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Staff Paper

Deterministic Nonparametric Market Power Tests: An Empirical Investigation

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**DETERMINISTIC NONPARAMETRIC MARKET POWER TESTS:
AN EMPIRICAL INVESTIGATION**

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Abstract: A review of recent literature reflects the development of several deterministic nonparametric market power tests. We use Monte Carlo experiments to evaluate the veracity of four monopolistic and four monopsonistic market power tests that use the deterministic nonparametric approach. The experiments are implemented using data from ten known market structures. When results are compared to Raper, Love, and Shumway's (1999) findings concerning parametric market power tests in the Bresnahan-Lau tradition, we find that the parametric tests perform well while only two of the nonparametric tests appear able to identify market power.

Keywords: market power, Monte Carlo, nonparametric, monopoly, monopsony.

JEL Classification: L1.

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**DETERMINISTIC NONPARAMETRIC MARKET POWER TESTS:
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Abstract: A review of recent literature reflects the development of several deterministic nonparametric market power tests. We use Monte Carlo experiments to evaluate the veracity of four monopolistic and four monopsonistic market power tests that use the deterministic nonparametric approach. The experiments are implemented using data from ten known market structures. When results are compared to Raper, Love, and Shumway's (1999) findings concerning parametric market power tests in the Bresnahan-Lau tradition, we find that the parametric tests perform well while only two of the nonparametric tests appear able to identify market power.

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1. Introduction

In economic theory, monopoly market power is the ability to set price greater than marginal cost, that is, above the competitive level where prices are presumed equal to marginal cost.¹ If market power is exerted, *deadweight welfare loss* occurs. This denotes, in the case of monopoly power exertion, that consumer surplus decreases, producers receive a surplus (profit), and some of the former consumer surplus becomes a loss to society. Knowledge of the degree of market power exertion is used to guide decisions regarding merger policy or antitrust enforcement in such markets. Thus, it is important to be able to detect monopolistic or monopsonistic behavior by a firm or industry to assess whether the market structure should be changed through, for example, government intervention. An example is the United States Department of Agriculture's (USDA) Grain Inspection, Packers and Stockyards Administration's (GIPSA) recent investigation into monopsony power exertion by meat packers in procuring live cattle. Significant evidence of imperfectly competitive behavior by packers could lead to new regulations regarding price reporting, the cattle bidding process, or ultimately to a breakup of the packers by the Justice Department.

Three major approaches to measurement of market power exertion have developed within New Empirical Industrial Organization (NEIO): parametric, nonstructural, and nonparametric market power tests. In this paper, we will focus on deterministic nonparametric market power tests and their performance compared to parametric market power tests. Both, parametric and deterministic nonparametric market power tests develop from profit maximization assumptions and result in direct measures of market power exertion. The parametric approach econometrically estimates market power by parameterizing the monopoly

¹We do not follow the Chicago School which asserts that markups are due to efficiency. This efficiency lowers costs which translates into lower prices and thus benefits consumers. The benefits are assumed to be greater than under the situation where less efficient but competitive firms which do not charge a markup, have higher costs so that prices are in the end higher than from a more efficient firm.

(monopsony) markup (markdown) term (Appelbaum 1979; Bresnahan 1982; Lau 1982). It relies on a calculus approach which assumes that the entire demand and supply function is available for analysis. Parametric tests yield testable hypotheses regarding market power exertion. However, these hypotheses depend on the functional form chosen for the underlying model. Additionally, econometric identification of the market power parameter restricts functional form choice somewhat.

The deterministic nonparametric approach to market power measurement is relatively new and developed in response to criticisms of the parametric approach (Ashenfelter and Sullivan 1987; Driscoll, Kambhampaty and Purcell 1997; Lambert 1994; Love and Shumway 1994; Ussif and Lambert 1998). Deterministic nonparametric tests are an exhaustive search for violations of the given hypothesis using an algebraic approach assuming only a finite number of observations on firm behavior. In contrast to parametric tests, deterministic nonparametric tests do not require *ad hoc* specifications of functional form for production, cost, profit, supply, or demand functions, so the problem of testing joint hypotheses is avoided (Varian 1984; Varian 1985; Varian 1990). Additionally, less data is required than for parametric tests because opposing supply or demand curves are not needed and they can handle disaggregated inputs and multiple output technologies. However, deterministic nonparametric tests are not imbedded in a stochastic framework, that is, “the data are assumed to be observed without error, so that the tests are ‘all or nothing’: either the data satisfy the optimization hypothesis or they don’t” (Varian 1985, pg. 445). This can result in the possible rejection of hypotheses that are only violated once because the magnitude of violations is not considered.

Various authors argue the merits of each type of market power test (Ashenfelter and Sullivan 1987; Hyde and Perloff 1994; Hyde and Perloff 1995), but to date no comprehensive comparison of the performance of deterministic nonparametric and parametric tests has been conducted. For comparison of performance, it is necessary to apply the tests to data where the degree of market power exertion is known.

This is accomplished via Monte Carlo experiments. Love and Shumway (1994), Hyde and Perloff (1994; 1995), and Raper, Love, and Shumway (1996; 1999) use this technique to assess the accuracy of market power tests. Hyde and Perloff compare the performance of nonstructural tests to the performance of parametric tests in detecting monopoly or monopsony market power. Love and Shumway explore the robustness of their deterministic nonparametric monopsony market power test while Raper, Love, and Shumway (1996) test the accuracy of their statistical nonparametric market power tests. Raper, Love, and Shumway (1999) assess the accuracy of traditional NEIO models (Bresnahan-Lau approach) under misspecification of market structure using a monopoly test, a monopsony test, and a flexible composite market power test which allows for both monopoly and monopsony market power exertion.

They report mean values and standard deviations of market power parameters for ten market structures over 1000 simulations for each of the three tests using the same data set as this study. They find that both the monopoly and monopsony market power tests using the Bresnahan-Lau approach perform remarkably well at estimating the magnitude of market power exertion. However, when the direction of market power is misspecified, in the unilateral tests, technology parameter estimates are highly biased. The composite model combines the two uni-lateral market power tests into one test that does not assume *a priori* one side of the market to be perfectly competitive, but allows for either or both sides of the market to have some degree of market power. The composite model gives results similar to the monopoly and monopsony tests when considering the significance of market power estimates. It also performs quite well at estimating both direction and magnitude of market power exertion. Additionally, Raper, Love, and Shumway's (1999) composite model is able to distinguish between perfect competitive and bilateral monopoly data.

In this study, we assess the performance of deterministic nonparametric market power tests via Monte Carlo experiments. We first present a brief description of several deterministic nonparametric market power

tests from the literature. Then, we implement these tests using Raper, Love, and Shumway's (1999) simulated data from 10 different market structures, including perfect competition, monopoly, monopsony, Cournot and Stackelberg duopoly and duopsony, and three forms of cooperative bilateral monopoly. We compare the performance of these deterministic nonparametric tests to each other and to that of Bresnahan-Lau type parametric market power tests as reported in Raper, Love, and Shumway (1999). Thus, in this study, we hope to add to the knowledge base regarding which tests should be used in the future to determine whether a firm and/or industry exerts market power.

2. Deterministic Nonparametric Tests

Deterministic nonparametric tests, which employ a revealed preference approach, were introduced by Afriat (1972), Hanoch and Rothschild (1972), Diewert and Parkan (1983), and Varian (1984) in the production economics literature. Varian (1984) proposed the Monopolistic Axiom of Profit Maximization (MAPM) which gives the conditions under which observed behavior can be rationalized as monopolistic behavior. Ashenfelter and Sullivan (Ashenfelter and Sullivan 1987) developed the first deterministic nonparametric monopoly market power test based on the Weak Axiom of Profit Maximization (WAPM) that directly measures the importance of the monopoly markup term in profit maximization.. Others followed in developing market power tests with foundations in this literature (Driscoll, Kambhampaty and Purcell 1997; Lambert 1994; Love and Shumway 1994; Ussif and Lambert 1998). The general approach measures the importance of the monopoly markup or monopsony markdown term in profit maximization. In the case of monopsony power, market power translates to an input price less than the value of marginal product. In the case of monopoly power, market power translates to an output price higher than the marginal cost of production. For consistency with competitive behavior, WAPM states that the observed input and output

quantity choices at output price p and the vector of input prices, \mathbf{w} , must yield profit at least as great as any other quantity set that could have been chosen. Quantity choices made in each period will provide evidence of market power.

Consider firm i 's profit maximization problem

$$(1) \quad \text{Max}_{y_i} \pi_i = p y_i - \sum_{m=1}^n w_m z_{mi} \quad \text{subject to } F_i(\mathbf{z}) \geq y_i,$$

where p is output price, y_i is firm i 's output, w_m is the price of input m , z_{mi} is the quantity of input m demanded by firm i , \mathbf{z} is the vector of variable inputs, and $F_i(\mathbf{z})$ is firm i 's production function. The perfectly competitive firm's discrete first-order profit-maximizing condition is

$$(2) \quad \Delta \pi_i = p \Delta y_i - \sum_{m=1}^n w_m \Delta z_{mi} \leq 0.$$

This is the WAPM. Here we assume that prices are exogenous since the firm cannot influence prices through input or output quantity choice. However, a firm with monopoly power in the output market can influence output price p by its choice of output level y_i . Thus, the monopolistic firm's first-order profit-maximizing condition in discrete terms is

$$(3) \quad \Delta \pi_i = p \Delta y_i + y_i \Delta p - \sum_{m=1}^n w_m \Delta z_{mi} \leq 0,$$

where the output price p is now dependent on firm i 's output quantity decision. The monopoly markup term is the second term on the right-hand-side. By reducing output of y_i , the firm can increase the price it receives for every unit sold. Equation (3) represents a modification of WAPM to allow for monopolistic market power. A similar equation can be derived for the monopsony case.

$$(4) \quad \Delta \pi_i = p \Delta y_i - \sum_{m=1}^{n-1} w_m \Delta z_{mi} - w_n \Delta z_{ni} - z_{ni} \Delta w_n \leq 0,$$

where the monopsony markdown term is the fourth term on the right hand side. By reducing the quantity bought of the monopsonistically exerted input z_{ni} bought, the firm can decrease the price, w_n , it has to pay for this input.

2.1 Ashenfelter and Sullivan Method

Ashenfelter and Sullivan (1987) were the first to test for monopoly market power exertion using the deterministic nonparametric approach. They construct a deterministic nonparametric test of the monopoly model based on revealed preference arguments and extend the test to assess the validity of some less extreme oligopoly models. They make two assumptions that simplify the empirical implementation: (1) the assumption of increasing costs and (2) the maintained hypothesis that variations in the excise tax are equivalent to changes in marginal cost. This allows Ashenfelter and Sullivan to drop input costs from the equation since their exclusion will not affect the equation's integrity. The monopoly markup term is parameterized and its parameter, β^{mp} , lies between zero for perfect competition and one for monopoly while values in between correspond to oligopoly situations. The parameter β^{mp} is thus an equivalent to the Lerner index (1934) of monopoly market power, $L = \frac{P - MC}{P}$, which exhibits these properties under the assumption that a monopolist does not operate in the inelastic portion of the demand curve. Ashenfelter and Sullivan adjust also for structural shifts (shifts in the demand or cost functions) by comparing only observations no more than two years apart, but do not incorporate the possibility of technical change. The original industry-level monopoly market power test is

$$(5) \quad \beta^{\text{mp}} \leq \frac{-(p^t - e^s)(y^t - y^s)}{(p^t - p^s)y^s} \quad \forall t \neq s \quad \text{where } |t - s| \leq 2,$$

where t and s represent time periods, with $t = 1, 2, \dots, T$ and e^s is the excise tax. Applying this model to the U.S. cigarette industry from 1955 to 1982 by state, they find little evidence for the monopoly hypothesis (true only 37% of the time). Additionally, they calculate a *Cournot numbers equivalent* (CNE) which is greater or equal to the inverse of β^{mp} . More than 75% of the data support the hypothesis that the U.S. cigarette industry behaves equivalent to having five or six Cournot-type firms in the market. More than 86.5% of the data support the hypothesis that the industry works as if nine Cournot-firms compete in the same market.

To generalize this test to industries that do not exhibit excise taxes, the test can be modified to

$$(6) \quad \beta^{\text{mp}} \leq \frac{-p^t(y^t - y^s)}{(p^t - p^s)y^s} \quad \forall t \neq s \quad \text{where } |t - s| \leq 2.$$

Using the same method as Ashenfelter and Sullivan, we can also develop an analogous test for monopsony market power exertion, given by

$$(7) \quad \beta^{\text{ms}} \leq \frac{p^t(y^t - y^s)}{(p^t - p^s)y^s} \quad \forall t \neq s \quad \text{where } |t - s| \leq 2,$$

where β^{ms} is equal to a Lerner-type index for monopsony market power exertion, $M = \frac{\text{VMP} - w_n}{w_n}$, which has a lower bound of zero. VMP represents the value of the marginal product.

Raper, Love, and Shumway (1998) revise Ashenfelter and Sullivan's test to explicitly include input parameters to account for possible changes in costs. Additionally, they use Love and Shumway's (1994) method to account for obvious structural shifts in the opposing market. For the measurement of monopoly

market power, we are concerned with shifts in the demand curve from the opposing market. Such shifts unmatched by supply shifts occur where the change in output prices, i.e., where Δp is of the same sign as the change in output quantity, Δy_i . The resulting monopoly market power test is

$$(8) \quad \beta^{mp} \leq \frac{-p^t(y_i^t - y_i^s) + \sum_{m=1}^n w_m^t(z_{mi}^t - z_{mi}^s)}{(p^t - p^s)y_i^s}$$

$\forall t \neq s \text{ except when } y_i^t - y_i^s \stackrel{S}{=} p^t - p^s.$

They also develop the analogous monopsony market power test using the same revisions. Here, we are concerned with shifts in the supply curve from the opposing market, represented by the situation where the change in the price of the potentially monopsonistically exerted input, Δw_n , is not the same as the change in its price, Δz_{ni} .

$$(9) \quad \beta^{ms} \leq \frac{p^t(y_i^t - y_i^s) - \sum_{m=1}^{n-1} w_m^t(z_{mi}^t - z_{mi}^s) - w_n^t(z_{ni}^t - z_{ni}^s)}{(w_n^t - w_n^s)z_{ni}^s}$$

$\forall t \neq s \text{ except when } z_{ni}^t - z_{ni}^s \stackrel{S}{\neq} w_n^t - w_n^s.$

2.2 Love and Shumway Approach

Love and Shumway (1994) develop a deterministic nonparametric monopsony market power test using a linear programming technique. The test is grounded in the revealed preference approach of Ashenfelter and Sullivan, but includes the possibility of Hicks-neutral (additive output-augmenting) technical change and adjusts for structural change as discussed above. “Technical change is said to be Hicks neutral if the marginal rate of substitution between inputs is not affected by the change” (Chavas and Cox 1990, pg. 450). Its introduction into deterministic nonparametric tests has been pioneered by Chavas and Cox (1990; 1992; 1995) and Cox and Chavas (1990). Love and Shumway are the first to employ the method in a

nonparametric market power test. The test may be implemented using firm-level data or industry-level data.

The resulting linear programming formulation is

$$(10) \quad \min_{ms_i^{ts}, a_i^{t+}, a_i^{t-}} \sum_{t=1}^T (b^{t+} a_i^{t+} + b^{t-} a_i^{t-} + \sum_{s \neq t=1}^T c^{ts} ms_i^{ts})$$

subject to

$$(i) \quad \begin{aligned} & p^t (y_i^t - a_i^{t+} + a_i^{t-} - y_i^s + a_i^{s+} - a_i^{s-}) \\ & - \sum_{m=1}^n w_m^t (z_{mi}^t - z_{mi}^s) - ms_i^{ts} w_n^s (z_{ni}^t - z_{ni}^s) \geq 0 \\ & \forall t \neq s \text{ except when } z_{ni}^t - z_{ni}^s \neq w_n^t - w_n^s, \end{aligned}$$

$$(ii) \quad a_i^{t+}, a_i^{t-} \geq 0 \quad \forall t,$$

$$(iii) \quad ms_i^{ts} \geq 0 \quad \forall t \neq s,$$

where the parameters b^{t+} , b^{t-} , and c^{ts} in the objective function are weights and a_i^{t+} and a_i^{t-} are positive and negative Hicks-neutral technical change variables, respectively. Output is denoted by y_i , and z_{ni} represents the potentially monopsonistically exerted input. The monopsony market power parameter is ms_i^{ts} and is representative of the price flexibility of the opposing supply curve. It is thus a Lerner-type index of monopsony market power exertion with a lower bound of zero. Love and Shumway examine for the validity of their test by simulating a firm-level Monte Carlo data set for four different market structures (perfect competition, Stackelberg duopsony, Cournot duopsony, and monopsony). They find that the test's results are consistent with the assumptions regarding market structure. However, they note that the choice of criterion function weights results in differing market power estimates.

Raper, Love, and Shumway (1998) adapt the model to test for monopoly market power exertion.

It is represented by the linear programming problem

$$(11) \quad \min_{mp_i^{ts}, a_i^{t+}, a_i^{t-}} \sum_{t=1}^T (b^{t+} a_i^{t+} + b^{t-} a_i^{t-} + \sum_{s \neq t=1}^T c^{ts} mp_i^{ts})$$

subject to

$$(i) \quad p^t (y_i^t - a_i^{t+} + a_i^{t-} - y_i^s + a_i^{s+} - a_i^{s-}) - mp_i^{ts} p^s (y_i^t - y_i^s) - \sum_{m=1}^n w_m^t (z_{mi}^t - z_{mi}^s) \geq 0$$

$$\forall t \neq s \text{ except when } p^t - p^s \stackrel{S}{=} y_i^t - y_i^s,$$

$$(ii) \quad a_i^{t+}, a_i^{t-} \geq 0 \quad \forall t,$$

$$(iii) \quad mp_i^{ts} \geq 0 \quad \forall t \neq s,$$

where mp_i^{ts} is the monopoly market power parameter and represents the price flexibility of demand, also known as the Lerner index.

3. Data and Implementation

The Monte Carlo data set implemented in this paper was developed by Raper, Love, and Shumway (1999). It contains data for each of ten different market structures: monopsony (MS), Stackelberg duopsony (SS), Cournot duopsony (CS), perfect competition (PC), Cournot duopoly (CP), Stackelberg duopoly (SP), monopoly (MP), and three forms of cooperative bilateral monopoly (buyer dominates (BMU), seller dominates (BML), and equal profit split (BM)). They chose the normalized quadratic functional form for the cost functions, assuming two competitive variable inputs for upstream markets and a restricted normalized quadratic cost function in downstream markets with one competitive variable input and one conditional input in the market with potential monopsony power. Returns to scale are slightly decreasing for the upstream firm while the downstream firm's technology exhibits increasing returns to scale. The industry-level data are generated for 68 periods with exogenous variables held constant across alternative simulations. In duopsony cases, firm-level data is simulated and then aggregated to industry level. One thousand experiments are

conducted for each market structure. More specific details regarding the simulation may be found in Raper, Love, and Shumway (1999).

We use this data set to implement the previously discussed deterministic nonparametric market power tests. Ashenfelter and Sullivan's monopoly test (equation 6), our monopsony modification thereof (equation 7), and Raper, Love, and Shumway's (1998) revisions for both monopoly (equation 8) and monopsony (equation 9) are calculated in SAS. Love and Shumway's monopsony test (equation 10) and Raper, Love, and Shumway's (1998) analogous monopoly test (equation 11) require linear programming and are implemented using GAMS and the solver MINOS.

4. Results

In this section, we present the results of the Monte Carlo experiments for the deterministic nonparametric market power tests discussed above. The mean market power value is calculated over all 1000 (N) experiments for each market structure. The Love and Shumway type tests yield some infeasible outcomes (I) which we delete before calculating the mean market power value. Additionally, to avoid biased means, we delete probable outliers (O) as defined for a modified Boxplot. We report the number of feasible outcomes (N-I) as well as the number of observations after deletion of probable outliers (N-I-O). The reported average market power values are then calculated over the latter number of observations. We also report the standard error for each mean market power parameter and the probability with which the hypothesis that this parameter is equal to zero is rejected.

4.1 Ashenfelter and Sullivan's Method

In Ashenfelter and Sullivan's monopoly market power test, comparisons of data more than two periods apart are excluded from the calculation of the market power parameter, identifying these pairwise comparisons as structural shifts; thus, 4290 pairwise comparisons are omitted in each simulation. Negative values of the market power parameter are considered to be violations of profit maximization and thus are also excluded. Theoretically, the monopoly market power parameter (β^{mp}) should lie between zero and one, which is not the case for the mean values of calculated market power parameters for any of the ten market structures. All results lie outside of these bounds (Table 1). For example, $\beta^{\text{mp}} = 6.8812$ for monopoly data and 4.0037 for perfect competition data. The latter should theoretically be equal to zero. Ashenfelter and Sullivan's Cournot Numbers Equivalent (CNE), a measure of the least number of firms with Cournot behavior that the industry could support, is calculated as $\frac{1}{\beta^{\text{mp}}}$. Table 1 reveals that for the monopoly market structure, 92.5 % of the data support the hypothesis that the industry behaves equivalent to having less than or equal to four firms in the industry (CNE4). The cumulative percentage of the data where the CNE is less than or equal to one, two, three, etc. should increase more rapidly with high levels of monopoly market power exertion. For data representing market structures where low or no market power exertion is expected, the size of the CNE should increase more slowly. This is not the case for Ashenfelter and Sullivan's monopoly test. For example, 93% of the perfectly competitive data support the assumption that the industry's behavior is equivalent to that of four Cournot firms. This result is comparable to the monopoly result and thus inconsistent with the data.

The Lerner-type monopsony market power index for our monopsony modification of Ashenfelter and Sullivan's original test has a lower bound of zero. Thus, the results from our implementation of the test are consistent with theory in this respect (Table 2). For example, $\beta^{\text{ms}} = 1.8355$ for monopsony data and 6.8170

for perfect competition data. Note that β^{ms} for perfect competition should equal zero. Only 56 % of the monopsony market structure data actually support a CNE of four firms, while 90 % of the monopoly and 86% of the perfect competition market structure data support a monopsonistic CNE of four firms. The monopoly and monopsony results should be switched to lend support to the hypotheses behind the test and the perfect competition results should be lower than the monopsony results. Thus, Ashenfelter and Sullivan's test represents an important step for deterministic nonparametric market power tests, but our study supports Ashenfelter and Sullivan's call for potential improvements. It is possible that information inadequately accounted for, such as measurement errors, technological change, structural change, or input costs might seriously bias the estimates. Additionally, the exclusion of all negative market power parameters from the calculation of the CNE's because they are assumed to be violations of profit maximization might be over-restrictive. Admitting a reasonable tolerance level for small violations may improve results. The assumption that the monopoly market power test can be generalized to industries without data on excise tax or a similar movement in marginal cost might also be misleading.

Results for Raper, Love, and Shumway's (1998) revision of Ashenfelter and Sullivan's test measuring monopoly market power exertion are reported in Table 3. Recall that Raper, Love, and Shumway explicitly include input cost and omit obvious structural demand shifts. The mean of the monopoly market power parameter for each market structure are indeed different from those obtained from implementation of the original test. However, now only 79% of the data support a CNE4 for the monopoly market structure, while 96% of Cournot duopoly data and 94% of Stackelberg duopoly data support a CNE4. Additionally, the CNE4 for perfect competition data increased to more than 95%.

Raper, Love, and Shumway's (1998) analogous monopsony market power test produces somewhat more plausible results (Table 4). Again, input costs are explicitly included and obvious structural shifts in

supply are omitted. For monopsony data, 96% of the observations support a monopsonistic CNE4. Further, 87% of Cournot duopsony and 84% of Stackelberg duopsony data support a CNE4. However, for all other simulated market structures, between 76% and 82% of the data support the assumption of CNE4 in the market, making it difficult to distinguish between market structures. Thus, Raper, Love, and Shumway's revision of Ashenfelter and Sullivan's test for either monopoly or monopsony market power exertion does not substantially improve estimates of the degree of market power nor confidence in the results.

4.2 Love and Shumway's Method

We implement Love and Shumway's monopsony test and Raper, Love, and Shumway's (1998) monopoly modification thereof using the value one as weights for both technical change parameters, b^{t+} and b^{t-} , and for the criterion function parameter, c .² For Love and Shumway's monopsony market power test, the mean of the market power parameter, $\bar{m}s^{ts}$, is significantly different from zero ($p = 0.0001$) for each market structure (Table 5). Theoretically, only the market power parameters for monopsony, Cournot duopsony, and Stackelberg duopsony market structures should be different from zero. However, the values for perfect competition and the bilateral monopolies are economically small with values between 0.005 and 0.1. The mean market power parameter for the monopsony market structure is 1.9022. This implies that the industry pays 190.22% less for the monopsonistically exerted input than the last input unit's internal marginal value. With simulated data, we have the luxury of knowing the true values of $\bar{m}s^{ts}$ for each structure and, thus, can test whether our estimates are statistically different from their true values. The null hypotheses that the monopsony market power parameter, $\bar{m}s^{ts}$, of 1.9022 is equal to the true value of 2.06

²We realize that the choice of the weights could slightly impact the outcome of the measures, but for simplicity in comparing to other tests, we have chosen to use one as a base value.

for the simulated monopsony data, the Cournot \bar{m}^{ts} of 0.3390 is equal to its true value of 0.78, and that the Stackelberg \bar{m}^{ts} of 0.2462 is equal to its true value of 0.46 are all rejected with $p = 0$. Thus, the monopsony market power test performs well in detecting the presence of monopsony market power, though less so at distinguishing between magnitudes when market power exertion is not as extreme. However, in our experiments the test also detects some monopsony market power when oligopolistic data are used.

Raper, Love, and Shumway's (1998) modification of Love and Shumway's test which tests for monopoly market power does not perform quite as well (Table 6). Again, mean market power parameters for all market structures are significantly different from zero ($p = 0.0001$). For perfect competition, $\bar{m}^{\text{ts}} = 0.028$. This measure is significantly different from its true value of zero, but is economically very small and thus not necessarily an indicator of invalidity of the test. For monopoly ($\bar{m}^{\text{ts}} = 0.159$), Cournot duopoly ($\bar{m}^{\text{ts}} = 0.3143$), and Stackelberg duopoly data ($\bar{m}^{\text{ts}} = 0.3405$), the market power parameters are also significantly different from their true market power values of 1.0, 0.5, and 0.4046 ($p = 0$), respectively. A \bar{m}^{ts} value of 0.4046 means that 40.46% of the output price received by the firm is monopoly markup over marginal cost of the last unit produced. The values for Cournot duopoly and Stackelberg duopoly are relatively large, indicating economically significant market power exertion. However, the market power estimate for monopoly data is relatively small as compared to the duopoly cases, while \bar{m}^{ts} for monopsony is very large at 6.4611 and actually out of the theoretical bounds. Theoretically it should be near zero, while \bar{m}^{ts} for monopoly should be near 1.0. Monopsony, Cournot duopoly, and Stackelberg duopoly data all result in maximum market power values of a much greater magnitude than the other market structures. Hence, Raper, Love, and Shumway's monopoly market power test does appear to be able to detect monopoly market power exertion, though it exhibits problems in accurately detecting magnitude in our experiments. Further,

the market structure specification of the model is again very important as the test detects some market power when market power is instead being exerted from the opposite party in the market.

Overall, our experiments suggest that Love and Shumway's approach and Raper, Love, and Shumway's analogous monopoly test work reasonably well in identifying market power when the direction of market power is correctly specified. However, the test appears to attribute market power in the absence of such when market power is actually being exerted by the opposite party in the market, i.e. the test detects monopsony power when monopoly power is instead being exerted and vice versa. This emphasizes the importance of correctly specifying the direction of market power exertion. On the surface, this may appear to be a simple task. However, in certain cases conditions exist for both parties of market transactions that cloud the issue of who may hold market power. For example, many sellers organized as a cooperative to gain bargaining power may face concentrated buyers. In such cases, Love and Shumway's test may give an incorrect assessment of market power exertion.

6. Conclusions

Knowledge of the degree of market power exertion is important in guiding antitrust and merger policies. This study performs a comprehensive analysis of the relatively new approach of deterministic nonparametric market power tests. Ashenfelter and Sullivan's (1987) test for monopoly market power and its counterpart for monopsony market power developed in this paper, as well as revisions of the test proposed by Raper, Love, and Shumway (1998), are implemented. Additionally, Love and Shumway's (1994) monopsony test and Raper, Love, and Shumway's (1998) monopoly counterpart, are implemented using Raper, Love, and Shumway's (1999) Monte Carlo data set that simulates data for ten different market structures. The results are then compared to Raper, Love, and Shumway's (1999) analysis of Bresnahan-Lau

type parametric market power tests for market power exertion, including monopoly, monopsony, and bilateral market power exertion.

Ashenfelter and Sullivan make a major contribution to the field by introducing the first deterministic nonparametric market power test. However, as they point out, their market power test might benefit from modifications. This result is confirmed by this study. The results are not satisfactory for the original Ashenfelter and Sullivan monopoly market power test, the analogous monopsony market power test, or Raper, Love, and Shumway's (1998) revisions to Ashenfelter and Sullivan for monopoly and monopsony market power. This suggests that researchers should be hesitant about choosing Ashenfelter and Sullivan type tests to measure the degree of market power exertion in an industry.

Love and Shumway's approach extends Ashenfelter and Sullivan's approach by incorporating technical change variables and an alternative method of dealing with structural shifts. Love and Shumway's monopsony market power test yields estimates close to the true market power value on the downstream firm's side. However, to some extent the test incorrectly attributes upstream market power to downstream firms. This implies that Love and Shumway's monopsony market power test can be implemented under the restriction that the model is specified for the 'right' direction. The monopoly market power test in Love and Shumway's tradition performs less accurately and should be implemented under the same restrictions. This indicates that if there is any potential for market power from the opposing side of the market, biased results may be obtained unless proper modifications are made.

All three parametric market power tests perform very well in Raper, Love, and Shumway's (1999) study. The composite model incorporates the monopoly and monopsony market power tests into one test and performs equally as well as the unilateral monopoly and monopsony market power tests at determining market power magnitude, when unilateral market power is present. Further, it has the advantage of

incorporating bilateral market power, thus avoiding the *a priori* assumption of perfectly competitive behavior by one party in the transaction. This suggests that the composite model should be implemented when choosing to perform a parametric market power test. Hyde and Perloff (1994; 1995) came to a similar conclusion finding that even with increasing measurement error, the parametric monopsony and monopoly market power tests find the correct market structure in virtually all of the cases. However, they also point out that parametric market power tests may be biased when the functional form is misspecified.

The question remains as to which approach is preferred for empirical measurement of market power. Our comparison suggests that unilateral parametric tests are more robust than unilateral deterministic nonparametric tests to misspecification bias with respect to the direction of market power in that they do not incorrectly attribute market power where it does not exist. However, our analysis does suggest that Love and Shumway's unilateral nonparametric monopsony power test and Raper, Love, and Shumway's monopoly counterpart do distinguish between perfect competition and imperfect competition when market power direction is correctly specified. Only for these two deterministic nonparametric methods do we obtain results sufficiently close to the true value of market power exertion in the market to recommend them for use with real data. Thus, we recommend these two deterministic market power tests as preliminary tests to specify whether the data exhibits an economically significant amount of market power exertion. The tests may be particularly useful in this respect since they are easily implemented and only need a small amount of data. Consequently, if market power exertion has been found using Love and Shumway type tests, it may be worthwhile to collect more data to implement parametric market power tests such as the composite parametric model in Raper, Love, and Shumway (1999).

Table 1. Mean Value of Estimated Market Power Parameters and Cumulative Cournot Numbers Equivalents (CNE) for Original Ashenfelter and Sullivan Monopoly Market Power Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CP	SP	MS	CS	SS	BM	BML	BMU
$\bar{\beta}^{mp^b}$	4.0037	6.8812	3.1620	3.0134	1.0248	2.7852	3.1692	5.3144	3.7003	4.8022
Standard Error	0.0662	0.1352	0.0730	0.0668	0.0156	0.0443	0.0538	0.0970	0.0899	0.0869
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
CNE \leq 1	63.70	69.90	41.34	41.84	18.47	47.79	53.43	56.05	41.09	61.12
CNE \leq 2	83.56	84.66	61.46	62.90	39.91	71.53	75.83	72.81	57.84	78.71
CNE \leq 3	89.85	89.92	71.92	73.54	52.53	81.49	84.45	80.89	68.16	85.74
CNE \leq 4	92.68	92.49	77.99	79.59	60.74	86.50	88.75	85.48	74.78	89.25
CNE \leq 5	94.20	94.03	81.97	83.29	66.70	89.54	91.20	88.30	79.14	91.43
CNE \leq 6	95.24	94.99	84.62	85.81	71.21	91.49	92.80	90.21	82.25	92.84
CNE \leq 7	95.95	95.68	86.70	87.73	74.81	92.81	93.89	91.52	84.52	93.80
CNE \leq 8	96.53	96.22	88.25	89.20	77.73	93.79	94.72	92.61	86.40	94.58
CNE \leq 9	96.96	96.64	89.46	90.36	80.06	94.53	95.35	93.35	87.87	95.21
CNE \leq ∞	100	100	100	100	100	100	100	100	100	100
N-I-O ^c	898	907	858	862	911	916	900	778	787	855
N-I ^d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).
^bMean value based on N-I-O experiments.
^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.
^dN-I = Number of feasible outcomes.

Table 2. Mean Value of Estimated Market Power Parameters and Cumulative Cournot Numbers Equivalents (CNE) for Modification of Ashenfelter and Sullivan to Monopsony Market Power Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CP	SP	MS	CS	SS	BM	BML	BMU
$\bar{\beta}^{ms^b}$	6.8170	8.5815	1.9837	1.9113	1.8355	4.3288	4.9850	5.3182	2.9998	5.8255
Standard Error	0.1692	0.1876	0.0358	0.0344	0.0434	0.0925	0.1138	0.1027	0.0553	0.1288
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
CNE \leq 1	58.07	66.43	32.27	31.94	25.75	46.81	49.99	56.82	45.78	55.63
CNE \leq 2	74.15	81.21	67.91	69.75	40.22	64.22	67.43	73.29	65.55	73.92
CNE \leq 3	81.48	87.04	81.48	82.96	49.70	73.31	76.08	81.23	74.66	81.82
CNE \leq 4	85.50	90.15	87.01	88.23	56.18	78.70	81.24	85.68	80.27	86.17
CNE \leq 5	88.18	92.07	89.93	90.94	61.07	82.28	84.52	88.42	84.04	88.75
CNE \leq 6	89.98	93.32	91.78	92.65	64.93	84.85	86.82	90.31	86.67	90.55
CNE \leq 7	91.34	94.29	93.01	93.77	68.00	86.83	88.46	91.62	88.58	91.88
CNE \leq 8	92.37	95.00	93.94	94.59	70.55	88.33	89.85	92.60	90.00	92.89
CNE \leq 9	93.19	95.52	94.63	95.23	72.79	89.55	90.85	93.40	91.09	93.69
CNE \leq ∞	100	100	100	100	100	100	100	100	100	100
N-I-O ^c	892	897	865	866	904	913	911	778	786	857
N-I ^d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).
^bMean value based on N-I-O experiments.
^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.
^dN-I = Number of feasible outcomes.

Table 3. Mean Value of Estimated Market Power Parameters and Cumulative Cournot Numbers Equivalents (CNE) for Raper, Love, and Shumway's (1998) Revised Ashenfelter and Sullivan Monopoly Market Power Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CPI	SPI	MS	CSI	SSI	BM	BML	BMU
$\bar{\beta}^{mpb}$	4.7248	11.4490	5.1217	4.1825	1.4661	7.1698	6.7928	5.6359	3.6457	24.7017
Standard Error	0.0476	0.1169	0.0473	0.0371	0.0153	0.0723	0.0753	0.0445	0.0444	0.2273
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
CNE ≤ 1	71.10	58.01	71.68	68.57	20.07	64.04	64.43	78.26	43.20	86.97
CNE ≤ 2	88.97	66.99	87.71	85.16	38.38	82.74	83.19	94.32	86.29	91.55
CNE ≤ 3	92.92	73.44	92.99	90.81	48.46	88.77	89.18	97.73	94.47	93.50
CNE ≤ 4	94.61	79.03	95.60	93.85	55.86	91.64	92.03	98.57	97.01	94.68
CNE ≤ 5	95.56	83.56	96.97	95.76	61.96	93.30	93.68	98.89	98.36	95.49
CNE ≤ 6	96.18	86.98	97.73	96.91	67.00	94.40	94.75	99.08	98.91	96.10
CNE ≤ 7	96.63	89.48	98.19	97.60	71.06	95.19	95.51	99.20	99.18	96.57
CNE ≤ 8	96.97	91.41	98.50	98.05	74.34	95.77	96.07	99.28	99.34	96.93
CNE ≤ 9	97.24	92.87	98.71	98.36	77.03	96.22	96.51	99.35	99.44	97.24
CNE ≤ ∞	100	100	100	100	100	100	100	100	100	100
Shifts	2242	3157	3029	2880	689	1729	1951	3051	2966	3869
N-I-O ^c	976	996	999	998	990	998	993	994	986	998
N-I ^d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).
^bMean value based on N-I-O experiments.
^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.
^dN-I = Number of feasible outcomes.

Table 4. Mean Value of Estimated Market Power Parameters and Cumulative Cournot Numbers Equivalents (CNE) for Raper, Love, and Shumway's (1998) Revised Ashenfelter and Sullivan Monopsony Market Power Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CP	SP	MS	CS	SS	BM	BML	BMU
$\bar{\beta}^{msb}$	3.8843	4.7004	2.0597	2.0240	15.7593	9.0864	7.2917	2.7983	2.4439	3.3455
Standard Error	0.0848	0.0943	0.0296	0.0287	0.2121	0.1556	0.1275	0.0519	0.0384	0.0840
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
CNE ≤ 1	46.48	49.59	37.08	39.27	83.81	62.63	57.51	47.20	39.88	40.98
CNE ≤ 2	62.87	64.78	62.65	65.09	91.59	76.72	72.59	68.27	61.69	50.14
CNE ≤ 3	71.14	72.21	73.04	74.90	94.26	82.91	79.78	77.34	71.32	58.74
CNE ≤ 4	76.10	77.10	78.40	80.04	95.61	86.48	83.93	82.15	76.40	64.99
CNE ≤ 5	79.57	80.24	81.96	83.26	96.43	88.85	86.64	85.24	79.52	69.79
CNE ≤ 6	82.09	82.74	84.44	85.51	97.01	90.48	88.54	87.33	81.70	73.33
CNE ≤ 7	84.14	84.68	86.25	87.19	97.42	91.71	90.00	88.75	83.44	76.04
CNE ≤ 8	85.63	86.15	87.69	88.57	97.74	92.68	91.12	89.85	84.79	78.25
CNE ≤ 9	86.92	87.39	88.86	89.66	97.99	93.43	92.02	90.71	85.97	80.15
CNE ≤ ∞	100	100	100	100	100	100	100	100	100	100
Shifts	2308	1395	1523	1674	3844	2822	2601	1503	1588	680
N-I-O ^c	949	964	961	963	986	970	973	977	977	951
N-I ^d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).
^bMean value based on N-I-O experiments.
^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.
^dN-I = Number of feasible outcomes.

Table 5. Mean Value of Estimated Market Power Parameters for Original Love and Shumway Monopsony Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CP	SP	MS	CS	SS	BM	BML	BMU
$\bar{\beta}^{ms\ b}$	0.0990	0.0780	0.1203	0.1603	1.9022	0.3390	0.2462	0.0212	0.0604	0.0045
Standard Error	0.0013	0.0009	0.0010	0.0016	0.0241	0.0047	0.0032	0.0001	0.0002	0.0001
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Shifts	2312	1395	1524	1673	3867	2829	2605	1505	1589	681
N-I-O ^c	944	954	954	944	946	953	933	959	966	954
N-I ^d	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).

^bMean value based on N-I-O experiments.

^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.

^dN-I = Number of feasible outcomes.

Table 6. Mean Value of Estimated Market Power Parameters for Raper, Love, and Shumway's (1998) Modification of Love and Shumway to Monopoly Test (1000 Experiments)

	Simulated Market Structure ^a									
	PC	MP	CP	SP	MS	CS	SS	BM	BML	BMU
$\bar{\beta}^{mp^b}$	0.0280	0.1590	0.3143	0.3405	6.4611	0.1229	0.0883	0.0127	0.0076	0.0555
Standard Error	0.0003	0.0027	0.0058	0.0063	0.1165	0.0010	0.0007	0.0002	0.0002	0.0008
Prob > T	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Shifts	2242	3161	3032	2883	689	1728	1951	3051	2967	3874
N-I-O ^c	979	933	937	935	899	975	973	992	990	982
N-I ^d	999	982	975	988	977	995	996	994	999	993

^aPC=Perfect Competition, MP=Monopoly, CP=Cournot Duopoly, SP=Stackelberg Duopoly, MS=Monopsony, CS=Cournot Duopsony, SS= Stackelberg Duopsony, BM=Bilateral Monopoly (Equal Profit Split), BML=BM (Seller Dominates), BMU=BM (Buyer Dominates).
^bMean value based on N-I-O experiments.
^cN-I-O = Number of observations after deletion of infeasible outcomes and probable outliers.
^dN-I = Number of feasible outcomes.

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