Estimation of Competitive Conduct When Firms Are Efficiently Colluding: Addressing the Corts Critique

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Abstract

I address a recent critique by Corts [1999] who finds that traditional approaches in New Empirical Industrial Organization to estimate the competitive conduct in an oligopoly market can yield inconsistent estimates of the conduct parameter if firms are engaged in efficient collusion. This paper derives a general empirical model that allows consistent estimation of the conduct parameter that is robust to efficient collusion.

JEL Classification: L1, L4, K2, L5

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1 Introduction

One goal in empirical industrial organization is to empirically distinguish between different forms of competitive behavior in particular markets. Oligopoly pricing theory offers a wealth of models with equilibrium outcomes ranging from perfect competition to joint monopoly pricing. Unfortunately, many markets have institutional features for which a variety of oligopoly pricing models are a priori plausible. Understanding which models best explain certain markets can inform both market design and antitrust policy.

The literature contains many empirical studies that make inferences about the pricing model that prevails in a particular industry. Studies in the New Empirical Industrial Organization (NEIO) literature have estimated firm conduct by parameterizing the firm's static first-order condition (Marginal Revenue=Marginal Cost) to allow for price-taking, Cournot competition, and monopoly pricing. This methodology is sometimes called the Conduct Parameter Method (CPM).

Unfortunately, a recent paper casts doubt upon the validity of the CPM. Corts [1999] shows that traditional approaches can lead to inconsistent estimates of the conduct parameter if firms are engaged in efficient tacit collusion. For example, suppose that firms are colluding on a price higher than the Cournot price but lower than the joint monopoly price. Corts shows that the traditionally estimated conduct parameter typically will underestimate market power.[1] Corts' critique has potentially severe implications for market power studies that attempt to estimate firm conduct. As a result, the existing empirical literature does not offer methods to consistently estimate conduct when one possible conduct is *imperfect* collusion.

This note suggests a solution to the Corts Critique. I derive a general model that incorporates static pricing and imperfect collusion as special cases. The intuition is simple. Firms in a collusive regime maximize joint profit subject to the constraint that no firm has an incentive to deviate and start a "price war." The resulting first-order condition is simply the static model (MR=MC) with an additional term that incorporates the incentive compatibility constraint for firms to remain in the collusive regime. Although the researcher does not have data on this term, she knows that the additional term is constant across all firms in a given period. If the researcher has a panel of all firms that are potentially colluding, the incentive compatibility term can be "conditioned out" with a fixed effect. The general model can be used to consistently estimate competitive conduct if the researcher has firm-level data, which is increasingly the case in empirical industrial organization.

2 Models of Firm Conduct Under Static and Dynamic Pricing Games

2.1 Static Pricing

In static models, firms maximize individual profits each period without explicit consideration of

[1] For empirical evaluations of the Corts Critique, see Genesove and Mullin [1998], Wolfram [1999], Clay and Troesken [2003] and Kim and Knittel [forthcoming].

the effect of behavior in one period on the competitive environment in other periods. Assume N firms simultaneously choose to supply individual quantities each period. Price is determined such that supply equals demand. Denote $P(\cdot)$ as inverse demand, $C_{it}(q_{it})$ as the total cost, and q_i as individual firm quantity. Firm i chooses quantity of output in period t to maximize profit:

$$\max_{q_{it}} \quad P(q_{it} + q_{-it}) \cdot q_{it} - C_{it}(q_{it})$$

The first-order condition characterizing an interior solution at the optimal quantity q_{it}^* is:

$$P(q_{it}^* + q_{-it}) - c_{it}(q_{it}^*) + \theta_i \cdot P_t' \cdot q_{it}^* = 0 \tag{1}$$

where $c_{it}(q_{it})$ is marginal cost. $\theta_i \equiv \frac{dQ_t^*}{dq_{it}} = 1 + \sum_{j \neq i} \frac{\partial q_{jt}}{\partial q_{it}}$ is the firm's belief about the effect of increasing its output on total industry output. The parameter θ_i parameterizes the MR=MC optimality condition. $\theta_i = \{0, 1, N\}$ corresponds to perfect competition, Cournot, and monopoly pricing (under symmetry), respectively. There are a limited set of values that θ_i may take to be either a Nash equilibrium or a consistent conjecture, and this affects estimation as I discuss below. Equation (1) (and aggregations of this equation) is the standard model used to justify the CPM.

2.2 Dynamic Pricing

Firms that engage in efficient tacit collusion choose output to maximize joint profits subject to the constraint that no firm has an incentive to deviate in order to earn higher one-time profits at the risk of starting a "price war". Deviation from the collusive quantity is punished by permanent reversion to a lower profit "punishment" outcome such as Cournot or price-taking (e.g. Green and Porter [1984], Rotemberg and Saloner [1986], Haltiwanger and Harrington [1991] and Staiger and Wolak [1992]). I assume a full-information environment similar to the model of Rotemberg/Saloner. Assume that firms are symmetric and that sharing rules specify each firm produces $\frac{1}{N}$ of the total output. Denote firm i profit as π_i. π_{is}^* is firm i's optimal collusive profit in future period s. Let $\pi_i^{br}(Q_t)$ represent the individual profit to any firm that unilaterally deviates from the collusive regime by producing its one-shot best response to the collusive quantities of the other firms. Deviation is punished by reversion to noncollusive "punishment" profit π_i^p. $E_t[\pi_{is}]$ denotes expectations of future period s profit conditional on information known in period t. Finally δ is the discount factor between periods. Firms choose joint quantity Q_t^* to maximize joint profit subject to the constraint that no firm has an incentive to deviate from the collusive regime:

$$\max_{Q_t} \quad \sum_{i=1}^{N} \pi_{it}(\frac{Q_t}{N})$$

$$s.t. \quad \pi_{it}^{br}(Q_t) + \sum_{s=t+1}^{\infty} \delta^{s-t} E_t[\pi_{is}^p] \leq \pi_{it}(\tfrac{Q_t}{N}) + \sum_{s=t+1}^{\infty} \delta^{s-t} E_t[\pi_{is}^*] \qquad \forall i$$

After taking the first-order condition and rewritting to find the condition that each firm in a collusive regime is satisfying, one obtains:

$$P(Q_t^*) - c_{it}(q_{it}^*) + N \cdot P_t' \cdot q_{it}^* - \frac{\mu_t^*}{1+\frac{\mu_t^*}{N}} \frac{d\pi^{br}}{dQ}_t = 0 \qquad \forall i \tag{2}$$

where μ_t^* is the Lagrange multiplier on the incentive compatibility constraint. This condition has a simple interpretation. In collusive equilibrium, the firm internalizes the effects of price changes on the revenue for all firms' inframarginal output (Nq_{it}^*). When the incentive compatibility constraint does not bind ($\mu_t^* = 0$), the last term is zero and I get the firm-level first-order condition for joint monopoly pricing. When the constraint binds ($\mu_t^* > 0$), joint output must rise and price must fall so that no firm deviates to earn best-response profits; firms collude on a price between Cournot and joint monopoly levels.[2]

3 An Empirical Model to Address the Corts Critique with Firm-Level Data

These models of static pricing and collusion can be represented within a general model that incorporates as special cases the static (1) and dynamic (2) first-order conditions:

$$P(q_{it}^* + q_{-it}) - c_{it}(q_{it}^*) = -\theta_i P_t' q_{it}^* + \frac{\mu_t^*}{1+\frac{\mu_t^*}{N}} \frac{d\pi^{br}}{dQ}_t \tag{3}$$

H_1: Competitive Pricing: $\theta_i = 0$, $\mu_t^* = 0$
H_2: Cournot: $\theta_i = 1$, $\mu_t^* = 0$
H_3: Efficient Tacit Collusion: $\theta_i = N$, $\mu_t^* \geq 0$

Equation (3) captures three common oligopoly models: competitive pricing, Cournot pricing, and efficient tacit collusion. Under competitive pricing, price-cost margins are zero. Under Cournot competition, price-cost margins are positive because firms unilaterally withhold output to raise the price and earn higher revenue on their *own* inframarginal units. Under efficient tacit collusion, firms jointly withhold output to raise the price on *joint* inframarginal units, with this regime maintained by adjusting quantity so that no firm has an incentive to deviate from joint profit maximization.

The general model of equation (3) provides another interpretation of the Corts Critique. Most NEIO market power studies add a stochastic error term to equation (1) and estimate θ (using, for example, GMM). Corts says this yields biased estimates of θ if firms are engaging in imperfect tacit collusion. This result is easily seen with my formulation. The last term in equation (3) is in the error term of a model estimating the static MR=MC first-order condition. If that term is

[2] Note that if one wanted to generalize the model to asymmetric firms, then a single fixed effect for each time period still would suffice; only one firm has a *binding* incentive compatibility constraint in equilibrium. However, modeling the sharing rule under asymmetric costs adds complications, so I simplify by assuming symmetry.

non-zero and it is correlated with the right-hand side variable q, coefficient estimates will be biased and inconsistent. More precisely, estimates of the conduct parameter θ are biased and inconsistent if (1) the incentive compatibility constraint constraint is ever binding ($\mu^* > 0$) and (2) the best-response profits are non-linear in q. Because profit functions are non-linear, the conduct parameter estimate is biased and inconsistent if firms are engaging in collusion below the joint monopoly price (i.e. $\mu_t^* > 0$).

However, equation (3) also suggests an empirical specification to avoid the Corts Critique. Learning about market power involves consistently estimating θ_i. Suppose the researcher has firm-level data on output. Increasingly, researchers and regulatory officials are acquiring access to such data (e.g. electricity markets, various auctions). The last term in equation (3) captures the effect on optimal pricing of the firm in the collusive regime with the binding incentive compatibility constraint. This term is equal across all firms in the collusive regime for a given period (i.e. it is not indexed by i). Although a researcher does not have data on it, this extra term can be "conditioned out" by including time fixed-effects. With these fixed effects, the model is correctly specified (i.e. there is no omitted variable that is correlated with the covariates), so the conduct parameter θ_i is consistently estimated under efficient tacit collusion. Moreover, if firms are playing a static pricing game, these fixed effects are zero, so equation (3) generalizes both static and dynamic pricing.

The estimation is illustrated in Figure 1. Under Cournot or competitive pricing, the supply relation is a ray through the marginal cost intercept (i.e. the fixed effect is zero), and the slope of the supply relation is θ_i. Under efficient tacit collusion, the fixed effect is a non-zero intercept and the slope=θ_i=N. Given a panel of firm-level data, θ_i is econometrically identified and can be consistently estimated. Using this empirical formulation, non-nested tests can estimate if the data are more consistent with one of the three equilibrium models of behavior.

4 Conclusions

This note derives an empirical specification for the consistent estimation of the conduct parameter when firms are playing either a static game or are engaging in efficient tacit collusion. This methodology is useful for empirical applications in which the researcher is estimating conduct but is concerned about potential bias due to the Corts Critique. Nevertheless, several caveats are in order. First, the researcher needs firm-level data in order to "condition out" the omitted variable arising from the incentive compatibility constraint. Second, this methodology is robust to *efficient* tacit collusion, but may not be robust to other forms of dynamic pricing. This approach leverages the binding incentive compatibility constraint that restricts the set of payoffs that can be obtained; this approach is not robust to forms of dynamic pricing not operating at the frontier of collusive payoffs.

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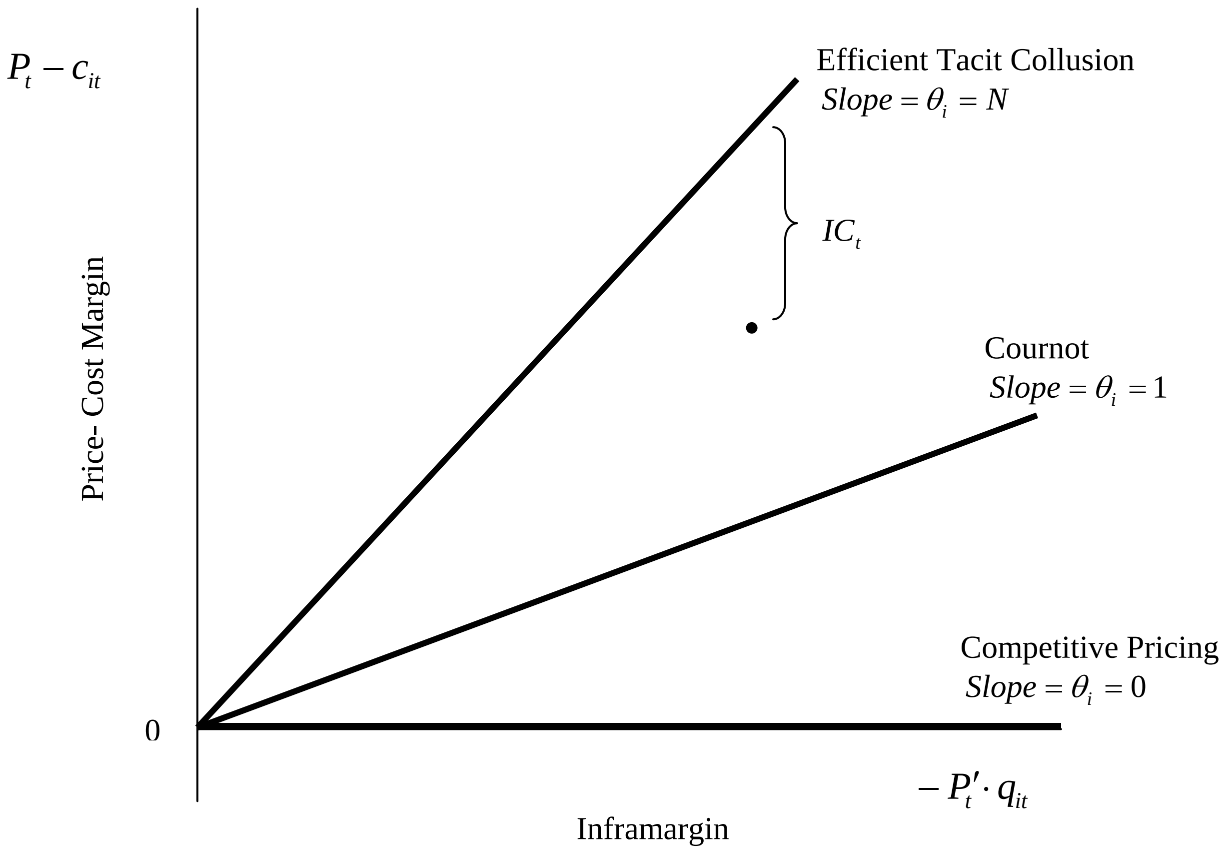
**Figure 1: Supply Relations Under
Competitive, Cournot and Efficient Tacitly Collusive Pricing**



Under tacit collusion, $IC_t = \frac{\mu_t^*}{1+\frac{\mu_t^*}{N}} \cdot \frac{d\pi^{br}}{dQ}_t$ is the adjustment from perfect collusion (the joint monopoly outcome) to respect the incentive compatibility constraint. This term is constant across all firms in period *t*.