Further Tests of Static Oligopoly Models: Whiskey, 1882-1898

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Using data from the turn-of-the-century whiskey industry, we conduct tests of the NEIO methodology similar to those conducted by Genesove and Mullin [1998]. Like Genesove and Mullin, we find that the NEIO methodology appears to perform reasonably well for low levels of market power. Conduct is somewhat overestimated, with estimates ranging from 0.17 to 0.35 as compared to direct estimates of 0.09. Cost parameters are generally underestimated. Estimates of conduct and remaining cost parameters improve significantly, however, with additional information on cost. Estimates improve further if conduct is allowed to have two regimes, which are identified based on historical evidence.

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I. Introduction

In a recent article, Genesove and Mullin [1998] tested static oligopoly models using detailed historical data on the sugar industry. Their work was motivated by recent questions about the New Industrial Organization (NEIO) approach to estimation. NEIO estimation has relied upon the first order condition for a firm relating price, conduct, output, inverse demand. The first order condition has been used to estimate the conduct parameter directly or to estimate cost for a given value of the conduct parameter. Questions about the approach have centered on the robustness of estimates across functional forms and, perhaps more importantly, on the Corts [1999] critique. In his critique Corts differentiates between the average and marginal 'collusiveness of conduct,' arguing that what the NEIO approach measures is the marginal and not the average collusiveness of conduct. Genesove and Mullin tested the NEIO approach by comparing direct estimates of conduct grounded in detailed cost information with indirect estimates of conduct that assume the econometrician is missing certain information about cost.[i] They found that in practice the NEIO approach performs well for low values of market power.

A skeptic might wish for more evidence, since it could be that the performance of the NEIO approach is somehow related to features of Genesove and Mullin's data. It is, however, relatively difficult to obtain data that will allow the NEIO approach to be tested. The technology must be simple enough that marginal cost can be accurately described. Detailed data on the components of marginal cost must be available. Additional data must be available that allows accurate estimates of demand. And it must be possible to identify the conduct parameter, either through nonproportional shifts in inverse demand or through shifts in cost.

Using data from the turn-of-the-century whiskey industry that satisfy the above constraints, we test the NEIO methodology. The Whiskey Trust and its rivals produced distilled spirits, the primary input into inexpensive (rectified) whiskey. The production technology was simple and heavily monitored by the government. Grain, the primary input, was transformed at a fixed known ratio into distilled spirits. The resulting output was heavily taxed, with tax accounting for 85 percent of the final price. Heavy government monitoring and government investigations of the Whiskey Trust allow us to be confident of the structural form of marginal cost. This information allows us to compute marginal cost and thus the price-cost margin. We compare conduct as measured directly by the elasticity-adjusted Lerner index with conduct measured indirectly using NEIO techniques. Because input prices including the real and the nominal tax rates varied over the period, we are able to identify the conduct and cost parameters from shifts in the input prices. Like sugar, the industry underwent significant changes in the degree of competition, so we are able to evaluate the methodology under different structural conditions.

The paper is structured as follows. Section 2 discusses the history of the distilled spirits industry, and Section 3 describes the production technology. In section 4, we motivate the general specification of demand and then provide estimates of demand using the four functional forms that Genesove and Mullin considered – quadratic, linear, log-linear, and exponential. Section 5 compares direct estimates of conduct with indirect estimates of conduct for the four functional forms. Initially the indirect estimates require that conduct be constant across the period. We then relax this assumption by allowing conduct to differ over time. Section 6 concludes.

II. Historical Background

The Whiskey Trust was among the most prominent combinations of the late nineteenth century. Three factors contributed to the trust's prominence. First, it produced a widely consumed commodity–namely, distilled spirits. In 1880, the average American adult consumed 2.4 gallons of spirits annually. And even though Americans consumed more beer (11.1 gallons annually), the majority of absolute alcohol (58 percent) was consumed through spirits because spirits had a much higher alcohol content (Downard [1980], pp. 227-28). Second, the Whiskey Trust was large, representing nearly 90 percent of industry output at its peak (United States Industrial Commission, p. 77; hereafter cited as IC). Third, rivals accused the Whiskey Trust of using anticompetitive strategies, such as predatory pricing and vertical restraints (Troesken [1998]).

The beginnings of the trust date back to the Peoria Pool of the early 1870s, a combination that was limited to distillers located in central Illinois (Downard [1980], p. 213). A much larger pool, the Western Export Association, formed in 1881. Industry observers claimed the association was created because over capacity had depressed prices. To increase prices, the association set production limits for members, and members who produced in excess of their limit were required to export the excess at their own expense. However, from its inception, the pool was beset by cheating, market entry, and periodic price wars (IC, pp. 76, 168-69; Lamoreaux [1985], pp. 99-101).

After the pools failed, distillers organized the Distillers and Cattle Feeders' Trust, better known as the "Whiskey Trust" in May 1887. Modeled after Standard Oil, the Whiskey Trust was a bona fide trust so that when a distillery joined the trust it surrendered control of its operations to a board of trustees. Of the eighty-six distilleries that eventually joined the combination, only ten or twelve were kept in operation. The remaining seventy-four or so distilleries were closed due to their high cost structure (usually due to small scale) or because they represented excess capacity. However, during the 1880s, state courts raised questions about the legality of trust arrangements. In 1890, fearing dissolution by state courts, the Distillers and Cattle Feeders' Trust reorganized as an Illinois corporation, the Distilling and Cattle Feeding Company. Although no longer a trust in the strict sense of the term, the combination was still referred to as the Whiskey Trust (IC, pp. 75-90; and 171).

The trust entered receivership in January 1895, and reorganized as the American Spirits Manufacturing Company, a New Jersey corporation, in the fall of 1895, though this new combination never realized the market dominance of its bankrupt predecessor.

Throughout the period, legal producers such as the Whiskey Trust competed directly with a small legal fringe and indirectly with a larger illegal fringe. There was a class of distilleries known as "registered stills." These were very small distilleries, located mostly in the South, that were licensed by the government. At large distilleries (like those in the trust), IRS gougers monitored production daily, and they monitored everything, how much grain was used; how many employees there were; how many barrels were used; how much alcohol was in the barrels, etc. At registered stills production was only estimated, and the taxes were paid based solely on these estimates. In the South alone, there were about 6,500 registered stills. The typical registered still had the capacity to process about five bushels of grain per day, while the very largest distilleries in the industry had the capacity to process 10,000 to 15,000 bushels per day (IC, p. 844).

An illegal still with the capacity to process one bushel per day could have been constructed for about $100.[ii] Although there are no precise data on the production of stills, industry observers suggested that illicit production might have been as high as 30-40 million gallons per year, or about 40-50 percent of legal production. In addition, illicit production was not limited to remote, Appalachian locations, as is commonly believed. Government investigators in 1900 found that illicit production "was all over the country," including major cities such as New York and Chicago (IC, pp.825 and 41).[iii]

III. Technology of Production

The Whiskey Trust produced and sold alcoholic spirits. Alcoholic spirits were perfectly homogenous; their content and flavor were identical across all producers. Almost never consumed directly, alcoholic spirits were usually sold to rectifiers and distributors, who blended the spirits with water, brown sugar, and other flavors to create rectified whiskey. In contrast to more expensive straight whiskey, such as bourbon and rye whiskey, rectified whiskey required no aging and could be consumed immediately.

Manufacturing alcoholic spirits entailed grinding corn into meal; soaking the meal in water; adding malt, which converted the corn starch into sugar; and using a small amount of yeast, which initiated fermentation and converted the sugar into alcohol. After fermentation, the corn mash was twice distilled and charcoal filtered to yield alcoholic spirits. As this description implies, the manufacture of spirits employed a fixed-proportions production technology predicated mainly on corn and malt, and there was little, if any, substitutability across these inputs. Because grain was central to the production of alcoholic spirits, most distilleries located in the Midwest and there was an especially high concentration of distilleries around Peoria, Illinois (IC, pp. 91, 201-02).

The technology used in distilling was simple and common across producers. Through the distilling process, corn and malt were transformed into distilled spirits at a known fixed ratio. In addition to the cost of grain, the variable cost of producing distilled spirits included yeast, labor, and other inputs. Thus, following Genesove and Mullin, the constant marginal cost of distilled spirits can be summarized as:

(1) $c = c_0 + k*P_{grain} + tax$

In this equation, c represents the marginal cost of producing a gallon of distilled spirits in dollars. c_0 is all marginal costs beyond the cost of the grain. k is the fixed ratio at which a bushel of grain was transformed into a gallon of alcohol. P_{grain} is the price of the corn and malt inputs assuming an 85/15 ratio of corn to malt.[iv] Tax is the federal tax on distilled spirits in real dollars.

Thanks to the high level of government involvement in production, we have fairly precise estimates of k, the number of bushels of grain that yielded one gallon of distilled spirits. Over the period, k fell from 0.27 in 1882 to 0.22 in 1898. This fall is the result of two new technologies – the introduction of copper tubing and chemical innovations hastening the process of fermentation – that improved efficiency in the distilling industry. The nominal tax rate was $0.90/gallon until 1893, when it was raised to $1.10/gallon. The real tax rate ranged from $0.91 to $1.35.

It is more difficult to draw inferences about c_0—the other components of marginal cost. Although we will not be able to identify c_0 precisely, one can establish reasonable bounds based on qualitative and other evidence. Existing estimates of average cost per gallon net of tax for 1891-1895 range from 12.71-15.05 cents.[v] Although use of average cost is inherently problematic, by subtracting off the average cost of grain inputs for this period, we can get upper bound estimates on c_0. During this period, the cost of grain inputs ranged 10.60- 17.00 cents, averaging 13.00 cents. This suggests upper bound estimates of c_0 of about 2 cents. A somewhat lower figure is suggested by the distributors who built their own plant. "[We] found that the cost of making spirits, provided it was through operation of building a distillery with out being loaded with these fixed charges, as they were, would be about 10 cents a gallon."[vi] This implies estimates of c_0 of close to zero.

The low values of c_0 are not entirely surprising. Industry observers considered labor a fixed cost because employment remained the same regardless of output. Observers also stated that the cost of labor was "not a significant factor" in distilling.[vii] Fuel, typically coal or wood, was needed to heat the mash and vaporize the alcohol during the distillation process.[viii] Because spirits were made in large batches, the fuel costs were largely fixed. Water was needed both in the production of the alcohol and as a cooling agent at various points in the distillation process. In Peoria, where most firms were located, underground sources supplied water that was an ideal, constant temperature year round. The pumps that brought the water into the plants were a fixed cost. The only other input of significance was yeast. Firms maintained their own supply of yeast, so the cost was negligible. By law, distillers were required to store and ship alcoholic spirits in barrels. Distillers typically owned the barrels and viewed them as capital, using the same barrel repeatedly. Thus the marginal cost of containers was close to zero. In some instances, part of the marginal cost was offset by the sale of the distillation residue as slops for cattle feed. A firm's ability to sell slops depended on two factors – the season, with winter having higher demand than summer, and whether the plant was located near cattle. When firms were able to sell slops, they yielded about 5 cents per bushel of grain used, or about 1.2 cents per gallon of distilled spirits.[ix]

We therefore take 0 as our best estimate of c_0. As noted above, c_0 falls somewhere in the range of 2.0 cents per gallon to –1.2 cents per gallon, the negative value arising from the sale of slops. This range reflects our inability to observe c_0 and not differences across firms, which were small.

The minimum efficient scale at the time was estimated to be 3,000-5,000 bushels. For instance, when several of the trust's distributors decided to vertically integrate into distilling, they chose to build a 4,000-bushel distillery that supplied 10 percent of the market. And, as one distiller explained, "after this limit is reached," a large distillery "can not produce any more liquor per bushel of corn" than a small distillery (IC, pp. 254-55). The additional gains to larger distilleries—those of 10,000 bushels or more—were considered small.[x] The 4,000-bushel plant was built at a cost of $150,000, a fairly modest investment.[xi] From this one can infer that the costs of entry were relatively low. As one government investigation explained, "the cost of establishing a distillery is slight," and as a consequence, the "various combinations have found competitors constantly arising (IC, p. 81)."And, as the trust found when it began to shut down inefficient plants, at least some of this investment was recoverable.[xii]

IV. Demand

Although our data are monthly, we follow Genesove and Mullin in aggregating up to quarterly level. The point of aggregation is to ensure that the estimated elasticity represents the long-run elasticity of demand and not the short-run elasticity. Because the short-run elasticity is typically lower than the long-run elasticity, it would imply a significantly higher monopoly price than would be desirable for a forward-looking monopolist. Our estimates were qualitatively similar when we used monthly data.

Our data extend from 1882 through 1898. Data on the price per gallon of alcoholic spirits are from United States Industrial Commission (pp. 818-25). The prices of corn and malt in bushels are from the Industrial Commission (pp. 818-25), the United States *Bulletin of the Bureau of Labor* [1902, pp. 446-47], the United States *Census of Manufacturers* [1902], and United States *Agricultural Statistics* [1938, pp. 66-67]. All price data have been adjusted for changes in the general price level using McCusker [1992].

Quantity sold is somewhat problematic. For unknown reasons, *Annual Report of the Commissioner of the Internal Revenue* [IRS, 1882-1898] reports the sales in gallons of alcoholic spirits only during June, July, and August of each year. Sales data are not available for June, July, and August of 1894; nor are they available for the remaining months of 1894 or any other year. Accordingly, we have 16 quarterly observations covering 1882-93 and 1895-98.[xiii] We also have firm level data for the Whiskey Trust for all twelve months of the year, from April 1888 through March 1895 (IC pp. 212-15; and 818-25). For this period, we use monthly data on trust and industry output to estimate what industry output would have been during the 22 quarters for which we have trust but not industry output. All results are presented both for the original 16 quarters of industry data and for the 38 quarters. Summary statistics are reported in Table I. The regression results are in reported in Table II. Because of the high degree of serial correlation in the monthly data, we used an ARIMA model with one lag. Adding additional lags had little effect.

Place Table I about here

Place Table II about here

Following Genesove and Mullin, we estimate demand for four cases of the general form of the demand curve – quadratic, linear, loglinear, and exponential demand. The general demand curve is

(2) $Q(p) = \beta(\alpha - P)^{\gamma}$

where Q is the quantity sold in gallons of distilled spirits; P is the price of distilled spirits; β is a measure of market demand, α is the maximum willingness to pay if γ is positive, and γ is the index of concavity. Given this, the implied price as a function of marginal cost and market power is

(3) $p(c, \theta) = (\alpha\theta + \gamma c)/(\theta + \gamma)$.

The demand for sugar was highly seasonal, with peak demand associated with summer canning activities. Thus, Genesove and Mullin allowed both β and either α or γ to depend on high season. This allows high season to both increase demand and to change monopoly price. The demand for whiskey, in contrast, did not exhibit any seasonality.

Demand for whiskey did, however, expand over time. One approach would have been to characterize this change in demand as low during the early years and high during the later years. Although in principle it should be feasible to separately identify the high and low β and α in our data, in practice it was difficult to do with 16 observations.[xiv] We tested two alternatives – allowing demand to depend on time and allowing demand to depend on U. S. industrial production.[xv] Because of the identification problems, we allowed either i) β or ii) α or γ to depend on one of these factors, but not both. In Table III, we compare the time invariant specification with the four alternatives for the linear model to illustrate the improvement in fit.[xvi] Regressions with time and U. S. industrial production have better fits than the time invariant demand function, with U. S. industrial production producing a better fit than a linear time trend. We focus on the specification that permits β to vary with U. S. industrial production (I). The alternate specification, that permits α or γ to depend on U. S. industrial production yielded similar results.

Place Table III about here.

The four functional forms that we estimate are as follows:

(4) Quadratic $\ln Q = \ln(\beta_0 + \beta_1 I) + 2\ln(\alpha - P) + \varepsilon$

(5) Linear $Q = (\beta_0 + \beta_1 I)(\alpha - P) + \varepsilon$

(6) Log-linear $\ln Q = \ln(-\beta_0 - \beta_1 I) + \gamma \ln(P) + \varepsilon$

(7) Exponential $\ln Q = \ln(\beta_0 + \beta_1 I) + (\gamma/\alpha)P + \varepsilon$

All of the functional forms except for the linear case are nonlinear. We estimate them using nonlinear instrumental variables (Amemiya [1985]).

We use instrumental variables, because the price of distilled spirits in the demand equation is clearly endogenous. Corn, malt, and tax are the largest components of cost, so they are natural instruments for the price of distilled spirits. If the prices of corn and malt were likely to be correlated with U.S. demand shocks for distilled spirits, however, then we would have to seek other instruments. Fortunately, the production of all distilled spirits in 1900 consumed less than 1 percent of all corn and barley malt produced in the United States in 1900, so the price of corn and the price of malt can safely be thought of as exogenous.[xvii]

Table IV presents the demand estimates separately for the 16 quarters of industry sales and the 38 quarters of estimated industry sales. For the 16 quarters, the reported standard errors are Huber-White standard errors, since we only observe one quarter per year. For the 38 quarters, the reported standard errors are Newey-West standard errors, corrected for serial correlation of up to four lags. Recall that β_0 is the constant, β_1 is the coefficient on U. S. industrial production, α measures willingness to pay in the quadratic and linear specifications and γ or γ/α are coefficients on P in the log-linear and exponential specifications. In all four specifications, increases in price lead to lower sales and increases in U. S. industrial production lead to higher sales.

Place Table IV about here.

V. Conduct

The first two rows of Table V present the general pricing rules implied by the demand equations. The rules based on 16 observations suggests a higher price than the rule based on 38 observations. The difference may reflect the increased frequency of the observations, the time period in which they are added, or any biases in the estimation of industrial output for the additional quarters. Unless θ is small, the pricing rules will also vary substantially across specifications. For example, the implied monopoly ($\theta = 1$) price for 16 observations ranges from \$1.67 to \$2.76 depending on the specification.[xviii] For $\theta = 0.10$, a symmetric ten-firm Cournot oligopoly, the price ranges from \$1.262 to \$1.275. Under perfect competition ($\theta = 0$), the price would be \$1.19. The estimated values of elasticity range from 1.5 to 2.0. This is in line with Cook and Tauchen [1982], who found an elasticity for alcohol of 1.8.[xix]

Place Table V about here.

Because we know the price cost margin and the elasticities for each functional form, we can compute the unadjusted and elasticity-adjusted Lerner Index. Table V shows that if we assume that $c_0 = 0$, the average unadjusted Lerner index was 0.052. The elasticity-adjusted values in Table VI range from 0.76 to 0.103, with most of the observations being clustered around $L_\eta = 0.09$.[xx] Hence, like sugar, whiskey appears to have exhibited conduct equivalent to that of an eleven-firm symmetric Cournot oligopoly. Not surprisingly, we can reject both $\theta = 0$ (perfect competition) and $\theta = 1$ (monopolistic behavior). Given that the trust had a market share of 40 percent or greater during the late 1880s and the early 1890s, it is surprising that its conduct was not more monopolistic.[xxi] In 1883, during a successful period of pooling, and again at the formation of the trust in 1888, the Lerner index was closer to 0.20, suggesting that the pool and later the trust were attempting to exercise its market power. Higher prices combined with low entry costs led, however, to more competition from the legal and illegal entrants.

Place Table VI about here.

If we substitute $c_0 + k^* P_{grain} + tax$ in for c in the implied pricing rule, we get

(8) $P = \alpha\theta /(\theta + \gamma) + \gamma(c_0 + k^* P_{grain} + tax)/(\theta + \gamma)$.

In what follows, we will estimate the foregoing nonlinear equation directly under two different assumptions about the cost structure. First we will assume that both k and c_0 are unknown. Then we will assume that k is known, but that c_0 is not known. Genesove and Mullin are able to get identification from changes in α between the high and the low season. We get identification through changes in tax.

Table VII presents estimates of c_0, k, and θ together with our direct estimates of these variables. The nonlinear estimation utilized demand estimates from Table IV. Standard errors are Newey-West with lags of 4 quarters. Estimates of c_0 were not constrained to be positive, because as discussed above c_0 could have been negative. The estimates where all three parameters are unknown are not very close to direct estimates for two reasons. First, k varies over time, but the regression estimates a constant k. With inclusion of information on k in the second column of every pair, our estimates of c_0 and θ improve significantly. Second, θ varies over time, but the regression estimates a constant θ. Prices were unusually high during some of the successful pooling periods, during the first two quarters after the formation of the trust and in the last quarter of 1892 and the first quarter of 1893.[xxii] Table VIII presents the results of estimation where there are two separate conduct parameters θ_0 and θ_1, which correspond to normal and more collusive states of the world. The first column assumes that both c_0 and k are unknown, and the second column assumes that k is known but c_0 is unknown. The estimates from the two linear models match almost exactly our direct estimates of θ during the standard pricing and high pricing states of the world.

Place Table VII about here.

Place Table VIII about here.

As expected, the estimates of θ are sensitive to assumptions of functional form. Recall that in the pricing rule, identification of θ is coming from the coefficient on tax, which is equal to $\gamma/(\gamma+\theta)$. Since the pricing rule is linear in its elements, this amounts to a regression on a constant, the price of grain, and tax. In Table XI we present regression results for three specifications of the pricing rule. The estimated coefficients on tax range from 0.852 to 0.863 and are precisely estimated. Mechanically, if γ is assumed to be 2 (quadratic) or estimated to be 2 (log-linear), the resulting estimate of θ will be higher than if γ is assumed to be 1 (linear). Note also that the coefficient is not consistent with the exponential model.

Place Table IX about here.

The foregoing results are relatively insensitive to our assumptions about c_0. Our lower bound estimate of c_0 (-0.012) increases the elasticity adjusted Lerner to 0.10, while the upper bound estimate of c_0 (0.02) decreases it to 0.06. In neither case would we accept the hypothesis of monopoly conduct or the hypothesis of perfect competition. Our findings agree with the conclusions of Corts and Genesove and Mullin that NEIO techniques perform fairly well when θ is small.

Because Genesove and Mullin have information on the number of producers and their capacity, they also estimate models with a range of assumed conduct. In particular, they can estimate models that assume Cournot behavior. Unfortunately, we have neither the number of producers nor any measures of capacity. Thus we are restricted to estimating models where conduct is assumed to be perfectly competitive ($\theta = 0$) or monopolistic ($\theta = 1$). In results not reported here, we found that both models do a very poor job of estimating c_0, with estimates ranging from –0.62 to –1.96. The competitive model does a good job of estimating k at 0.24, while the monopoly model does a poor job at 0.09.

VI. Conclusions

Using data from the turn-of-the-century whiskey industry, we conducted tests of the NEIO methodology similar to those conducted by Genesove and Mullin [1998]. Like Genesove and Mullin, we find that the NEIO methodology appears to perform reasonably well for low levels of market power. Conduct was somewhat overestimated, with estimates across functional forms ranging from 0.17 to 0.35 as compared to direct estimates of 0.09. Cost parameters were generally underestimated. With additional information on cost, specifically the actual rate of transformation between grain and alcohol, estimates of conduct and remaining cost parameters improved significantly. If conduct was allowed to have two regimes – normal and more collusive – which were identified based on historical evidence, estimates improved further. For the linear model, estimates of conduct were 0.07-0.09 for the normal regime and 0.15-0.18 for the more collusive regime depending on the informational structure. This compares well to direct estimates of 0.08 for the normal regime and 0.18 for the more collusive regime.

For researchers familiar with turn-of-the-century trusts, the low levels of market power suggested by both the direct and the indirect estimates might at first face be surprising. The Whiskey Trust's market share was nearly 50 percent between 1889 and 1892. It was the subject of numerous newspaper articles and government investigations; yet, it appears not to have exercised much market power. An 1899 government investigation suggests the reason: only if distillers 'kept prices low' would they not 'provoke competition.' Low entry barriers and the presence of substantial illegal product effectively disciplined the trust and contributed to its bankruptcy in 1895. In addition to the Whiskey Trust, firms such as the Sugar Trust (Genesove and Mullin [1998]), Kodak (Kadiyali [1996]), and various pharmaceutical companies (Ellison and Ellison [1999]) have all used price as a means to deter entry.

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Table I: Summary Statistics

	Mean /SD	Mean /SD
Observations	16 obs (quarterly)	38 obs (quarterly)
Price	1.26 (0.134)	1.26 (0.112)
P_{grain}	0.54 (0.111)	0.55 (0.104)
Tax	1.07 (0.165)	1.07 (0.130)
$P\text{-}k^{*} P_{grain}$ -tax	0.073 (0.035)	0.072 (0.037)
Quantity	18,065,235 (2,596,192)	19,548,441 (3,060,699)

Notes: Standard errors are in parentheses.

Table II: Predicting Monthly Industry Output

Dependent variable	Industry Sales
Constant	3,275,580 (371623.3)
Firm Sales	1.217 (0.122)
AR (1)	0.936 (0.042)
MA (1)	-0.563 (0.148)
Observations	18
Log likelihood	-254.3422

Notes: Standard errors are in parentheses.

Table III: Comparison of Specifications for Linear Regression

16 obs	Industry Output				
	1	2	3	4	5
Constant	9806523* (4630119)	18660425*** (2383737)	29613640*** (4829865)	12273206*** (1332552)	23549224*** (2331231)
Time (β)		670813*** (196677)			
Time (α)			0.020*** (0.003)		
U. S. Industrial Production (β)				188945*** (39346)	
U. S. Industrial Production (α)					0.008*** (0.001)
α	3.105** (0.872)	2.023*** (0.109)	1.707*** (0.102)	2.131*** (0.090)	1.673*** (0.089)
Adjusted Rsq	0.1844	0.4011	0.4084	0.4690	0.4706

Notes: (1) $Q = (\beta_0)(\alpha_0 - P) + \varepsilon$; (2) $Q = (\beta_0 + \beta_1 * time)(\alpha_0 - P) + \varepsilon$;

(3) $Q = \beta_0 * (\alpha_0 + \alpha_1 * time - P) + \varepsilon$; (4) $Q = (\beta_0 + \beta_1 * I)(\alpha_0 - P) + \varepsilon$;

(5) $Q = \beta_0 * (\alpha_0 + \alpha_1 * I - P) + \varepsilon$, where I is U.S. Industrial Production. Results are similar for other functional forms and for 38 observations. All regressions were estimated using nonlinear two stage least squares. Standard errors are in parentheses. Significance levels are indicted with *'s, where *** indicates significance at the 1 percent level, ** indicates significance at the 5 percent level, and * indicates significance at the 10 percent level.

Table IV: Demand Equations

16 obs	Quadratic	Linear	Loglinear	Exponential
Constant	1331622*** (247876)	12273206*** (1332552)	-5029148*** (485576)	17770900*** (2947750)
U. S. Industrial Production	20336.8*** (5985)	188944.7*** (39346)	-83628.8*** (13721)	281629.8*** (78092)
α or γ or γ/α	2.890*** (0.174)	2.130*** (0.090)	-1.738*** (0.215)	-1.298*** (0.153)
Adjust Rsq.	0.4272	0.4690	0.4131	0.4243
38 obs	Quadratic	Linear	Loglinear	Exponential
Constant	1321595*** (275713)	10259531*** (1997249)	-4062105*** (724672)	17234729*** (3547111)
U. S. Industrial Production	37311*** (8885)	315242*** (56126)	-123286*** (17413)	503226*** (117858)
α or γ or γ/α	2.691*** (0.117)	2.017*** (0.062)	-1.992*** (0.166)	-1.489*** (0.126)
Adjust Rsq	0.5855	0.5989	0.5522	0.5721

Notes: Standard errors are in parentheses. Significance levels are indicted with *'s, where *** indicates significance at the 1 percent level, ** indicates significance at the 5 percent level, and * indicates significance at the 10 percent level. The first stage regression for (38 obs) is

Price = 0.250 + 0.670*k*Pgrain + 0.868*tax. Adjusted Rsq=0.9107

(0.065) (0.208) (0.036)

Note that all coefficients are significant at the 1 percent level. The first stage regression for 16 observations was similar.

Table V: Pricing Rules, Elasticity, and the Lerner Index

	Quadratic	Linear	Loglinear	Exponential	Lerner (unadjusted)
P(c,θ) 16 obs.	(2.89θ+2c)/ (2+θ)	(2.13θ+c)/ (1+θ)	1.74c/ (1.74-θ)	0.77θ+c	
P(c,θ) 38 obs.	(2.69θ+2c)/ (2+θ)	(2.02θ+c)/ (1+θ)	1.99c/ (1.99-θ)	0.67θ+c	
η at full mean 16 obs.	-1.557	-1.476	-1.738	-1.634	
η at full mean 38 obs.	-1.762	-1.670	-1.992	-1.874	
Elasticity-adjusted Lerner 16 obs.	0.081 (0.049)	0.076 (0.047)	0.090 (0.055)	0.084 (0.051)	0.052 (0.033)
Elasticity-adjusted Lerner 38 obs.	0.091 (0.057)	0.086 (0.054)	0.103 (0.065)	0.097 (0.061)	0.052 (0.033)

Notes: Standard errors are in parentheses.

Table VI: Lerner Indices by Year

Year	Unadjusted	Elasticity-adjusted (linear, 38 obs)	Market Share
1882	0.041 (0.017)	0.068 (0.029)	
1883	0.096 (0.003)	0.159 (0.005)	
1884	0.017 (0.012)	0.028 (0.019)	
1885	0.077 (0.041)	0.127 (0.068)	
1886	0.084 (0.011)	0.139 (0.018)	
1887	0.035 (0.005)	0.058 (0.009)	
1888	0.094 (0.027)	0.155 (0.045)	0.40
1889	0.034 (0.009)	0.056 (0.015)	0.47
1890	0.049 (0.005)	0.081 (0.008)	0.48
1891	0.053 (0.010)	0.088 (0.016)	0.46
1892	0.053 (0.034)	0.088 (0.056)	0.47
1893	0.069 (0.044)	0.115 (0.074)	0.38
1894	0.048 (0.037)	0.079 (0.061)	0.31
1895	0.006 (0.010)	0.009 (0.016)	0.29
1896	0.027 (0.002)	0.045 (0.003)	
1897	0.019 (0.005)	0.032 (0.008)	
1898	0.050 (0.003)	0.083 (0.005)	

Notes: Standard errors are in parentheses. The quotes indicating a 90 percent market share use a narrower definition of the market, looking at the trust's market share in alcoholic spirits as opposed to the broader distilled spirits.

Table VII: Nonlinear Estimates of Pricing Rule Parameters

	Linear 38 obs	Linear 38 obs	Quadratic 38 obs	Quadratic 38 obs	Log-Linear 38 obs	Log-Linear 38 obs	Direct
θ	0.173** (0.046)	0.120** (0.036)	0.346*** (0.092)	0.241*** (0.073)	0.346*** (0.092)	0.241*** (0.073)	0.090
c_0	-0.058** (0.029)	-0.029 (0.025)	-0.176*** (0.053)	-0.110** (0.050)	0.291*** (0.081)	0.215*** (0.049)	0.00
k	0.216** (0.0490)		0.216*** (0.0490)		0.216*** (0.049)		0.23

Notes: Standard errors are in parentheses. Significance levels are indicted with *'s, where *** indicates significance at the 1 percent level, ** indicates significance at the 5 percent level, and * indicates significance at the 10 percent level.

Table VIII: Nonlinear Estimates of Pricing Rule Parameters, Two Pricing Regimes

38 obs	Linear I	Linear II	Direct
θ_0	0.085** (0.035)	0.067* (0.038)	0.078
θ_1	0.176*** (0.036)	0.153*** (0.039)	0.176
c_0	-0.024 (0.032)	0.0012 (0.0290)	0.00
k	0.252*** (0.037)		0.23

Note: Standard errors are in parentheses. Significance levels are indicted with *'s, where *** indicates significance at the 1 percent level, ** indicates significance at the 5 percent level, and * indicates significance at the 10 percent level. Prices were considered high in the following quarters: 1883:3, 1885:3, 1886:3, 1888:3-4, 1892:4-1893:1.

Table IX: Regressions of Price on Inputs

38 obs	(1)	(2)	(3)
P_{grain}	0.184*** (0.054)	0.186*** (0.055)	0.174 (0.271)
U.S. Industrial Production * P_{grain}			0.00026 (0.0054)
U.S. Industrial Production		-0.00021 (0.00068)	-0.00037 (0.0033)
Tax	0.852*** (0.043)	0.862*** (0.054)	0.863*** (0.058)
Const	0.248*** (0.060)	0.247*** (0.062)	0.253 (0.155)

Notes: Standard errors are in parentheses. Significance levels are indicted with *'s, where *** indicates significance at the 1 percent level, ** indicates significance at the 5 percent level, and * indicates significance at the 10 percent level.

Endnotes

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[i] Wolfram [1999] also compares direct and indirect estimates of conduct for the British electricity market. Unlike Genesove and Mullin [1998], however, she does not explicitly evaluate different functional forms for demand or how the econometrician's information set effects indirect estimates of cost and conduct.

[ii] An illegal still could produce about 1,400 gallons per year. If the owners net $0.10/gallon because of the tax differential, then the cost would be recovered in less than a year. If illegal production was fairly competitive, the net could have been closer to $0.02/gallon and the cost would have been recovered in four years.

[iii] Illegal production would greatly expand during prohibition. Miron and Zwiebel [1991] show that although consumption initially fell to 30 percent of the pre-prohibition level, it rebounded over the next several years to 60-70 percent of the pre-prohibition level.

[iv] The theoretical limit is 10 percent malt. 'distilled spirit' *Encyclopædia Britannica Online*. <http://search.eb.com/bol/topic?artcl=106006&seq_nbr=1&page=n&isctn=4> [Accessed 28 January 2002]. Because malt is more expensive than corn, distillers rarely use more than 15 percent. Beyond Beer. 'Meet America's Other Grain-Based Drink.' by Charles K. Cowdery *BEER, The Magazine*, May/June 1995 issue.

[v] IC pp. 212-213.

[vi] IC, pp. 244, 827.

[vii] See IC (pp. 90, 185-91, 848). Furthermore, data from the U.S. Bureau of Labor indicate the wages of distillery laborers varied little. Between 1890 and 1900, the average annual change in the nominal wage of distillery workers was .1 percent. Over the same time period, the nominal

wage of the average distillery worker peaked at $.311 per hour and bottomed out at $.306 per hour (BLS 1904, pp. 827-30).

[viii] 'distilled spirit' *Encyclopædia Britannica Online*. <http://search.eb.com/bol/topic?eu=108453&sctn=1> [Accessed 28 January 2002].

[ix] IC, p. 258.

[x] See IC, pp. 184, 203.

[xi] IC, pp. 248-249. Such a plant would produce about 5.84 million gallons per year. If the owners were able to net $0.01/gallon, the profits would have been $58,400 and the cost of building the plant would have been recovered in three years. Higher rates of profitability would have led to a more rapid recovery of the initial investment.

[xii] IC, p. 216.

[xiii] Technically, the IRS does not report the sales of alcoholic spirits. Rather it reports the amount of all distilled spirits on which taxes were paid during these months. However, because the tax on spirits was not paid until the date of sale, there is perfect correspondence between sales and taxes paid. Also, the IRS reports taxed quantities and tax payments by state. By focusing on the states which produced primarily alcoholic spirits (as opposed to other types of distilled spirits) we construct estimates of the sales of alcoholic spirits.

[xiv] The reason why is suggested by the fact that in the linear instrumental variables regression $Output = \delta_0 + \delta_1 * break + \delta_2 * Price + \delta_3 * Price * break$ (from which we can back out values for β_0, β_1, α_0 and α_1) none of the coefficients are significant at the 10 percent level or better. In

regressions that allowed either β or α to vary with the break (break is identifies the high period as beginning in 1890), β_0 was 16,030,346 and β_1 (the change) was 3,808,942, similarly, α_0 was 2.001 and α_1 was 0.241. All coefficients were significant at the 1 percent level. So in both cases, the changes were not very large.

[xv] Data on industrial production are from Miron and Romer (1990).

[xvi] In unreported regressions, the other three functional forms showed similar patterns across the five alternative specifications.

[xvii] United States [1900, pp. 602, 615] and United States [1937, pp. 40-77].

[xviii] Recall that $c = k^* P_{grain}$ + tax, $1.19 on average, and that the average price was $1.26.

[xix] Ornstein and Hanssens' [1985] estimates of elasticity for spirits are significantly lower, 0.8-1.0.

[xx] The elasticity adjusted Lerner index is a direct measure of the conduct variable. It derives from the monopolist's generalized first order equation $P + \theta QP'(Q) = c$. Solving for θ, we get $\theta = \eta(P)(P-c)/P$.

[xxi] One possibility is that we have used too high a value of cost or too low a value of elasticity in computing the Lerner index. Using the lower bound estimate of cost only increases the average to 0.10. As we noted, however, our estimate of elasticity is in line with Cook and Tauchen's [1982] estimate and above Ornstein and Hanssen's [1985] estimates.

[xxii] In 1888, the Trust was newly formed and so may have underestimated the effect that higher prices would have on entry. It is less clear why the Trust chose to raise prices in late 1892 and early 1893. In 1890 it was the subject of a significant antitrust suit in Nebraska and other trusts were the subject of antitrust cases during this period. A federal antitrust investigation concluded

in late 1892. In the summer of 1893 the Trust was the subject of another suit, this time in Illinois. Prices may well have been correlated with legal activity – low during periods of investigation and in other periods such as between the end of the federal investigation and the beginning of the Illinois one.