is a function of the tax: $p = p(t)$. The tax inci-

dence, $I_\lambda(t)$ [henceforth, $I(t)$], defined in equation (5), is a function of the

tax and demand and cost factors.

In order to be able to estimate, the demand function is assumed to be

log-linear:

$$p = AQ^\epsilon, \tag{8}$$

where p is a price index for television sets and A is a shift function that

depends on income and time trends. A firm's cost function is also Cobb-

Douglas:

$$c(q) = Bq^\gamma, \tag{9}$$

where B is a function of factor prices and time trends.

Substituting (8) and (9) into (5) and simplifying, the tax incidence is:

$$I(t) = \frac{[1 - (1 - t)^{\epsilon/(1+\epsilon-\gamma)}]}{t}. \tag{10}$$

Thus, the tax incidence, I(t), does not depend explicitly on λ, although it varies with t. It may, therefore, appear that λ is superfluous. Such a conclusion is unwarranted. If we had falsely assumed λ = -1, then, the estimated of ε and γ would be biased, resulting in a biased estimate of I(t), as discussed above. Moreover, we could express (10) explicitly as a function of λ. We eliminated λ in (10) by using equations (7), (8), and (9) to express λ as a function of ε and γ.

In summary, to calculate the tax incidence using the aggregate model, we simultaneously estimate equations (8) and (9). We then use the parameter estimates of γ and ε to calculate λ and I(t) using equations (7) and (10). Both λ and I(t) are nonlinear functions of the estimated parameters, so we calculate confidence intervals on them using Taylor expansions around the point estimates.

From equation (10), the tax incidence is less than 100% if γ > 1 (decreasing returns to scale), equal to 100% if γ = 1 (constant returns to scale), and greater than 100% if γ < 1 (increasing returns to scale). The constant elasticity of demand and cost make the formula for λ and I particularly simple. However the choice of function forms in (8) and (9) was tested in the statistical analysis, as reported below, and was not chosen solely on the bases of convenience. If a more general demand function had been used, tax incidences in excess of 100% would also be possible with γ > 1.[12]

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[12]Seade (1985) and Wright (1987) show that tax incidences in excess of 100% are possible given enough curvature of the demand curve. Sufficient curvature is not possible given a Cobb-Douglas specification, so in our estimates, incidences above 100% can only result from increasing returns to scale..

Disaggregate Model

If cost and demand conditions vary across types of television sets, aggregation across types of set may bias estimates of tax incidence. As a result, we now consider a disaggregated model where cost functions vary by type:

$$C_i(q_i) = B_i q_i^{\gamma_i}, \tag{11}$$

where i indexes the type of television set and B_i is a function of factor prices and time trends.

Ideally, one would similarly estimate separate demand equations corresponding to the various types of sets. Since our data set only contains information on total color television sets, we estimate a single demand equation (8) jointly with the cost equations (11). We assume that the demand for television type i is:

$$p_i = A_i Q^{\epsilon}. \tag{12}$$

That is, we allow only the intercept and not the demand elasticity to vary across sets. The elasticity, ϵ, is obtained from estimation, while the shift parameters A_i are calculated to equal firm i's average price for television type i divided by the average total quantity raised to the ϵ power. Thus, equation (8) is still the overall demand curve, where A is appropriately defined using (12).

The firm's problem is to choose the q_i to maximize profits:

$$\pi = \sum_i [(1 - t)p_i q_i - c(q_i)]. \tag{13}$$

The conjectural variations are defined by $dQ/dq_i = 1 + \lambda_i$. Using the definitions $s_i \equiv q_i/Q$ (the share of the firm's line with respect to all color televisions), the firm's first-order conditions may be written as:

$$\frac{(1-t)p_i - C_i'(q_i)}{\varepsilon(1-t)\Sigma p_j s_j} = -(1 + \lambda_i). \tag{14}$$

If the market is perfectly competitive, $\lambda_i = -1$ and price (after tax) equals marginal cost. If the firms have formed a cartel, $\lambda_i = \lambda_k = \Sigma A_j \underline{Q}_j / \Sigma A_j q_j$, where $\underline{Q}_j$ is the total production of television type j by other firms. If the other firms produce the television types in the same proportion as firm i, then this condition becomes $\lambda_i = \lambda_k = (1 - s)/s$, where s is firm i's total share of the market across all types of televisions ($s \equiv \Sigma s_j$). Again, these conditions on λ_i are necessary but not sufficient conditions for testing market structure since the firms are not identical.

Define a weighted average "conjecture" as $\lambda = \Sigma s_j \lambda_j$, where the weights are proportional to the market share of each type of television. By multiplying both sides of (14) by s_i and summing over i, we obtain an expression in λ:

$$\frac{\Sigma[s_j p_j(1 - t) - s_j C_j'(q_j)]}{\varepsilon(1 - t)\Sigma s_j p_j} = -(s + \lambda). \tag{15}$$

In order to calculate the tax incidence we require assumptions analogous to Assumptions 1 and 2 above:

Assumption 3: The shares, s_j, are independent of Q.

Assumption 4: The weighted average conjecture, λ, is independent of Q.

Assumption 3 states that firm i's relative product mix, q_i/q_j, and aggregate

output relative to industry output is independent of total output. Given

assumption 4, equation (15) states that the weighted average of the markup of

price over marginal cost for the various types of televisions is independent

of the total quantity, and hence of the tax.

We can substitute for quantities in (15) using $q_j = s_jQ$, and

$$Q = [p/A]^{1/\varepsilon},$$

from the demand curve (8), to obtain an implicit functional relationship be-

tween price, p, and tax, t. Since this relationship cannot be written as an

explicit function, the tax incidence cannot be written in closed form. Numer-

ical methods, however, can be applied to obtain a point estimate of the inci-

dence and an estimate of the variance.

As was the case in the aggregate model, both the estimation of tax inci-

dence and of market structure can be conducted without interpreting λ_i as a

conjectural variation. The chief advantage of such an interpretation is that

it implies that the market equilibrium is the result of maximizing behavior on

the part of the firms.

In the previous model, the maximization hypothesis can be tested by check-

ing the second-order condition.[13] In the disaggregated model, it is not possi-

ble to check the second-order condition, since Assumption 4 is inconsistent

with the assumption that all λ_i are constant. Assuming that the λ_i's are

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[13]In the aggregate model, using the conjectural variation interpretation, the
second-order condition for profit maximization is:
$$(1-t)p\varepsilon[2+(\varepsilon - 1)s(1 + \lambda)]/Q - \gamma(\gamma-1)c/q^2.$$
If the less formal, "markup interpretation" to the aggregate model is adopted,
however, there is no underlying maximization so the second-order conditions
cannot be tested.

constant would be inconsistent with a market equilibrium given the form of the demand functions. Therefore, λ_i must depend on Q. The nature of this dependence, however, is unspecified; and given the limited data set it cannot be estimated. Therefore the maximization hypothesis cannot be tested in this manner. Thus maximizing behavior must be taken as a maintained assumption or the atheoretical "simple markup" interpretation adopted.

Comparison of the Two Models to the Standard Approach

Both our approaches rely on the assumption that the markup (or a weighted average of the markup) is constant. This assumption may be incorrect, but it cannot be tested given the available data.

The standard approach makes the same assumption of a constant markup, and moreover claims to know that the markup is zero (the market is competitive). Our models include the standard approach as a special case so that our approach is less restrictive. By allowing the data to indicate the historical markup, our models avoid a major source of bias and are likely to provide more reliable estimates of tax incidence.

The Estimations

We estimate several systems of equations based on both the aggregate and the disaggregate models. Both approaches involve estimating market share and tax incidence based on data for a single firm and the industry aggregates. Given data for more than one firm, we can estimate the models using each firm and then compare the results.

In most of the following, we use data from two firms.[14] Firm 1 and Firm 2

are two of the five largest firms in the industry. They provide data for

overlapping but not identical time periods. Moreover, neither firm produces

all possible types of sets and each produces types of sets the other does not.

Thus, our ability to compare results across the two data sets is limited.

Most of our discussion concerns estimates based on data from Firm 1, the

larger of the two firms. First, we estimate the aggregate model consisting of

four equations: demand for color and for black and white televisions, equation

(8), and cost functions for color and for black and white televisions, equa-

tion (9). Second, we estimated the disaggregate model consisting of eight

equations: demand for color and for black and white televisions, equation (8),

cost functions for the five types of color televisions and one cost function

for black and white televisions, equation (11).[15]

Later we also discuss other system of equations used to test hypotheses

about the Firm 1 cost functions and to estimate the Firm 2 cost functions.

Data used in all estimates are discussed in the appendix.

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[14]Data supplied by four other firms were more aggregate, available for too short
a time period, or in other ways unsuitable for use in estimating our model.
Those data are used in creating price indexes. See the appendix.

[15]Firm 1 produced only 5 of the 6 types of color televisions for the entire
sample period and only 1 of 3 types of black and white sets. As a result,
there is little difference between the aggregate and disaggregate estimates
for black and white sets.

The Specifications

Log-linear specifications are used for both the cost and the demand equations. The cost functions are assumed to be Cobb-Douglas. Equation (9) is written as:

$$\ln C(q) = \alpha_0 + \alpha_1 t + \alpha_2 t^2 + \alpha_3 t^3 + \gamma \ln q + \Sigma \beta_i \ln w_i + \xi_1, \qquad (6')$$

where q is the output of a particular type of television set (color or black and white in the aggregate model and a particular type in the disaggregate model), $C(q)$ are the variable costs, t is a time trend (t = 1, 2, 3, ...), w_i are the factor price indexes (wages, wholesale price index of semifinished materials, the prime rate, and the wholeseale price index of fuel), γ is the scale elasticity, and the β_i coefficients equal the factor shares in cost so they add to one, and ξ_1 is a random normal error term. We would have liked to use a more general cost function such as the translog or the generalized Leontief, but the limited number of observations (16: 1980:1 - 1983:4) prevented us from using such specifications. Tests on the log-linear specification and the Cobb-Douglas restrictions on shares are reported below.

The demand function (8) for color sets is written as:

$$\ln Q_c = \nu_0 + \nu_1 t + \nu_2 t^2 + \nu_3 t^3 + \nu_4 \ln I + \eta_c \ln p_c + \eta_b \ln p_b + \xi_2, \quad (5')$$

where I is real disposable income, the subscripts c and b refer to color and
black and white sets respectively, $n_c = 1/\varepsilon_c$ is the own-elasticity of demand
for color televisions, and ξ_2 is a random normal error term.[16] The black and
white demand function is the same with the c and b subscripts reversed.

The Aggregate Model

Table 1 reports the three-stage least squares estimates of the four equa-
tion system of the aggregate model. The Cobb-Douglas restrictions that the
coefficients on the factor prices equal that factor's share of total variable
costs are imposed.[17]

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[16]We would have liked to included other durable goods as possible substitutes
but we had problems obtaining appropriate series. For example, the price
index for radio cassette tape recorders was constant and that for passenger
cars relatively constant for the entire period and there was no price index
for video tape recorders in the early part of our period. We therefore de-
cided that the constant term serves as a reasonable proxy for other durable
goods.

[17]Instead of setting the coefficients equal to the average factor shares, one
can simultaneously estimate factor demand equations (the shares regressed on a
constant) and impose cross equation constraints. While that is easy to do
with a single cost function, when estimating a large system, the number of
equations become unwieldy. In the disaggregated model 23 equations would have
to be estimated simultaneously. The results are virtually identical (when
single equations are estimated), so the loss from using this simpler approach
is probably negligible. When the alternative approach is used, the t-statis-
tics on the factor prices tend to be very large (often 50 or higher). The
instruments used are discussed in the appendix.

Based on this model, the aggregate color televisions are produced with decreasing returns to scale ($\Upsilon_c = 1.1446$) while the black and white sets are produced with increasing returns to scale ($\Upsilon_b = 0.93923$). Apparently there were substantial time trends in production costs that were not captured by factor prices. Presumably, in part, these trends reflect technological progress and changes in institutional rules and laws over time.

Apparently color and black and white sets are not close substitutes. An increase in one type of set's price does not have a statistically significant effect on the type's quantity. Hence, as discussed above, we can examine the two markets separately. As might be expected, color televisions have a relatively elastic demand ($n_c = -3.1909$) while black and white televisions have a less elastic demand ($n_b = -1.6855$). Color televisions are a superior good (the income elasticity = 2.34) while black and white televisions are an inferior good (the income elasticity = -2.41). Indeed, the quantity of black and white televisions sold dropped in half from 1980:1 to 1983:4.

Evaluating at the means of the sample, $\lambda_c = 3.17$ and $\lambda_b = 1.03$. If the industries were cartelized, $\lambda_i = (1 - s_i)/s_i$, $i = c, b$. If we normalize the λ_i so that $\Lambda_i \equiv \lambda_i s_i/(1 - s_i)$, then $\Lambda_i = 1$ corresponds to a cartelize industry. Here, the point estimates are $\Lambda_c = 1.13$ and $\Lambda_b = .44$. The Wald test statistic that the color television industry is cartelized is 0.0019 with 1 degree of freedom (the critical value for the $\chi^2(1)$ at the 95% level is 3.84.[18] The corresponding test statistic for the black and white industry is 0.093.

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[18]All the test statistics and standard errors reported in this paper are asymptotic. Given the small samples involved, they should be viewed with some caution. Moreover the test statistics on nonlinear hypotheses are based on a Taylor expansion approximation. As Lafontaine and White (1986, pp. 38-40) point out, the use of a χ^2 table in evaluating Wald statistics on nonlinear tests can be misleading.

The Wald test statistics of the hypothesis that firms behave Cournot-Nash are 0.25 and 0.067 for the color and black and white industries. The corresponding statistics for competition are 0.45 and 0.35. Thus, on the basis of this model we cannot clearly determine the market structure, though the point estimates suggest that the color television industry is closer to cartelized than the black and white industry and that neither is competitive. The second-order sufficient conditions for profit-maximization are -0.43 and -3.08 at the sample means, so that these models are consistent with maximizing behavior.

On the basis of a Box-Cox test, we cannot reject the log-linear specification. Moreover, the Wald test statistic on the Cobb-Douglas restrictions on the factor price coefficients for the color televisions is 2.28 with 4 degrees of freedom (the $\chi^2(4)$ at the 95% level is 9.49), while the statistic for black and white sets is 8.20. Thus, we cannot reject the Cobb-Douglas specification on the basis of either of these types of tests.

As mentioned above, in the aggregate model, the tax incidence falling on consumers does not depend on λ explicitly. The estimated tax incidences for the color and black and white markets are 96.0% and 103.4%, respectively. The Wald test statistics (1 degree of freedom) are 2367 for color and 1448 for black and white against the hypothesis of 0% tax incidence; while the corresponding statistics against the hypothesis of 100% incidence are 4.12 and 1.60. Thus, on the basis of these test (and subject to the caveats mentioned above), we can reject the hypothesis that the incidence is 0% in either market. We cannot reject the hypothesis that it is 100% in the black and white market, but we can reject the hypothesis in the color market, at the 95% level.

Disaggregate Model

The 3SLS estimate of the disaggregate model are presented in Table 2. The demand equations and the black and white cost equations are the same as in the aggregate model. Not surprisingly, the results for these equations are quite similar. Again, the demand equations indicate that it is appropriate to consider the color and black and white markets separately.

Four out of five scale elasticity on the disaggregated color cost functions, unlike in aggregation model's cost equation, show increasing returns to scale (the exception is large, plain sets). These results cast some doubt on the aggregation model's assumption that it is appropriate to aggregate across types of color televisions.[19]

The Durbin-Watson statistic on the black and white demand equation is relatively high (as in the aggregate model), possibly reflecting a drop in demand for black and white sets that is not captured by price or time trend effects. The Durbin-Watson on the large, fancy color televisions is relatively low. The other Durbin-Watson statistics are very close to 2.00.

On the basis of Wald tests, the Cobb-Douglas restrictions for the five color types and the black and white cannot be rejected at the 97.5% level and can only be rejected at the 95% level for the small, fancy sets and the large, fancy sets. As a result of these tests and the Durbin-Watson results, we believe that the cost equation for large, fancy sets should be viewed with

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[19]If the underlying disaggregate cost functions are Cobb-Douglas, then the aggregate cost function is not Cobb-Douglas. One might prefer to think of it as a first-order approximation to a general cost function. The Wald test statistic that the five scale elasticities are equal is 31.65 with 4 degrees of freedom, so we have not imposed equality across types.

caution. If one estimates the log-linear cost functions without Cobb-Douglas restrictions, the scale elasticities are virtually unchanged. Since the Wald test is an asymptotic test and possibly the critical values are higher than the χ^2 table indicate, we chose to continue using the Cobb-Douglas restrictions based on theoretical considerations. Again, we would have liked to estimate more general cost functions, but we lacked sufficient observations to do so.

The estimated values for the black and white λ, at the sample means, is virtually the same as in the aggregate model, 0.97. The estimated values for the color λ_i at the means of the sample are shown in Table 3, as are the Wald test statistics against various hypotheses. Based on these Wald test, and subject to the usual caveats, we can reject competition in all cases, including black and whites (unlike in the aggregate model). Similarly, we can reject Cournot-Nash behavior for all color types, but not for black and whites.

It is not obvious what cartel behavior means in this case. If, as the estimates indicate, at least one firm is operating in the increasing returns to scale portion of its cost function (i.e., costs fall as it increases output), then a profit-maximizing cartel would have firms specialize in particular lines. If one believes that increasing returns are observed, but that for institutional or legal reasons a cartel were unwilling or unable to allocate the market in that manner, then the cartel would attempt to maximize profits subject to that constraint. Were a cartel behaving in that fashion, then a weak test of cartelization would be that the λ_i were equal across all lines. A stronger test would be that the $\lambda_i = (1 - s)/s$, as discussed above.

The Wald test statistic of equality across λ_i (i.e., the weak test of cartelization) is 27.02 with 4 degrees of freedom. The strong test, Wald statistic is 562.60 with 5 degrees of freedom. That is, on the basis of either test, we would reject the cartelization hypothesis.

These results indicate that the industry is oligopolistic. It is not perfectly competitive or perfectly cartelized. The point estimates of the λ_i indicate that the industry equilibrium lies between the Cournot and the cartel equilibria.

The incidence of the tax (at a tax rate of 15%) that falls on consumers, based on the disaggregate model, is 118.8%. The corresponding estimated asymptotic standard error is 1.01%. That is, the confidence interval is tight, (116.8, 120.8). The incidence for black and white sets is 104.0 with a 95% confidence interval of (99.6, 108.4). Based on the Wald test statistics, we would definitely reject the hypotheses that either incidence is 0%. Indeed, we would reject the hypothesis that it is as low as 100% in the color market.

Table 4 summarizes the point estimates and confidence intervals for the aggregate and disaggregate models. We can compare these results to those that would be obtained given the assumption of competition. In this industry, the competitive assumption is implausible since we find increasing returns to scale. If we assume competition and constant returns to scale, then the consumer tax incidence would be 100%, regardless of the demand elasticity. Such an estimate is not significantly below those of the aggregate model, but is 19% lower than the estimate of the disaggregated model for color sets.[20]

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[20]In the theoretical section, we showed that where there is decreasing returns to scale, inappropriately assuming the competitive model leads to an overestimate of the consumer tax incidence. Here, where there is increasing returns

Tests that Costs Depend on All Output

Our modeling is simple because we have assumed that costs only depend on the quantity of a particular line of output produced. Costs are assumed to be independent of other output of the same firm. We tested this assumption by including in the cost function measures of the firm's other output sold domestically and in the United States.[21]

For example, in the aggregate model, we tested whether black and white sets sold domestically and in the United States and color sets sold in the United States also affected the cost of producing color sets. In all cases, we individually and collectively reject the hypotheses that other lines affect costs of producing color televisions for sale in Japan. Similarly we reject the comparable hypotheses for black and white sets. Moreover, the coefficients on the own-output term were essentially unaffected when the additional output terms were included.

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to scale, the competitive assumption makes no sense. If we compare the incidence given the assumption of constant returns to scale and competition to the more general model with increasing returns, then the bias goes the other way. This result, obviously, does not contradict our theoretical results above.

[21]We do not know how much they sold in countries other than Japan and the United States. In our tests, we added terms like $\delta \ln q_o$, where q_o is another type of television or sold in the United states, to our log-linear cost specification, equation. The test then is an asymptotic t-test on δ.

In the disaggregated model, only 2 out of 24 of the additional quantity terms had coefficients that were statistically different from zero individually.[22] We could reject the hypothesis that these 24 terms collectively matter. We therefore continued to maintain the assumption that only own output affects costs for a particular type of television.

Firm 2

We compared our results for Firm 1 to those from Firm 2 for color televisions. Firm 2 only produced three types of color television sets (medium fancy, medium plain, and large fancy) for the entire period and no black and white sets.

Firm 2's aggregate equation shows decreasing returns to scale ($\gamma = 1.128$). Two of the disaggregate equations show slight decreasing returns to scale (though not statistically different from constant returns), while one shows slight increasing returns (statistically significantly different from constant returns).

The estimated λ_i for the disaggregate model are 11.482, 0.835, and 40.403. The corresponding normalized Λ_i terms are 0.512, 0.0111, and 0.401. The λ for the aggregate model is 9.458, and its normalized value is 0.666. The second order condition for the aggregate model is -0.794, so we cannot reject the profit-maximization assumption.

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[22]Only the other color quantity term and the sets sold in the United States were statistically different from zero according to asymptotic t-tests for the large, fancy sets.

The tax incidence falling on consumers (at t = 15%) is 89.1% in the disaggregate model and 96.4% in the aggregate model. Thus, even though Firm 2 sells far fewer sets than Firm 1, the estimates based on the two models appear comparable, albeit the Firm 2 numbers reflect more decreasing returns to scale and hence a lower tax incidence on consumers.

Tax Incidence Varies with Tax Rate

Above, we have reported estimated tax incidences at the tax rate, 15%, used by the Japanese. In both models, the tax incidence varies with the tax rate. The calculations are done by comparing the price at a given tax rate to that at a zero tax rate. Table 5 shows the calculated incidence at rates from 1% to 30% for Firm 1 color television sets.

The incidence falls under the disaggregated model as the tax rate rises. Thus, the calculated incidence at a tax rate of 1% is 3% higher than the incidence at a tax rate of 30% under the disaggregated model. The incidence slightly rises with the tax rate in the aggregate model. The incidence is 0.7% higher at a tax rate of 30% than at a 1% rate.

Conclusions

A number of new techniques and results are presented in this paper. First, we show that tax incidences on consumers can substantially exceed 100% in oligopolistic markets. Second, we develop a technique to estimate market structure where one has information on some, but not all firms, and industry aggregate information. Third, we find that the Japanese television industry is oligopolistic; and that its structure probably lies between Nash-Cournot and collusive.

Fourth, we theoretically derive the size of the bias on the estimate of tax incidence from mistakingly assuming that the industry is competitive when it is not. In our empirical work, we show that inappropriately assuming competition and constant returns to scale where the industry is oligopolistic and operating under increasing returns to scale, leads to an underestimate of the consumer tax incidence by 19%.

In addition to being of academic interest, this research demonstrates that studies used in dumping cases in the U. S. that have assumed a competitive structure probably produced biased results. This study demonstrates that it is feasible to estimate market structure and tax incidence using a more general approach.

Appendix: Data

The data come from five firms, Japanese Governmental Agencies, the International Monetary Fund, and Japanese trade associations. In the estimates based on Firm 1's data, the data cover the period 1980:1 (first quarter) to 1983:4 or sixteen time periods; while in the Firm 2 estimates, the data are for the period 1981:1–1985:4.

The output, cost factor shares, and some prices come from Firm 1 (or Firm 2). Our cost functions use total variable costs, which are defined as the sum of labor, material, energy, and capital costs.[23] For the aggregate model, aggregate color quantity data are formed by taking a weighted average of the various types of color televisions, where the weights are proportional to the quantity of each type of set.

All price and cost variables are deflated using the Japanese Consumer Price Index (CPI) to obtain real values. The CPI and most aggregate variables used as instruments in the three stage least squares estimates reported below come from the International Monetary Fund, International Financial Statistics. National Disposable Income comes from the Research and Statistics Department, The Bank of Japan, Economic Statistics Annual. The instruments include imports, government consumption, manufacturing employment, the exchange rate, and industrial production.

The total number of color and black and white sets sold in Japan was calculated using a variety of data sources. Television shipments to the Japanese domestic market are determined by taking total shipments and sub-

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[23]The companies also report a category called "other costs," which are not included in variable costs. As these costs typically were substantially less than 1 percent of total costs, ignoring these costs is unlikely to be a significant issue.

tracting exports. The data come from the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry, Yearbook of Machinery Statistics and the Japan Tariff Association, The Summary Report, Trade of Japan.

The retail price of Japanese color televisions are for the Ku-area of Tokyo and come from the Statistics Bureau, Management and Coordination Agency, Monthly Statistics of Japan. Since the definition of the representative color television changed after March 1983, using the wholesale price index for color televisions, an adjustment was made to create a consistent data series.[24] No comparable black and white series was found so that a weighted average of Firm 1's and Firm 3's black and white prices were used, where the weights were the number of sets sold.[25]

The factor prices are the contract monthly wage, the Wholesale Price Index (WPI) of semifinished goods, the WPI of fuels, and the prime interest rate. The contract monthly wage series was used since the total monthly wage series shows pronounced seasonality due to bonuses. We also tried substituting the wholesale price index of raw materials for that of semifinished goods, but the estimates were virtually unaffected.

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[24]The real color television prices (deflated by the Japanese CPI) for Firm 1, Firm 3, and Firm 4 and the constructed retail price series are highly correlated (r^2 = .85, .96, .75), so the adjustment is unlikely to have created substantial biases. The correlations between firms are also fairly high.

[25]The average uses data from only these two firms since they were the only ones to provide data for the relevant period. The correlation of the overall index and the two firm's prices are substantially lower than for color prices: r^2 = .46 and .83 respectively. The prices between the two firms are virtually uncorrelated. Thus, we have less confidence in the black and white price index than in the color index.

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Table 1
3SLS Aggregate Model
Coefficients and (asymptotic standard errors)

Variables	Cost		Quantity Demanded	
	Color	B & W	Color	B & W
Output	1.145 (0.0654)	0.939 (0.0433)		
Wage	0.0396 *	0.0586 *		
WPI semifinished materials	0.948 *	0.909 *		
Prime Rate	0.0100 *	0.0285 *		
WPI fuel	0.00193 *	0.00408 *		
Color television price			−3.191 (0.607)	−2.757 (2.773)
Black and White television price			−0.171 (0.123)	−1.686 (0.564)
Time	0.126 (0.0317)	0.107 (0.0293)	−0.183 (0.0431)	−0.336 (0.193)
Time squared	−0.0202 (0.00428)	−0.0169 (0.00397)	0.0121 (.00360)	0.0178 (0.0154)
Time cubed	0.000770 (0.000166)	0.000640 (0.000150)	−0.000354 (0.000129)	−0.000468 (0.000547)
Constant	3.969 (0.399)	3.747 (0.152)	23.297 (3.939)	32.705 (18.049)
Durbin-Watson	1.82	1.98	1.77	2.83
R^2 between observed and predicted	0.960	0.996	0.976	0.845

System χ^2 = 222.08 with 20 degrees of freedom.

* The factor price coefficients were restricted to equal the factor shares.

Table 2
3SLS Disaggregate Model

| Variable | Color Cost | | | | | B & W | Demand | |
	Small Plain	Medium Fancy	Medium Plain	Large Fancy	Large Plain	Small	Color Price	B & W Price
	Coefficients (asymptotic standard errors)							
Output	0.945 (0.0131)	0.920 (0.0583)	0.890 (0.0265)	0.988 (0.0280)	1.111 (0.0428)	0.927 (0.0317)		
Wage	0.0417 *	0.04249 *	0.0321 *	0.0443 *	0.0492 *	0.0586 *		
WPI Semi-Finished Materials	0.947 *	0.944 *	0.960 *	0.941 *	0.935 *	0.909 *		
Prime Rate	0.00859 *	0.0116 *	0.00659 *	0.0125 *	0.0139 *	0.0285 *		
WPI Fuel	0.00225 *	0.00211 *	0.00149 *	0.00217 *	0.00237 *	0.00408 *		
Color TV Price							-3.137 (0.500)	-1.150 (2.424)
B & W TV Price							-0.177 (0.103)	-1.7449 (0.497)
Disposable Income							2.414 (0.111)	-2.551 (0.528)
Time	0.102 (0.0244)	0.131 (0.0566)	0.113 (0.0257)	0.101 (0.0300)	0.130 (0.0590)	0.110 (0.0280)	-0.183 (0.0370)	-0.254 (0.172)
Time Squared	-0.0170 (0.00319)	-0.0219 (0.00727)	-0.0195 (0.00347)	-0.0177 (0.00405)	-0.0188 (0.00813)	-0.0172 (0.00379)	0.0123 (0.00328)	0.0130 (0.0143)
Time Cubed	0.000646 (0.000123)	0.000878 (0.000279)	0.000740 (0.000135)	0.000722 (0.000157)	0.000703 (0.000314)	0.000649 (0.000145)	-0.000366 (0.000119)	-0.000314 (0.000514)
Constant	4.3894 (0.0519)	4.737 (0.241)	4.519 (0.0725)	5.286 (0.0924)	5.390 (0.213)	3.283 (0.128)	14.493 (3.030)	16.258 (14.674)
Durbin-Watson	2.06	1.77	2.14	1.51	2.11	2.04	1.79	2.78
R^2 between observed and predicted	0.998	0.907	0.988	0.984	0.991	0.996	0.976	0.840

System χ^2 = 509.48 with 36 degrees of freedom.

* These coefficients are restricted to equal the corresponding factors' share of costs.

Table 3
Market Structure Parameters in the Disaggregated Model

	λ_i	Wald Tests (1 degree of freedom)	
		Competitive	Cournot
Color Televisions:			
Small, Plain	1.42	20.45	7.05
Medium, Fancy	4.87	22.99	15.83
Medium, Plain	1.82	22.10	9.19
Large, Fancy	9.30	25.71	20.96
Large, Plain	6.07	11.9	8.77
Black and White Televisions:			
Small	0.978	9.68	2.35

Note: $\chi^2(1)$ at the 95% level is 3.84.

Table 4
Consumer Tax Incidences
(Percentage)

Model	95% Confidence Interval	Point Estimate	Confidence Intervals: ( ) Point Estimates: *
Disaggregate Model			
Color	(116.8, 120.8)	118.8	(*)
Black and White	(99.6, 108.4)	104.0	(*)
Aggregate Model			
Color	(92.1, 99.9)	96.0	(*)
Black and White	(98.1, 108.7)	103.4	(*)

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                                    .|....|....|....|....|....|....|.
                                    90   95   100  105  110  115  120
                                         Consumer Tax Incidence
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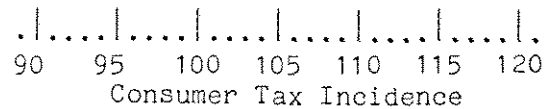
Table 5
Tax Incidence varies with the Tax Rate

Tax Rate (%)	Consumer Tax Incidence (%)	
	Disaggregate	Aggregate
1	120.14	95.69
2	120.04	95.71
3	119.95	95.73
4	119.85	95.75
5	119.76	95.77
6	119.66	95.79
7	119.57	95.81
8	119.47	95.84
9	119.37	95.86
10	119.27	95.88
11	119.17	95.90
12	119.06	95.92
13	118.96	95.95
14	118.86	95.97
15	118.75	95.99
16	118.65	96.02
17	118.54	96.04
18	118.43	96.06
19	118.32	96.09
20	118.21	96.11
21	118.10	96.14
22	117.99	96.16
23	117.88	96.19
24	117.76	96.21
25	117.65	96.24
26	117.53	96.26
27	117.41	96.29
28	117.29	96.31
29	117.17	96.34
30	117.05	96.36