Deterministic Demand Cycles in Cartel Price Data: The Joint Executive Committee (1880–1886)[1]

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[1] The idea that deterministic demand cycles drive pricing in the Joint Executive Committee (1880-1886) was first introduced by Lobato and Walsh (1994). Andrew Coleman (2004) has kindly given us the weekly transportation price data for the Great Lakes and Canals that he put together from "The Aldrich Report". This allows us to give more direct and formal evidence that deterministic demand cycles did drive the general pattern of price and quantity movements in the JEC. This paper was presented at the IOS conference in Boston 2006, CEPR/IIIS productivity workshop in Dublin 2006 and to EARIE 2006 in Amsterdam. We thank Gregory Crawford, Peter Davis, Joseph Harrington, John Haltiwanger, Robert Porter, John Sutton and Chad Syverson for detailed comments.

Abstract

We incorporate, a previously omitted variable, the weekly transportation prices of grain over the Great Lakes and Canals from the Aldrich Report (1893), into an analysis of the JEC railroad cartel. Within the structural model of equilibrium pricing in Porter (1983), we incorporate pricing over the Great Lakes and Canals into our modeling of industry demand, conduct and stability. Replacing structure with data generates clear deterministic mark-up cycles for the Railroad during periods of cartel stability. Periods of cartel instability are explained by the presence of unusually low seasonal pricing on the Great Lakes and Canals, amongst other factors.

Keywords: Deterministic Demand Cycles, JEC Railroad Cartel Pricing, stuctural modeling versus new data on transportation prices of grain over the Great Lakes and Canals.

JEL Classification: L92 & L10.

Introduction

Porter (1983), in a structural model of equilibrium, using railroad cartel price data from the Joint Executive Committee (1880–1886), estimates the following generalised first order condition for dynamic pricing in an imperfectly competitive homogenous good industry,

$$P_t + \frac{dP_t}{dQ_t} Q_t \theta_t = MC_t$$

Porter (1983) estimates the unobservable theta, consistent with the theory of Green and Porter (1984), as a hidden regime that switches between finite periods of collusive and non-collusive pricing[2]. Such temporary periods of cartel breakdown have lead several theoretical papers to discuss the problem of cartel breakdown in the JEC, both from traditional and game theoretic frameworks. The focus of this work has been on the apparent causes of 'price wars' identified by Porter (1983) [Ulen (1983), Porter (1985), Ellison (1994), Rotemberg and Saloner (1986) and Vasconcelos (2004)]. Work on the JEC to date seems to provide empirical support for many opposing theoretical viewpoints on the reasons for cartel breakdown with little insight into the factors that affect the general run of pricing during periods of cartel stability.

[2] Theory based on repeated games suggests that the Bresnahan (1989) theta is not static, but rather the intensity of price competition (market share rivalry) can vary overtime. The way one models demand impacts the trade-off between one shot gains and discounted losses in Incentive Compatibility Constraints (ICC) in repeated games. This has been shown to generate very different time paths of theta and equilibrium price cost mark-ups (see for example Green and Porter (1984), Rotemberg and Saloner (1986**),** Haltwanger and Harrington (1991) and Fabra (2006)). Genesove and Mullin (1998) provides us with a nice overview and application of the empirical issues surrounding the estimation of the generalised first order condition for pricing in homogenous good industries.

One major drawback of all work on the JEC to date is the absence of weekly transportation prices of grain over the Great Lakes and Canal. This data has since been compiled by Coleman (2004) from the Aldrich Report (1893). Porter (1983) allowed for the dates of lakes opening and closing to affect demand but not industry conduct. We wish to investigate whether industry conduct did reponse to external pricing over on the Great Lakes and Canals and the changes in expected demand in the weeks coming up to the date of lakes opening and closing.

Our strategy is to estimate the structural model of equilibrium pricing in Porter (1983) while allowing pricing over the Great Lakes and Canals to affect industry demand, conduct and periods of cartel instability. We work with precisely the same functional form for cost, but model the Porter (1983) unobservable (mark-up) with observables in a non-parametric and not as a hidden regime.[3] Our strategy for modelling the unobservable (mark-up) is similar to Appelbaum (1982) but we model the relationship betweeen our exogenous variables and the unobservable in non-parametric form[4]. Our objective is to show that the inclusion of previously omitted data outperforms structural approaches when dealing with the unobservable. For this reason we provide a direct comparison of

[3] Ellison (1994) takes this further by imposing more structure on the omitted variable, a first order Markov process, modelled with various proxies for demand shocks. However we prefer to model our unobservable with less structure using our proxies for current and expected demand shocks.

[4]Our philosophy is similar to Olley and Pakes (1986) who motivate the use of an investment proxy, alongside exogenous variables, in a non-parametric form to control for unobservable productivity. Here we estimate the parameters of a specific cost function in an equilibrium Lerner index controlling for our unobservable (mark-up) in a non-parametric, identified with exogenous demand (Lake and Canal prices) and expected demand movements. We then back out our unobservable as a deterministic residual. Appelbaum (1982) explicitly writes down the form of the unobservable and cost function in an equilibrium Lerner index at the industry level and estimates the parameters of the system parametrically.

results with Porter (1983), and hence make no attempt to separate out the unobservable in pricing from costs using the techniques found in Berry, Levinsohn and Pakes (1995).

Our strategy is dependent on price setting on the Great Lakes and Canals being independent of the rate set in the JEC cartel. Lakes and Canals were the dominant mode of grain transportation between Chicago and New York. Coleman (2004) using data on inventories, transportation prices and spot prices for grain in Chicago and New York, estimates that spot price differences in Chicago and New York were driven by Lake and Canal transportation prices plus storage cost. This highlights the dominance of transportation over the Lakes and Canals. New York did not accept high winter transport costs, but rather used inventories to benefit from the low transportations costs in the open season.

Coleman's (2004) results suggest that inventory and pricing on the Lakes and Canal route imposed exogenous but predictable changes in demand on the JEC railroad cartel. In particular, using data before, during and after the JEC, we see that Great Lakes and Canals transportation prices tended to start low but were gradually increased every week between July and the end of the shipping season. This was due to pressures created from harvesting in August and the need to manage inventories before the lakes closed. The expectation of such low and high pricing cycles during lakes opening and the use of inventories during lakes closed should have an interesting impact on railroad pricing.

We include the following observables into the nonparametric modeling of the Porter (1983) unobservable: Exogenous seasonal pricing cycles over the Great Lakes and Canals, a measure of endogenous cartel instability and movements in expected future demand, as motivated by Haltiwanger and Harrington (1991). We capture the latter with counts on the number of weeks that lakes are opened (closed). We use *duration* (weeks into the season) to proxy for expections of increasing (decreasing) demand as we move along the weeks in lake open season (closed). We control for exogenous movements in current demand using the prices of the Lakes and Canals, month dummies and endogenous movements in current demand through cost. Could duration just reflect week effects in current demand rather than expectations of demand? Maybe but we show that for the same level of current demand, in either lakes open or closed, mark-ups are higher coming into a period of growing demand and lower coming into a slump period. We feel *duration* is at least consistent with and does control for the effects of expected demand.

Our results provide us with a very interesting deterministic cycle in the mark-up of the JEC. In the weeks before lakes closing the volume of trade presented to the Railroad increased during harvesting alongside price increases on the lakes (inventory management). This pushed Railroad mark-ups to rise consistently over the lakes open period. Indeed estimated profits for the Railroad were higher coming into the lakes closed regime when compared to those coming into the lakes opening season. We see an independent effect created by our proxy for expected demand, as we control for changes in current demand, the count on the number of weeks that lakes are opened has an increasingly upward effect on the Railroad mark-up. Conversely, controlling for changes in current demand, a count on the number of weeks that lakes are closed decreases the Railroad mark-up as time to an anticipated slump approaches. These results emulate those in Borenstein and Shepard (1996).

Unlike the earlier literature, having controlled effectively for the omitted variable, we now observe economies of scale in marginal cost. While Fabra (2006) show us that the results of Haltiwanger and Harrington's (1991) would be less likely to hold in industries with capacity constraints, economies of scale theoretically reinforces the mechanisms in Haltiwanger and Harrington (1991).[5] Such anticpicated movements in current costs would also reinforces the mechanisms in Rotemberg and Saloner (1986).

Within our structural model of equilibrium pricing, we allow for the periods of cartel instability, as documented in Porter (1983), but we model them to be driven by unexpected low seasonal pricing by the Great Lakes and Canals, among other factors. As Ulen (1983) stresses, factors such as export demand had a big impact on transportation prices across the Great Lakes and hence on the volume of trade presented to the Cartel, making cartel enforcement difficult.

Overall this paper provides evidence that inventory and pricing cycles over the Great Lakes and Canals induced systematic mark-up cycles for the Cartel. It would seem that unexpected seasonal pricing over the Great Lakes and Canals were responsible for cartel breakdown.

In section I, we describe the industry and data. In section II, we replicate Porter (1983). In section III we outline our extension of Porter (1983) and provide results. Finally, we make some conclusions.

[5] When demand is expected to be high, then costs are expected to be low. A threat of a revision to a zero profit becomes more binding as expected demand rises and less binding as expected demand falls.

Section I:

In the years before the formation of the Inter-State Commerce Commission (1887) and the passing of the Sherman Act (1890), the JEC managed a railroad cartel. Regulatory and common law restraints on collusion were minimal. The committee controlled east-bound freight shipments of grain, flour and provisions from Chicago to the Atlantic Coast. The JEC set official rates, market share allotments and managed clearing arrangements for those above and below their allocated tonnage for traffic out of Chicago. All members had full information on official rates, tonnage of traffic by each company and any deviations between allocated and actual tonnage. These statistics were published in weekly reports in the *Railway Review* and the *Chicago Tribune*.

<u>Data from Porter (1983): Week 1 in 1880 to Week 16 in 1886</u>

gr	The official grain rate, in dollars per 100 lbs
tqg	Total quantity of grain shipped, in tons.
po	Cheating reported in the Railway Review and the Chicago Tribune
pn	Estimated cheating dummy estimated in Porter (1983).
Lakes (l)	Lakes reported open =1, otherwise zero
S1	= 1 from week 28 in 1880 to week 10 in 1883; = 0 otherwise; Reflecting entry by the Grand Trunk Railway.
S2	= 1 from week 26 in 1883 to week 11 in 1886; = 0 otherwise; Reflecting entry by the Chicago and Atlantic Railway.
S3	= 1 from week 26 in 1883 to week 11 in 1886; = 0 otherwise; Reflecting entry by Chicago and Atlantic Railway.
S4	= 1 from week 12 in 1886 to week 16 in 1886; = 0 otherwise; Reflecting the departure of Chicago and Atlantic Railway.

We have observations on the above variables for 328 weeks between January 1, 1880 and April 18, 1886. The focus of most analysis is on the shipments of grain, justified on the grounds that through-shipments of grain accounted for 73% per cent of all dead freight tonnage handled by the JEC. A key feature of the industry was the seasonal pattern of demand faced by the railroad industry. The Lake Steamers and Sail Ships, which operated during the spring, summer and fall, but not during the winter season, were the principal source of competition for this railroad cartel. All the studies to date suggest that competition from the Great Lakes had little effect on industry conduct. Andrew Coleman's (2004) excellent analysis of the late nineteenth century corn markets in Chicago and New York suggest that this may not be the case.

In what follows we summarize some of Coleman's (2004) key insights into the late nineteenth century transportation of grain between Chicago and New York to facilitate the export of grain from the Great Plains to Europe. The slowest and least expensive method was to send grain to Buffalo by ship via the Great Lakes, and then to forward it to New York along the Erie Canal. This method took approximately three weeks. A faster and more expensive method, taking ten days, was to ship grain over the Great Lakes to Buffalo and then send it by rail to New York. Transportation over the Great Lakes was not available between November and late April, however, as both the canal and the Great Lakes were frozen. The fastest and most expensive method, available all year round, was to send grain over three or fours days by rail to New York.

During the period 1878 and 1890 Coleman (2004) estimates that 95 per cent of corn that was transported in the open water season was shipped by lake and 78 per cent of that arrived in New York by canal rather than by the lake and rail route. We have no doubt that the Lakes and Canal route was by far the dominant player. Coleman's (2004) dataset includes weekly data on spot and future prices, storage quantities and the cost of different modes of transport for a fourteen year period. The focus of his paper is on the difference between the Chicago and New York spot prices for grain. The main point that emerges from the paper is how inventories were used to smooth price fluctuations over the lake opening and closing seasons. New York did not accept high winter transport costs, but used inventories to benefit from the low transportations costs of the Great Lakes and Canals in open season. Our focus is clearly to model the transportation prices of the railroad cartel. It is a maintained assumption that price setting on the Lakes and Canal route could not be influenced by the Railroad, but pricing and inventory management on the lakes could impose exogenous demand cycles on the Railroad.

Weekly Data, the Aldrich Report (1893), 1878-91

gr_l&c: Aldridge p521, weekly rates, corn and wheat by Lake and Canal, 1878 – 1891, in dollars per 100 lbs

l&c: Lakes and Canal open dummy = 1 if gr_l&c > 0 , otherwise zero.

ponew: Aldridge pp514-15 has the rates for all classes of Rail transport from 1871– 1891. *ponew* =1 if the JEC grain rate was equal to the Chicago-New York grain rate that Railroads, including the JEC, tried to peg to, zero otherwise.

nwo: Count on the number of weeks lakes are open.

nwc: Count on the number of weeks lakes are closed.

The data from the Aldrich Report (1893*)* was put together by Coleman (2004). Transport prices between Chicago and New York had a marked seasonal pattern in shipping costs. Figure 1 (a) to (c) indicates the seasonal pattern of the two types of weekly shipment prices, Rail and Lake & Canal transportation, during 1878-1891. It is interesting to look at the prices before (1878-79), during (1880-85) and after the Cartel years (1886-1891). In Figure 1 (a) and (b) rail rates varied seasonally between winter and summer, prior to 1886. In Figure 1 (c) the seasonal pattern in rail prices declined after the passing of the Interstate Commerce Act 1887, which regulated rail transport.

Lake and Canal prices were typically low at the opening of the Lakes season, but increased towards the closing of the season. Clearly, when New York was building up inventories during harvesting for the winter, the price rise benefited the railroad as well as the dominant mode of transportation. An exception to this trend is found in 1881 and 1885 when prices did not rise in the latter half of the summer. This may have resulted from low export demand or other external factors. One argument given for the presense of internal conflict was that the Railroad had low and high prices within Lakes closed and open periods. Here we see that Lakes and Canal prices where also low and high in the Lakes open season which could have an important impact on the Railroad in Lakes open periods and because of inventory management in Lakes closed periods. During 1878-1886, we also see downward revisions on Railroad rates in the weeks before lakes opening. The opening up of the Lakes seems to be affecting behaviour during the lakes closed season.

Compared to Porter (1983), the price data on the Great Lakes and Canals suggest differences on the timing of the lakes opening and closing. We work with Lakes and Canal prices as a way to define opening and closing. Figure 2 (a) we plot Porter's (1983) lakes dummy against that constructed by us. They are very close, but not an exact match. In addition, Porter's (1983) *po* variable, like the lakes dummy, is also constructed on the basis of reports of internal reports of "price wars" within the Cartel. We work with a *ponew* variable, which is equal to one when the JEC grain rate was equal to the Chicago-New York grain rate from the Aldrich report that Railroads, including the JEC, tried to peg to. In Figure 2b we plot this *ponew* against *po* variable in Porter (1983). In addition, we plot Porter's (1983) *pn* (endogenous switching estimate) variable, to be estimated in Table 1a. All are correlated. It is interesting that the *pn* and *ponew* are very close. Porter's (1983) techniques pinned down the periods of instability extremely well.

Section II: Porters Structural Model of Pricing

We follow the Porter model closely,

Demand Equation

$$\ln tqg_t = \alpha_0 + \alpha_1 \ln gr_t + \alpha_2 Lakes_t + \mu_{1t} \tag{1}$$

gr_t is the grain rate per bushel shipped. tqg_t is total quantity of grain shipped. $Lakes_t$ = 1, when the great lakes are open to shipping (all seasons, save winter), otherwise = 0.

Pricing Equation

We have *N* firms asymmetric with respect to costs

$$c_{it}(tqg_{it}) = a_{it}(tqg_{it})^{\delta} + F_i \qquad i = 1,\ldots,N \tag{2}$$

Thus, Marginal Revenue for firm *i*:

$$MR_{it} = gr_t\left(1 + \frac{\theta_{it}}{\alpha_1}\right) = MC_{it} = \delta a_{it}(tqg_{it})^{\delta - 1} \tag{3}$$

For homogenous goods, the gr_t is same for each firm. Define the market-share, s_{it}, weighted Conduct parameter as,

(4) $$\theta_t = \sum_{i=1}^{N} \theta_{it} s_{it}$$

Conduct will be allowed to vary over time to represent the predictions of the Green-Porter model, finite switches between *collusive* and *reversionary* pricing behaviour. Aggregating over the *N* firms we obtain the *industry* marginal revenue and cost conditions:

(5) $$MR_t = gr_t \left(1 + \frac{\theta_t}{\alpha_1}\right) = D_t (tqg_t)^{\delta - 1} = MC_t$$

Where $$D_t = \delta \sum_{i=1}^{N} \left(a_{it}^{1/1-\delta}\right)^{1-\delta}$$

The implied structural model of pricing is therefore:

(6) $$\ln gr_t = -\ln (1+\theta_t/\alpha_1) + \ln D_t + (\delta -1)\ln tqg_t$$

We identify θ_t by putting some structure about how it varies. Porter assumes there are only two regimes: one that is *collusive* and one that is *reversionary*. He estimates the following:

(7) $$\ln gr_t = \beta_0 + \beta_1 \ln \mathrm{tqg}_t + \beta_2 S_t + \beta_3 I_t + \mu_{2t}$$

Marginal cost is estimated as $\beta_0 + \beta_1 \log tqg_t + \beta_2 S_t$, where S_t is the set of structural dummies that accommodate entry/exit and β_0 is augmented with month dummies. $I_t = 1$ during collusive regime and zero otherwise. Theory predicts that θ_t is higher during collusive regimes and therefore β_3 should be positive (since α_1 is negative), $\beta_3 = -\ln (1+\theta_t/\alpha_1)$. When I_t is known, he estimates equation (1) and (7) using 2SLS. Identification comes from the fact that we have an explicit functional form for marginal cost. When I_t is not known, it is estimated using a straight maximum likelihood or an endogenous switching (hidden) regime model.

Results I: Original Porter

We first replicate the results of Porter (1983) outlined in Table 1 (a) & (b) (Tables 3 and 4 in Porter (1983), respectively) and Figures 3 (a)-(c). Figure 3(b) is our focal point, which depicts the mark-up, θ_t/α_1, computed from $\beta_3 = -\ln(1+\theta_t/\alpha_1)$, but not reported, by Porter (1983). Collusive mark-ups price were a little over 40% higher than those in the punishment phase. Cooperative prices seem to be less than joint-profit maximising prices *(as the absolute value of industry price elasticity of demand < 1).* In addition, revisions to price wars happened more regularly in later periods. Green and Porter's (1984) prediction that price wars should occur sometimes is verified, but there is no explanation about why price wars start, how long they last or vary in duration and magnitude. This type of analysis is undertaken in Porter (1985). No evidence of an external impact on conduct from the seasonal opening and closing of the Lakes are found. Finally, we note that output is not significant in the pricing equation. No scale economies or diseconomies are found.

Results II: Original Porter with Year Dummies

We now include time dummies in Porter's (1983) demand and pricing equations, and report our findings in Tables 2(a) and (b) and Figures 4(a) and (b). Time dummies increase the predictive power of the equations quite a bit. In addition we see that the industry price elasticity falls in the demand equations, while the structural dummies are not significant in the pricing equation in either our 2SLS or ML estimations. Yet, in Table 2 (b) and Figure 4(b) we see that estimates of *pn* (set equal to 1 if above 0.5 and equal to zero if below 0.5) and the mark-up, θ_t/α_1 [computed from $\beta_3 = -\ln(1+\theta_t/\alpha_1)$], are not so different. In the next section we simply ask what difference does the price data from the Lakes and Canals make when using the same structural model of pricing as Porter (1983) with time dummies.

Section III. Our Structural Estimation

Our empirical strategy is to estimate the structural model of equilibrium pricing in Porter (1983) while allowing pricing over the Great Lakes and Canals to affect industry demand, conduct and periods of cartel instability. We rewrite equation (6) as the following, the Porter (1983) pricing equation,

(8) $$\ln gr_t = \Omega_t(.) + \ln D_t + (\delta - 1)\ln tqg_t + \varepsilon_{st}$$

where we allow $\Omega_t(.) = -\ln(1+\theta_t/\eta_t)$, η_t is the industry elasticity of demand which is the sum of the own *and* cross price when lakes are open and is just an own price during lakes closed. The term $\ln D\text{-}_t + (\delta - 1)\ln tqg_t$, as in Porter (1983), is taken as marginal cost. We augment the constant with month and time dummies.

We model the Porter (1983) unobservable, $\Omega_t(.)$, with observables in a non-parametric, and not as a hidden one-zero regime. The observables used control for the exogenous pricing cycles over the Great Lakes and Canals, $lgr\_l\&c_t$, the effect of endogenous cartel instability, $ponew_t$,and the effect of movements in expected future demand as motivated by Haltiwanger and Harrington (1991). We use *duration* (counts on weeks into the season, nwc_t, & nwo_t) to proxy for the expections of increasing (decreasing) demand as we move along the weeks in lake open season (closed). We control for exogenous movements in current demand using the prices of the Lakes and

Canals, month dummies and endogenous movements in current demand through cost. Duration could reflect week effects in current demand but is consistent with and does control for the effects of expected demand.

We do not know the functional form but allow a Kernel Density Function (KDF) in the above variables to track it. We also report a polynomial series of order one (linear function) as a proxy for the KDF to see parametrically the independent impact of the various current and expected demand pressures on sustaining a mark-up. Our focus is on estimating equation (8) in the following reduced form equilibrium pricing equation ,

Reduced Form Pricing Equation

$$\text{(9)} \qquad \ln gr_t = \Omega_t(lgr\_l\&c_t, ponew_t, nwc_t, nwo_t) + \beta_0 + \beta_1 \ln tqg_t + \varepsilon_{st}$$

As in Porter (1983), we model marginal cost as the sum of $\beta_0 + \beta_1 \ln tqg_t$. The intercept, β_0, is augmented by month and year dummies. We include them as a control for marginal cost, but clearly this could be part of the mark-up. Hence we have to be careful about the interpretation of the *level* of the mark-up. Note in the Porter (1983) framework that $\beta_1 = (\delta - 1) < 0$, which indicates the presence of economies of scale. Having the estimates of marginal cost we back-out the mark-up, θ_t / η_t, from the above equation as $\Omega_t(\,.\,) = -\ln(1+\theta_t/\eta_t)$. Clearly, $ponew_t$ and tqg_t are endogenous and we will model the two auxiliary regressions as follows:

Auxiliary Demand Equation

$$\text{(10)} \qquad \ln tqg_t = \alpha_0 + \alpha_1 \ln gr_t + \alpha_2 \ln lgr\_l\&c_t + \Omega^*_t(\text{SD's}, nwo_t, nwc_t) + \varepsilon_{dt}$$

The demand equation is a function of the own price *and* the price of the dominant substitute. Our instruments allow for a possible error in the pricing variable as the official rate may not reflect company level discounts. Such differences are more likely during periods of structural change (Structural Dummies and the Lakes and Canal Dummy) and different points on the deterministic cycle (changes in expected demand as represented by $nwo_{t,}$ and nwc_t). We use a KDF function to proxy $\Omega^*{}_t(\cdot)$ Also we report a polynomial of order one to separate out the individual effects of the instruments parametrically.

Auxiliary Probit

$$ponew_t = \beta_0 + \beta_1 nwc_t + \beta_2 nwo_t + \boldsymbol{\beta} \ln \ln lgr\_l\&c_t \text{ *Years} + \varepsilon_{wt}$$

Cartel instability is allowed to be driven by expected demand cycles proxied by *duration* (counts on weeks into the season, nwc_t, & nwo_t), and we also interact the prices of the Lakes and Canals with year dummies to capture different yearly effects or in particular the usually low seasonal pricing on the Great Lakes and Canals in 1881 and 1885.

Results III: Original Porter with Lakes and Canal Prices

The results from the above specifications of pricing, demand, and cartel breakdown are reported in Table 3 and Figures 4 (a) – (d). We employ our Kernel Density Functions in pricing and demand, reported in columns three and four, which control for the omitted variables in a general way, but we do not see the role of the individual effects. We use the same semi-parametric estimation techniques as outlined in Olley and Pakes (1986). Our model explains 77 per cent of pricing and 57 per cent of demand movements at the industry level. We have evidence of economies of scale as the parameter on output in the pricing equation is negative and significant. In addition we observe that the own- price elasticity of demand (which is greater than one) and the cross price is positive are significant.

The non-parametric functions hide the individual effects of our exogenous demand and expected demand variables on the mark-up. In first two columns, we use a polynomial of order one to proxy $\Omega_t(\cdot)$ in the pricing equation and $\Omega^*_t(\cdot)$ in the demand equation to get a feel for the individual effects. This reduces to a very simple 2SLS approach, which is comparable to that in the first two columns of Table 1 (a), the original Porter (1983) 2SLS results. Our 2SLS model now explains 64 per cent of pricing, rather than 36 per cent, as our additional variables are having an effect. The exogenous price of lakes and canals has a positive effect on the mark-up. Internal endogenous "price wars" reduce the mark-up. Duration, 'number of weeks into lakes closed' has a downward effect on the mark-up and the 'number of weeks into lakes opened' has an upward effect on the mark-up. The later represent independent effects of our control for expected future demand as outlined in Haltiwanger and Harrington (1991). When we put all these factors in a non-parametric we can explain 77 per cent of pricing movements.

The demand equation (the IV regression for output in the price (official rate) setting equation) is different to Porter (1983). We include the price of the Lakes and Canals, which is clearly important. The instrumental variables used are in the KDF in $\Omega^*_t(\cdot)$. The idea here is that the actual prices may not be the same as the official rate. The times, when the Incentive Compatibility Constraint at the company level is coming under pressure, when temptations to have prices departing from the official rate, is when we have changes in the numbers of companies and deterministic cycles. Hence, we use errors in the reporting of price as our instrument for output. We should recall that the structural dummies are not significant in the pricing equation in the presence of time dummies. We also include a one zero dummy to indicate that lakes and canals are open or closed. This is where the identification of output in the pricing equation comes from which is independent of the error structure in the pricing equation. We note that the own price elasticity of demand is greater than one and the cross price elasticity of demand of industry demand is positive and significant.

Finally, Porter's (1983) price revisions (the IV regression for $ponew_t$ in the pricing equation) are explained nicely by our interaction of time with the prices on the lakes and canals. We have usually low seasonal pricing over the Lakes and Canals in 1881 and 1885. From Figure I (a)-(c) we see that from 1878 prices usually increased coming to the end of the season, but not in 1881 and 1885. When the the Lakes and Canals where pricing around 5 cent a bushel for transportation, it was hard for the Railroads to make profits. This is our key instrumental variable for $ponew_t$ in the pricing equation.

In Figure 5 (a) we plot the mark-up, constructed from our deterministic residual that comes out of our structural model of equilibrium pricing based on using polynomials of order one, proxy for $\Omega_t = -\ln(1+\theta_t/\eta_t)$. The term $\beta_0 + \beta_1 \ln \text{tqg}_t$ is taken as marginal cost where the constant is augmented with month and time dummies. The estimates of the mark-up, θ_t/η_t, ratio of predicted prices over marginal cost, are plotted over the lakes opening and closing periods, against periods of cartel instability as defined by our *ponew* and against the log of sales, to be aware of the volume of sales over the 328 weeks.

The mark-up drops over the lakes closed period and consistently rises over the lakes open period. In addition, we see the negative mark-ups during the periods of cartel instability plotted against the one and zero *ponew* variable, as documented in Porter

(1983). Do these mark-up cycles reflect current or expected demand? Are they Rotemberg and Saloner (1986) or Haltwanger and Harrington (1991) cycles? For the same level of sales, in lakes open season, the mark-up is higher as we approach lakes closing than just coming out of a period of lakes closed. Conversely, we can see that for the same level of sales, in lakes closed season, the mark-up is lower as we approach lakes opening than just coming out of a period of lakes opened. Obviously current demand cycles and economies of scale reinforce this, yet there are clear signs in the econometrics (significant *duration* effects) and in the plot of the mark-up, θ_t/η_t, in Figure 5 (a) that the Haltwanger and Harrington (1991) expected demand effect plays a role.

In Figure 5 (b), we plot the estimated Cartel profit, the mark-up times output. Railroad made losses over the period when *ponew* was zero. More importantly, the periods coming to the end of lakes opening normally generated the highest weekly profits for the Cartel. Harvesting and the race against the clock in inventory management normally induced price increases on the Great Lakes and Canals that increased the volume of trade for the Railroad. This rise in current and expected demand allowed the Cartel to sustain a higher price and exploit economies of scales leading to a surge in profits. Given that it was a monopoly during lakes closed, it is interesting to see that profits peaked at the end of the lakes open period. This highlights the external pressure that came from inventory management and pricing over the lakes and canals on the Railroad.

In Figures 5 (c) and 5 (d), the mark-up, θ_t/η_t , constructed from $\Omega_t = -\ln(1+\theta_t/\eta_t)$, and estimates of profits, respectively, based on employing KDFs in our structural model of equilibrium pricing, are plotted over the lakes opening and closing. The effect of current and expected deterministic cycles and periods of cartel breakdown on the mark-up and profit cycles are still clear. Competition from the Great Lakes and Canals created ongoing external pressure on industry conduct that induced interesting mark-up and profit cycles during periods of Cartel Stability. In addition, unexpected slumps in the prices of the Great Lakes and Canals (reflecting export demand or some other factor) lead the Railroad to losses in periods that normally gave the Cartel its highest profit.

Results IV: Dynamic Adjustment

The error structure in the demand equation suggests that we do not control for differences in actual prices (change daily) and the official rate (set weekly) well enough and we should allow for a one week partial adjustment model by including a lagged dependent variable. We report adjusted coefficients and standard errors. The results from the specifications of pricing demand with a lagged dependent variable, and cartel breakdown are reported in Table 4 and Figures 6 (a)–(d). Our semi-parametric approach now explains 78 per cent of pricing and 65 per cent of Demand. The own- and cross-price elasticity's of demand are slightly higher and we still see the presence of economies of scale.

In Figure 6 (a) and 6(c) the mark-up (constructed from our deterministic residual) coming out of our structural model of equilibrium pricing based on polynomials of order one and based on employing KDFs, respectively, are plotted as before. The effect of deterministic cycles and periods of cartel breakdown on the mark-up and profit cycles are even clearer when we allow for partial adjustment in demand.

Conclusions

The inclusion of additional data, pricing on Lakes and Canals, has a tremendous impact on the results of one of the best know pieces of applied work in Industrial Organisation. Modeling price and quantity movements without knowing the transportation prices of grain over the Great Lakes and Canals from the dominant competitor was always going to be problematic, particularly since harvesting and inventory management over the Great Lakes and Canals induced distinctive deterministic demand cycles for the Railroad to set prices against. In addition, identifying an unobservable (omitted variable) theta with a *hidden* switching regime was less than perfect, paarticularly during periods of cartel stability. We estimate the relationship between pricing and marginal cost, controlling for the omitted time varying mark-up, identified with exogenous current and expected demand movements, in a non-parametric. Good estimates of the parameters of the marginal cost function allow us to back-out estimates of the mark-up from a deterministic residual.

External pressure from activity on the Great Lakes and Canals give us interesting deterministic mark-up cycles during periods of Cartel Stability. Our estimated mark-up cycles reflect the role of expected demand movements. For the same volume of sales, the mark-up in earlier weeks of lakes open, when compared to later weeks, are lower. Conversely, for the same volume of sales, the mark-up in earlier weeks of lakes closed, when compared to later weeks, are higher. Periods of cartel instability, similar to those estimated by Porter (1983), are explained by the external pressure of having unusually low seasonal pricing on the Great Lakes and Canals. The Ulen (1983) story of cartel breakdown due to declines in the volume of trade has some merit.

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Figure I (a) Railroad and Lakes and Canals prices in Competitive Regimes

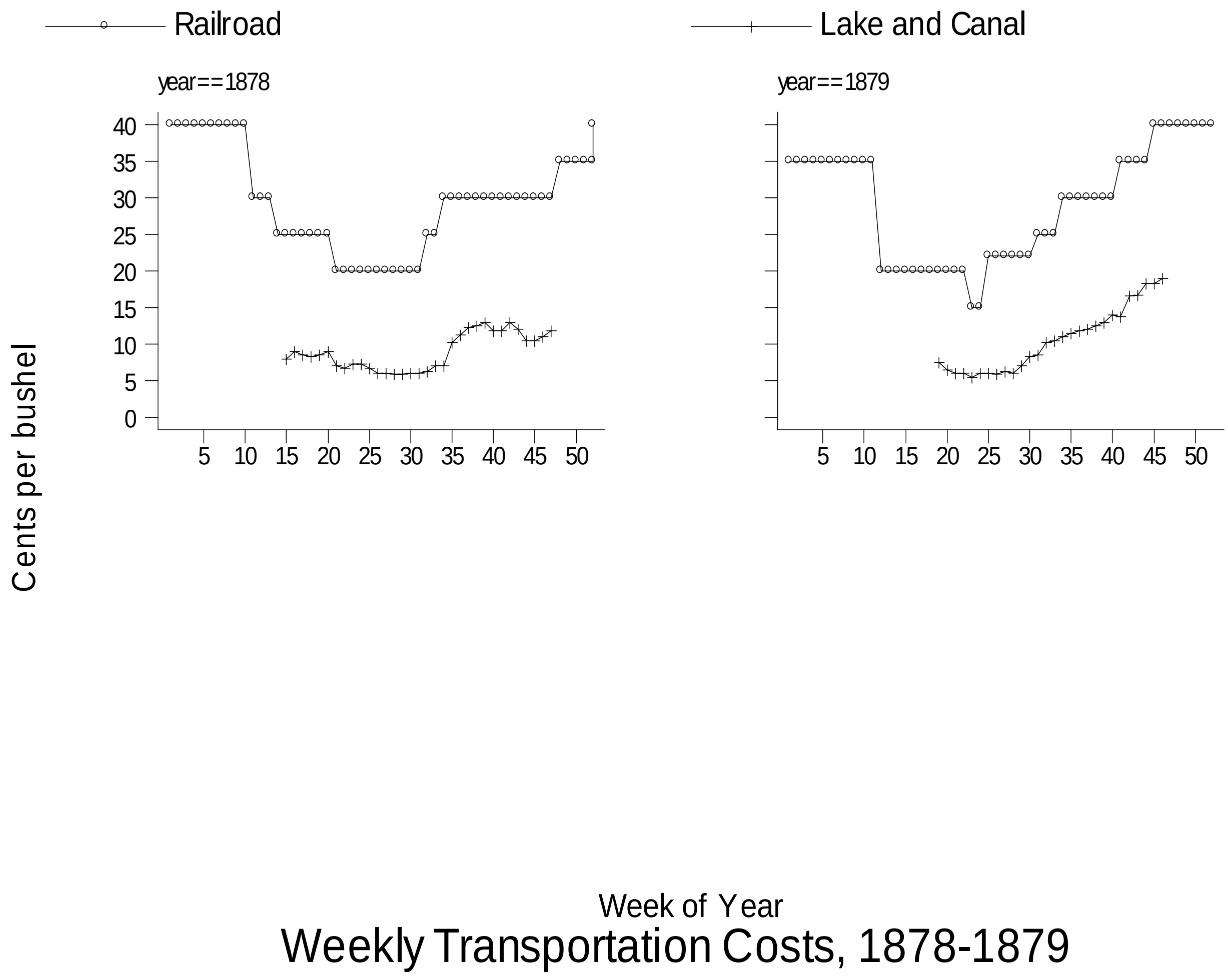


Figure I (b) Railroad and Lakes and Canals prices in Cartel Regimes

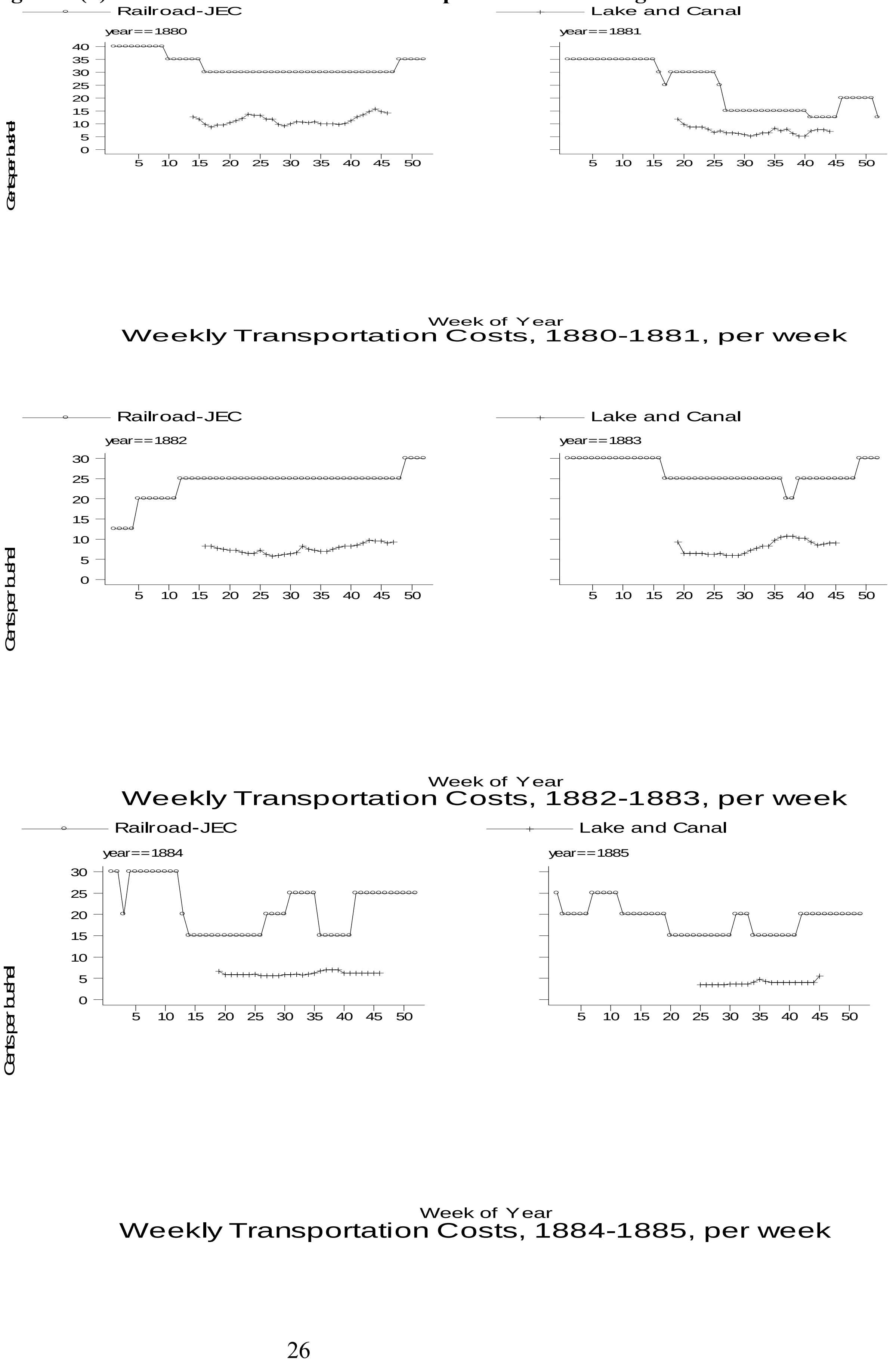
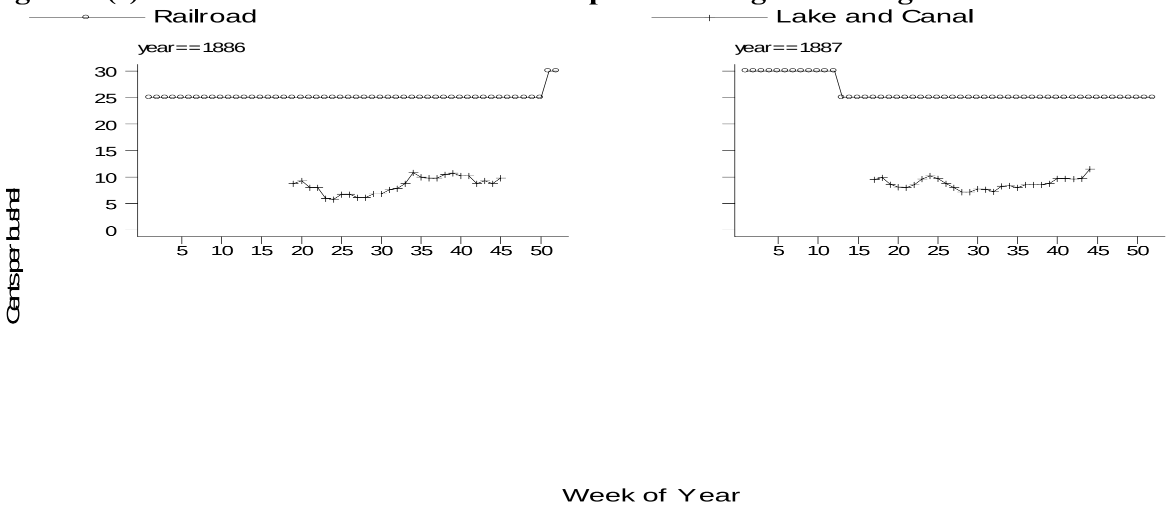
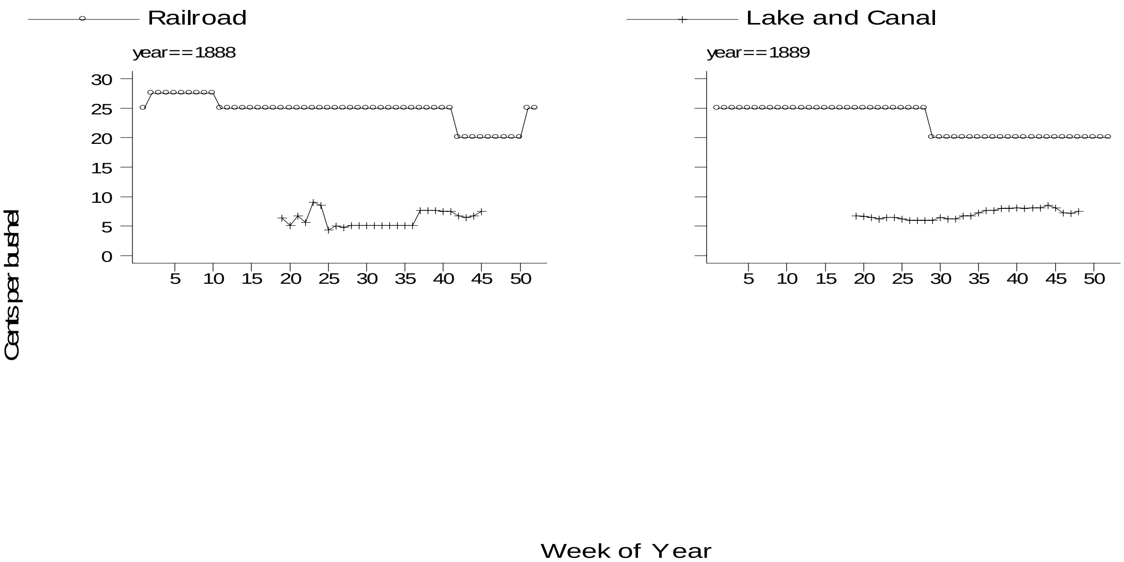


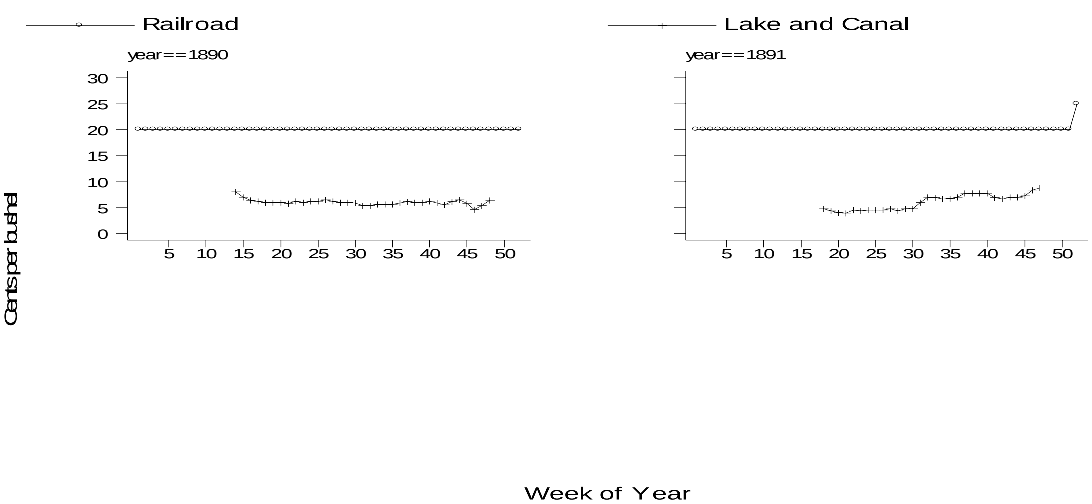
Figure I (c) Railroad and Lakes and Canals prices in Regulated Regimes



Weekly Transportation Costs, 1886-87, per week



Weekly Transportation Costs, 1888-89, per week



Weekly Transportation Costs, 1890-91, per week

Figure 2(a) The original Porter's lakes dummy (.1=closed, .9 opened); our lakes & canals dummy (0=closed, 1 opened).

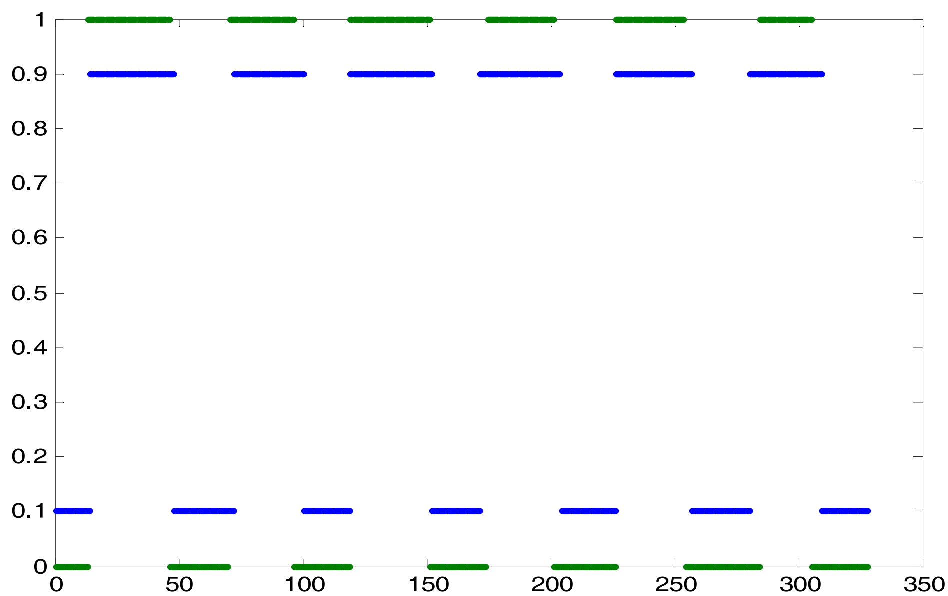
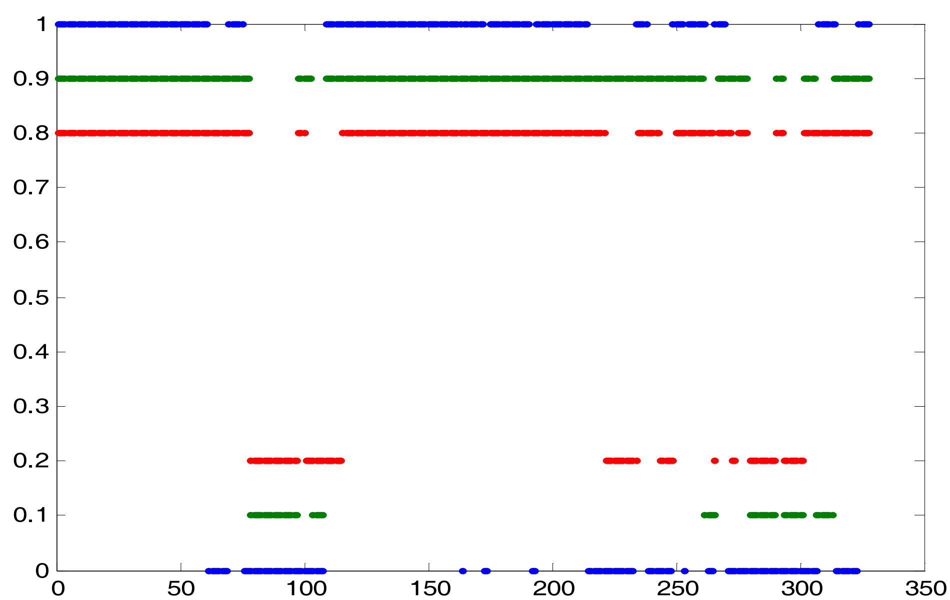


Figure 2 (b). The original Porter's po (0=cheating, 1= collusion); our ponew (.1=cheating, .9=collusion); Porter's estimated pn (.2=cheating, .8 collusion).



*Results I: Original Porter**

Table 1 (a) : (Table 3 in Porter 1983)

	2SLS (Employing po)		ML (Yielding pn)**	
VARIABLES	**Demand**	**Supply**	**Demand**	**Supply**
Constant (C)	9.152 (.182)	-3.939 (1.757)	9.014 (.148)	-3.307 (.913)
Lakes (l)	-.439 (.119)		-.453 (.117)	
Log price (lgr)	**-.725** **(.119)**		**-.841** **(.089)**	
Structural dummy (S1)		-.200 (.056)		-.160 (.031)
Structural dummy (S2)		-.169 (.080)		-.218 (.041)
Structural dummy (S3)		-.314 (.065)		-.307 (.037)
Structural dummy (S4)		-.204 (.183)		-.275 (.071)
Cheating dummy (po) / Estimated cheating dummy (pn)		**.367** **(.052)**		**.595** **(.043)**
Log sales (ltqg^)		**.249** **(.172)**		**.110** **(.088)**
R^2	.313	.361	.306	.826
S	.397	.245	.391	.121

* Monthly dummy variables are employed but not reported. Estimated standard errors are in parentheses.

** *pn* is the regime classification series ($\hat{I}_1,...,\hat{I}_T$). The coefficient attributed to *pn* is the estimate of β_3.

Table 1 (b): Price, Quantity, and Total Revenue for Different Values of *LAKES* and *pn (Table 4 in Porter)**

Price	**LAKES**	
	0	**1**
pn=0	.166	.156
pn=1	.281	.263
Quantity		
	0	**1**
pn=0	39936	26802
pn=1	25697	17246
Total Revenues**		
	0	**1**
pn=0	132588	83622
pn=1	144417	90713

* Computed from the reduced form of the maximum likelihood estimates of Table 3, with all other explanatory variables set at their sample means.
** Total Revenue = 20(Price x Quantity), to yield dollars per week.

Figure 3 (a): Markup- (estimation employing po).
One is for lakes open, zero otherwise; Top line is normalized log sales; The Bottom line is the estimated markup;

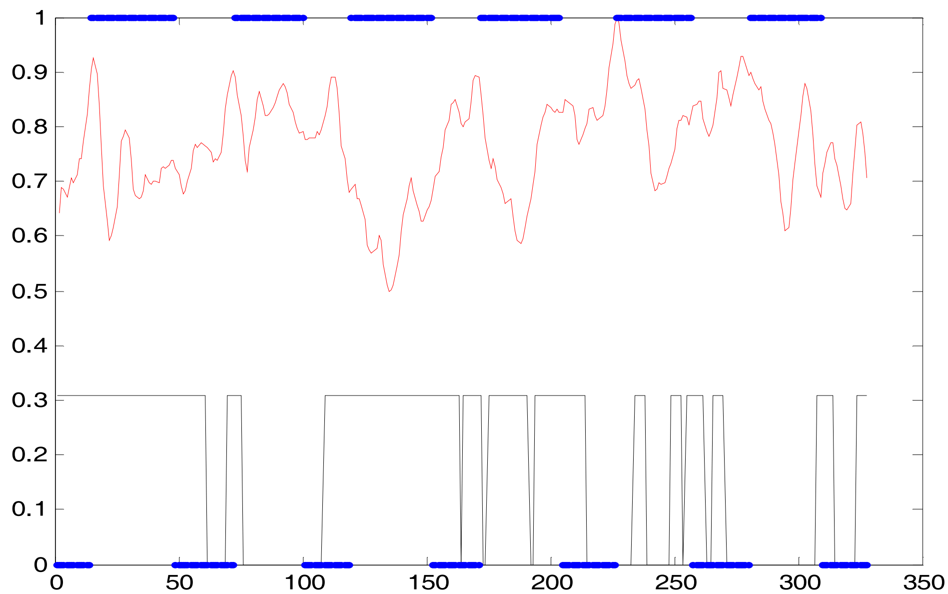


Figure 3 (b): Markup (estimation employing pn).
One is for lakes open, zero otherwise; Top line is normalized log sales; The Bottom line is the estimated markup;

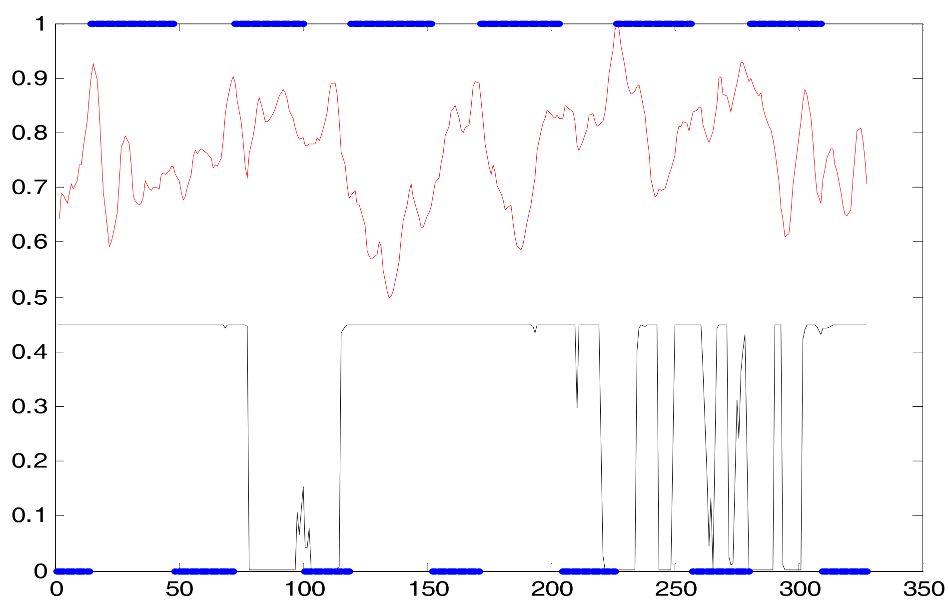
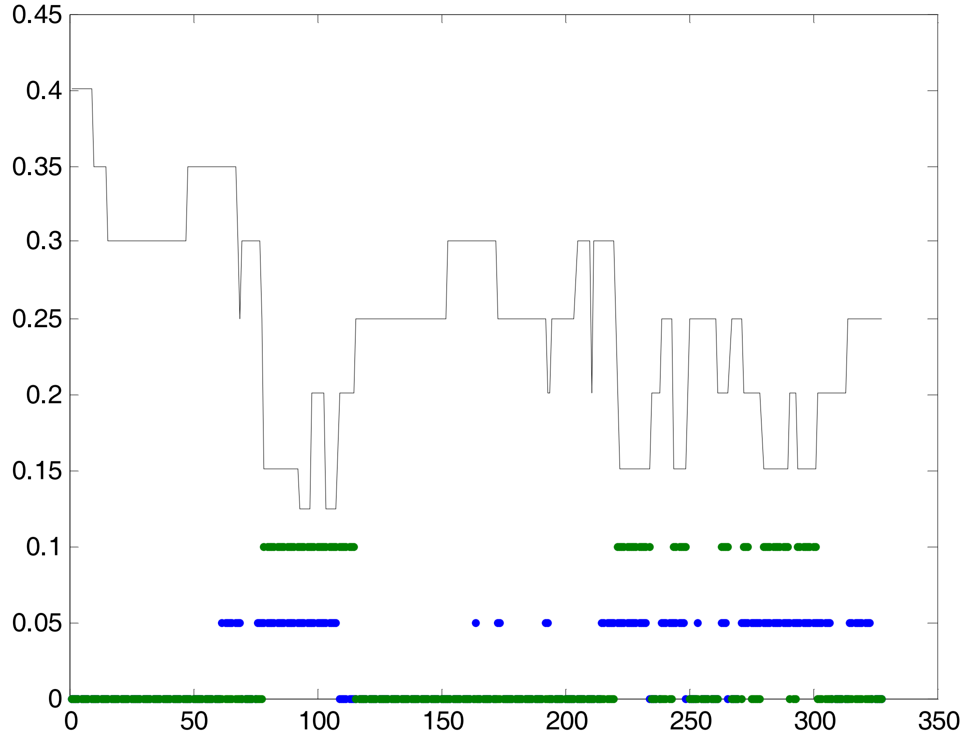


Figure 3 (c): Figure 1 in Porter (1983) using estimated pn



Results II: Original Porter with Year Dummies

Table 2 (a): Estimation Results*

	Two Stage Least Squares equation by equation (Employing po)		**Maximum Likelihood (Yielding pn)****	
VARIABLES	**Demand**	**Supply**	**Demand**	**Supply**
Constant (C)	9.383 (.212)	-3.626 (1.985)	9.214 (.133)	-3.368 (1.359)
Lakes (l)	-.413 (.105)		-.328 (.101)	
Log price (lgr)	**-.574 (.191)**		**-.709 (.104)**	
Structural dummy (S1)		.013 (.070)		.002 (.033)
Structural dummy (S2)		.047 (.129)		.066 (.057)
Structural dummy (S3)		.021 (.122)		.126 (.058)
Structural dummy (S4)		-.119 (.210)		-.013 (.087)
Cheating dummy (po) / Estimated cheating dummy (pn)		**.321 (.048)**		**.541 (.047)**
Log sales (ltqg^)		**.220 (.197)**		**.171 (.133)**
R^2	.514	.462	.509	.844
S	.337	.225	.338	.119

* Monthly **<u>and year</u>** dummy variables are employed. To economize space, their estimated coefficients are not reported. Estimated standard errors are in parentheses.

** *pn* is the regime classification series ($\hat{I}_1,...,\hat{I}_T$). The coefficient attributed to *pn* is the estimate of β_3.

Table 2 (b) (with year dummies): Price, Quantity, and Total Revenue for Different Values of LAKES and PN*

Price	**Lakes**	
	0	1
pn=0	.173	.164
pn=1	.280	.266
Quantity		
	0	**1**
pn=0	34466	25736
pn=1	24479	18279
Total Revenues**		
	0	**1**
pn=0	119252	84414
pn=1	137082	97244

* Computed from the reduced form of the maximum likelihood estimates of Table 3, with all other explanatory variables set at their sample means.
** Total Revenue = 20(Price x Quantity), to yield dollars per week.

Figure 4(a) (based on the estimates reported in Table 2a – employing po -): One is for lakes open, zero otherwise; Top line is normalized log sales; The Bottom line is the estimated markup;

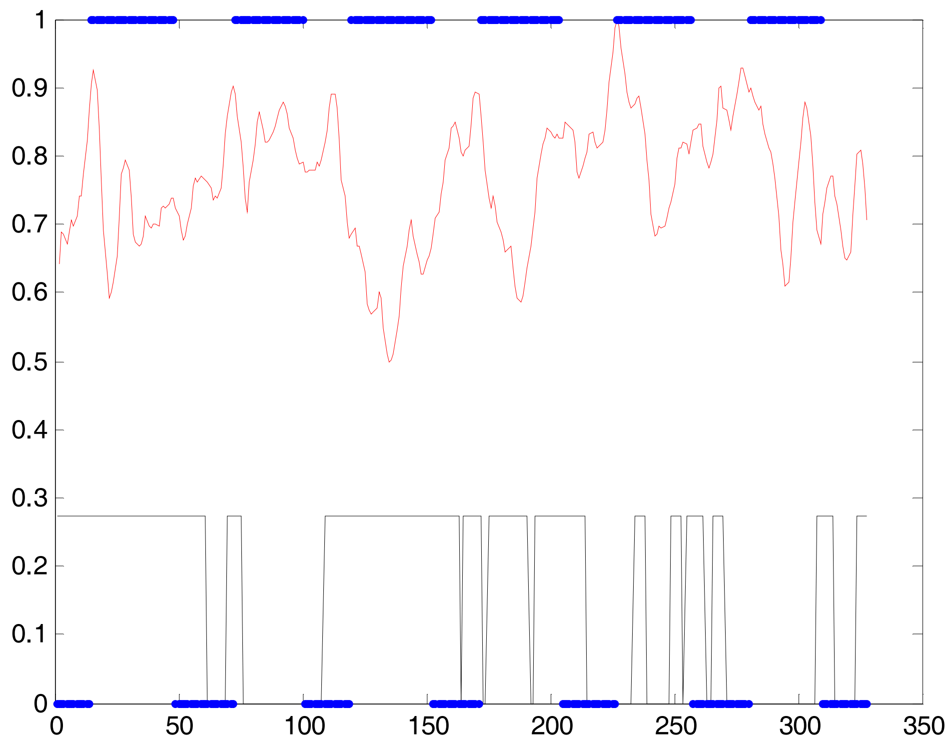
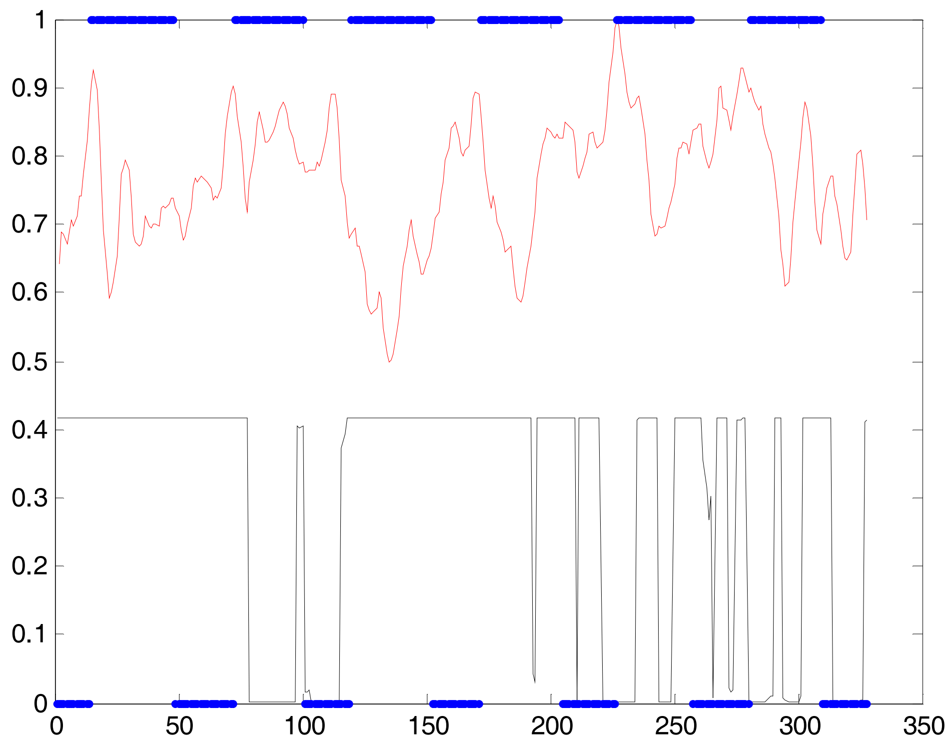


Figure 4 (b) (based on the estimates reported in Table 2 (a) – employing pn -): One is for lakes open, zero otherwise; Top line is normalized log sales; The Bottom line is the estimated markup;



Results III: Porter with Lakes and Canal Prices

Table 3 Estimation Results

	2SLS polynomial		**Semi-Parametric Kernel approach**		**Probit (Cheating dummy)**
VARIABLES	**D**	**S**	**D**	**S**	**Pr(ponew)**
Constant	9.066	1.091	8.819	.675	3.440
(C)	(.438)	(1.150)	(.295)	(1.022)	(.623)
Log price lakes&canals	**.345**	.155	**.068**		
(lgr_l&c)	**(.128)**	(.037)	**(.031)**		
Log price	**-1.28**		**-1.26**		
(lgr)	**(.293)**		**(.275)**		
Number weeks l&c closed	-.171	-.018			-.009
(nwc)	(.072)	(.005)			(.028)
Number weeks l&c opened	.121	.012			.060
(nwo)	(.032)	(.003)			(.043)
Lakes&canals Dummy	.610				
(l&c)	(.346)				
Structural dummy	-.061				
(S1)	(.115)				
Structural dummy	-.387				
(S2)	(.200)				
Structural dummy	-.181				
(S3)	(.204)				
Structural dummy	-.790				
(S4)	(.308)				
Estimated cheating dummy		.291			
(ponew^)		(.096)			
Log sales		**-.246**		**-.193**	
(ltqg ^)		**(.109)**		**(.103)**	
Lgr_lc*year1881					**-.931**
					(.289)
Lgr_lc*year1885					**-.123**
					(.227)
R^2	.51	.64	.57	.77	.59
S	.350	.179			

Month and year dummy variables are employed. Estimated standard errors are in parentheses.

Polynomial Order One:

Demand Omega: the lakes&canals dummy, the four structural dummies, number of weeks that lakes &canals areclosed (nwc) and the number of weeks that lakes and canals are open (nwo).

Supply Omega: estimated cheating dummy (phat), log of price of lakes&canals (lgr_lc), number of weeks that lakes&canals are open (nwo), number of weeks that lakes&canals are closed (nwc).

Kernel:

Demand kernel: the lakes&canals dummy, the four structural dummies, number of weeks that lakes&canals are closed (nwc) and the number of weeks that lakes and canals are open (nwo).

Supply Kernel: estimated cheating dummy (phat), log of price of lakes&canals (lgr_lc), number of weeks that lakes&canals are open (nwo), number of weeks that lakes&canals are closed (nwc).

Figure 5 (a): Estimated Markup (Table 3 Polynomial). Top line is normalized log sales; The Bottom line is the estimated markup; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise.

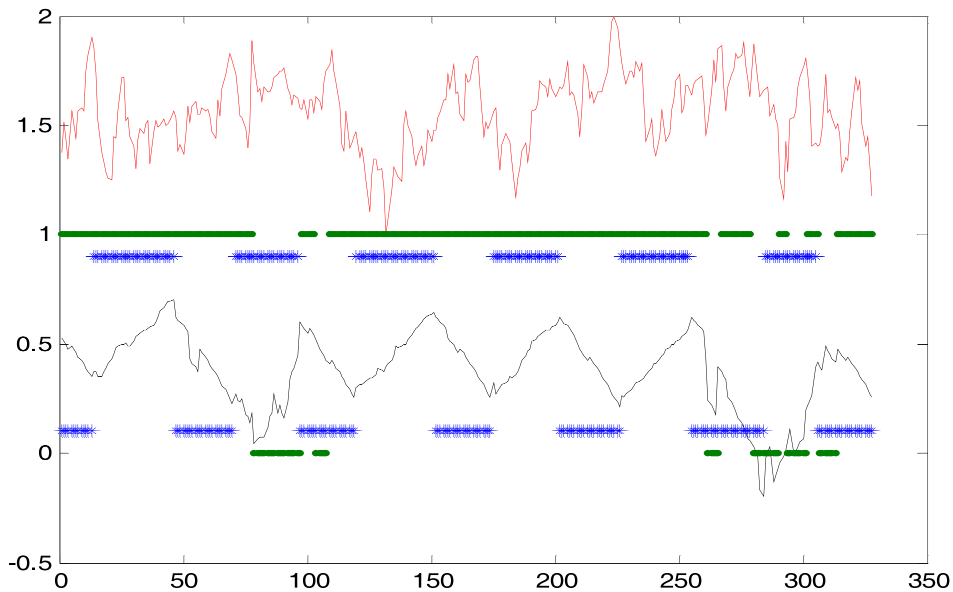


Figure 5 (b): Estimated Profits (Table 3 Polynomial). Top line is normalized log sales; The Bottom line is the estimated profits; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise.

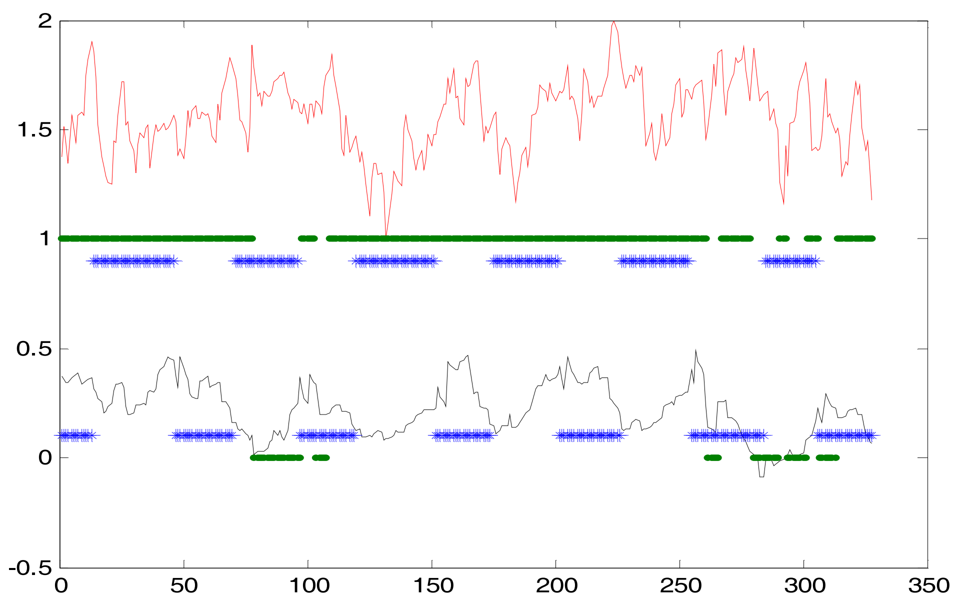


Figure 5 (c): Estimated Markup (Table 3 Kernel). Top line is normalized log sales; The Bottom line is the estimated markup; Dummy for collusion = 1 and 0 otherwise (*ponew* variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise.

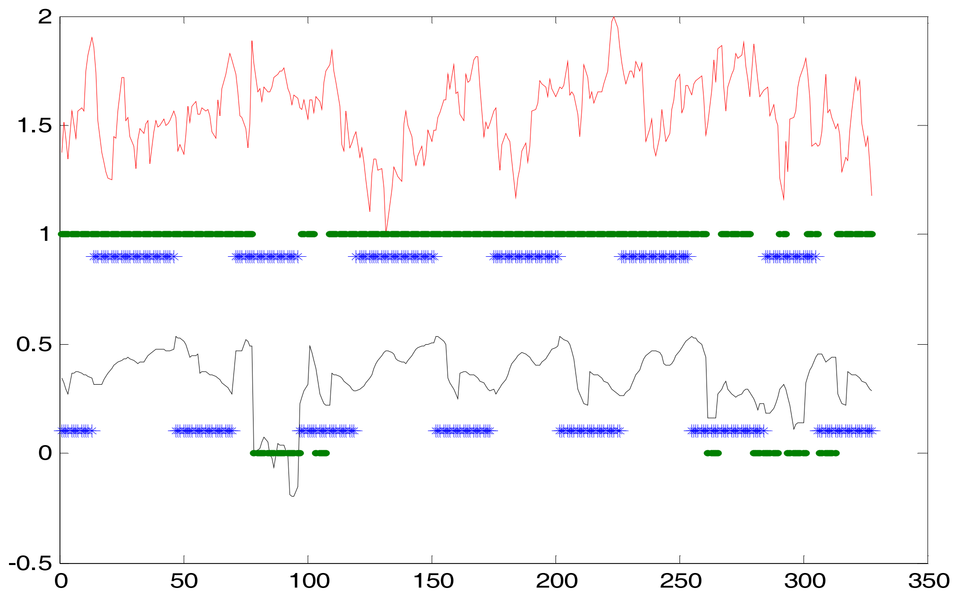
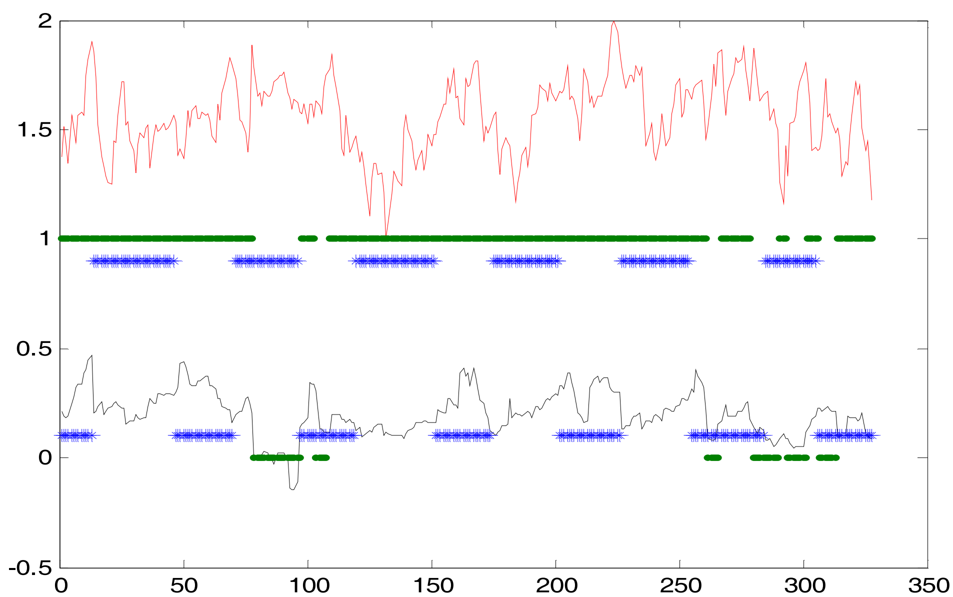


Figure 5 (d): Estimated Profits (Table 3 Kernel). Top line is normalized log sales; The Bottom line is the estimated profits; Dummy for collusion = 1 and 0 otherwise (*ponew* variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise



Results IV: Porter with Dynamic adjustment

Table 4 Estimation Results

VARIABLES	2SLS polynomial D	2SLS polynomial S	Semi-Parametric Kernel approach D	Semi-Parametric Kernel approach S	Probit (Cheating dummy) Pr(ponew)
Constant (C)	**9.386 (.463)**	**.830 (.610)**	**8.966 (.343)**	**.591 (.432)**	**3.440 (.623)**
Log price lakes&canals (lgr_l&c)	**.298 (.146)**	.154 (.037)	**.118 (.035)**		
Log price (lgr)	**-1.216 (.357)**		**-1.311 (.330)**		
Number weeks l&c closed (nwc)	-.214 (.079)	-.019 (.005)			-.009 (.028)
Number weeks l&c opened (nwo)	.151 (.051)	.012 (.003)			.060 (.043)
Lakes&canals (l&c)	.405 (.392)				
Structural dummy (S1)	-.148 (.128)				
Structural dummy (S2)	-.440 (.217)				
Structural dummy (S3)	-.231 (.222)				
Structural dummy (S4)	-.878 (.334)				
Estimated cheating dummy (ponew^)		.306 (.078)			
Log sales (ltqg ^)		**-.221 (.057)**		**-.194 (.043)**	
Lgr_lc*year1881					-.931 (.289)
Lgr_lc*year1885					-.123 (.227)
Lag Log sales (ltqg_1)	**.177 (.035)**		**.186 (.033)**		
R^2	.60	.65	.65	.78	.59
S	.315	.178	.094	.021	

Month and year dummy variables are employed. Estimated standard errors are in parentheses.

Polynomial Order One: *Demand Omega:* the lakes&canals dummy, the four structural dummies, number of weeks that lakes&canals areclosed (nwc) and the number of weeks that lakes and canals are open (nwo).

Supply Omega: estimated cheating dummy (phat), log of price of lakes&canals (lgr_lc), number of weeks that lakes&canals are open (nwo), number of weeks that lakes&canals are closed (nwc).

Kernel:*Demand kernel:* the lakes&canals dummy, the four structural dummies, number of weeks that lakes&canals areclosed (nwc) and the number of weeks that lakes and canals are open (nwo).

Supply Kernel: estimated cheating dummy (phat), log of price of lakes&canals (lgr_lc), number of weeks that lakes&canals are open (nwo), number of weeks that lakes&canals are closed (nwc).

Figure 6 (a): Estimated Markup (Table 4 Polynomial). Top line is normalized log sales; The Bottom line is the estimated markup; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise.

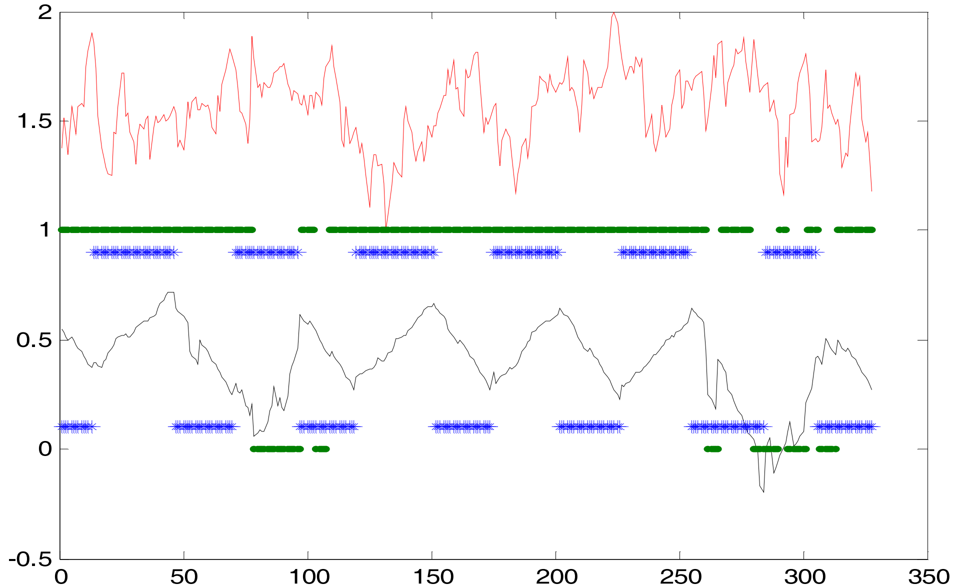


Figure 6 (b): Estimated Profits (Table 4 Polynomial). Top line is normalized log sales; The Bottom line is the estimated profits; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise

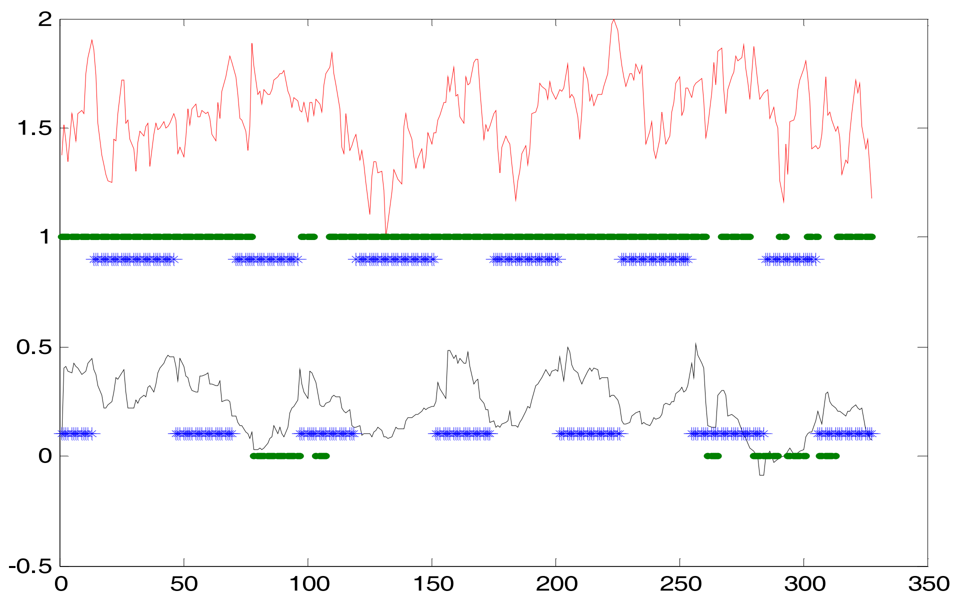


Figure 6 (c): Estimated Markup (Table 4 Kernel). Top line is normalized log sales; The Bottom line is the estimated markup; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise.

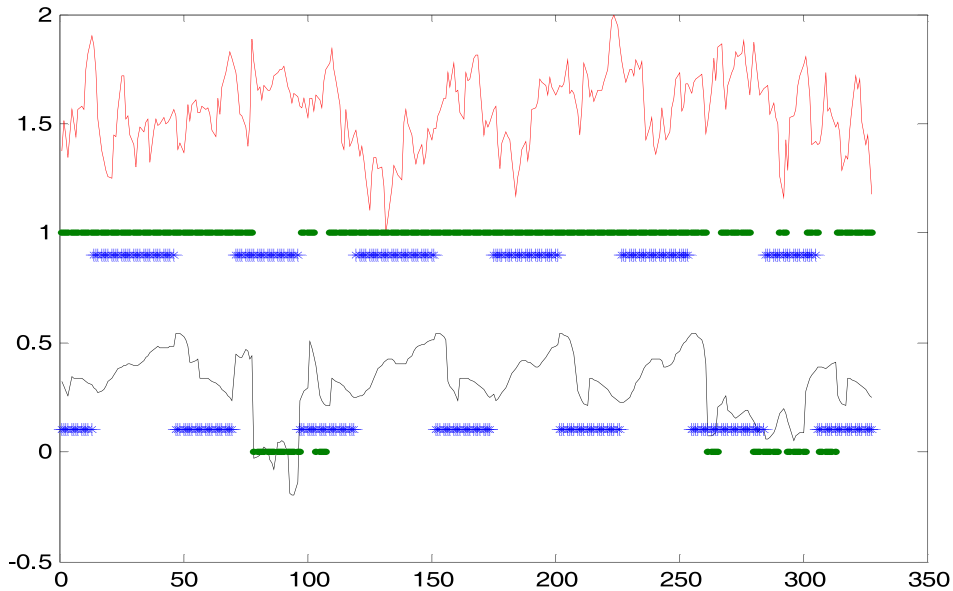


Figure 6 (d): Estimated Profits (Table 4 Kernel). Top line is normalized log sales; The Bottom line is the estimated profits; Dummy for collusion = 1 and 0 otherwise (PONEW variable); Dummy for lakes and canals is equal to 0.1 when closed and .9 otherwise