Government Regulation as a Collusion Facilitating Device: Evidence from the Ukrainian White Sugar Industry in 1993-2000.*

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Abstract

This study evaluates the degree of collusion among sugar refiners in Ukraine. It is hypothesized that the Ukrtsukor association that unites all sugar refinery firms in Ukraine used its power to facilitate collusion among its members. I extend the existing empirical literature on collusion by developing a structural model of collusive behavior when the objective function of a cartel is not known. In particular, I derive an empirical version of the individual first order conditions under the assumption that a cartel implements a proportional reduction technique of collusion. Estimation results reveal that output levels are persistently lower than predicted Cournot quantities.

1 Introduction

It is widely acknowledged that during most of the transition period the food industry in Ukraine was heavily regulated. The regulation took different forms, including price ceilings, output quotas, protectionist measures in international trade markets, and explicit restrictions on food products transfers across Ukrainian regional borders. Often, the government created associations that united all producers in an industry to maintain

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direct control over prices and outputs. On the one hand, government intervention was intended to provide some sort of social protection. On the other, it created distortions that allowed for non-competitive behavior.

This study evaluates conduct in sugar refining industry. The institutional structure provided all the prerequisites for collusive behavior. Through output quotas for individual producers and control of the market price the *Ukrtsukor* ("Ukrainian sugar") association appears to be a classical instance of a cartel. Moreover, protected by the government the cartel was virtually immune to regulation by the antitrust authority. It is less obvious to what extent the cartel used its market power. Sugar is an essential product and the Ukrainian government closely monitors sugar price to prevent social and political unrest. Therefore, the objective function of this type of industry cartel is likely to be a complex combination of profit and social welfare maximization.

In order to empirically test sugar refining industry conduct, I develop a model that is specifically designed for analysis of cases where collusion does not result in a perfect cartel case. This is an extension of the previous literature on collusion, most of which assumes discreteness of collusive possibilities (i.e. Bertrand, Cournot, Perfect Cartel). In many cases, as with government-controlled associations, researchers are unaware about the objective function of a cartel. Simple industry profit maximization may be a fairly strong assumption.

Instead, I suggest imposing an assumption on the way the collusion is implemented. Proportional reduction technique, defined by Schmalensee (1987), allows me to link observed quantity choices to the firms' competitive first order conditions through a single parameter measuring the degree of collusiveness. This approach has several advantages. The most important one is the interpretation of the parameter estimate, which represents the inverse share of the potential competitive quantity.

Several recent studies attempt to explain the poor performance of Ukrainian agricultural firms reflected in high retail sugar prices (see for example, Zorya and Nivyevsky (2005), Cramon-Taubadel et al. (2001), Zhosan (1999)). Absence of competition from foreign producers and a poor regulatory environment are usually mentioned among the major reasons for persistent inefficiency. Indeed, regulation of the white sugar price has had considerable adverse effect on sugar beet producers who supply inputs to the sugar refinery firms. This has already resulted in a considerable reduction of sugar beet supply since 1991. Thus we observe an instance of an adverse effect of inappropriate government policies in the downstream market (sugar refinery) on the related upstream (sugar beet producing) market. While direct effects of administrative interventions into the market transactions are well documented in the existing literature, little attention is devoted to possible indirect effects. The possibility of collusive behavior considered in this study represents one of such indirect effects.

In order to "efficiently" regulate markets, the Ukrainian government often establishes associations of producers. This simplifies control over the individual producers by directly interfering with their management decisions. Officially, such associations are designed to represent the interests of domestic producers. What is often neglected is the ability of such associations to exploit their status to effectively coordinate the activity of their members in both the output and input markets. It is plausible that the coordination may take quite pervasive forms, one of which is collusive behavior. In this way regulation has an additional negative effect through facilitating collusive behavior in the market.

Ukrainian sugar refining firms are united by the Ukrtsukor association. It is well documented that the association controls not only prices in the white sugar wholesale market but also allocates output quotas by interfering with the supplier-producer relationships. This study evaluates the degree of collusion and quantifies the resulting losses. Having such information would provide empirical evidence necessary to reform the sugar market. Estimation results indicate a moderate degree of collusion as compared to the quantity-setting competitive equilibrium. At the same time, if the primary purpose of regulation is to maximize social welfare, the losses due to collusive behavior could be much higher, particularly for regions with a small number of producers.

2 Literature review

I begin with a brief overview of the major theoretical findings in the literature on collusion. Generally, models of collusion are based on the trade-off between short run gains from deviations from a collusive agreement and the resulting long-run cost incurred by the deviants. Probably the most influential paper here is Friedman (1971). The author shows that a collusive outcome can be supported by using simple *grim trigger* strategies.

In the perfect information case "price wars" represent an off-equilibrium path, which is never played in equilibrium. However, as it was shown by Green and Porter (1984), under imperfect observability of other players' actions, price wars do take place and they represent a part of an equilibrium enforcing strategy.[1]

The relationship between short run gain from deviation and long run cost of punishment is reemphasized in the Rotemberg and Saloner (1986) model. Exogenous fluctuations in demand for oligopolistic products make it harder to sustain collusion in the periods of high demand, when temptation to cheat increases due to increase in the short-run gains from deviation. In such periods, collusion may be supported with low prices only. In turn, when the current state of demand is low and the firms expect an increase in the demand in the future, sustaining collusion becomes easier (or, alternatively, collusion can be sustained at higher prices). Hence, cartel price moves countercyclically with respect to demand fluctuations. A number of other papers consider different aspects of collusion sustainability (see for example Tirole (1988), Athey and Bagwell (2001), Athey et al. (2004). A good survey of past and recent theoretical studies of collusion can be found in Feuerstein (2005), while several directions for further research are outlined in Cabral (2005).

An important question for any collusion between firms that have asymmetric costs when side payments are not allowed is the distribution of rewards within the cartel because the rewards directly affect the cartel's sustainability. Schmalensee (1987) discusses four different types (or "technologies") of profits distribution under cartel agreements.[2] The

[1] This happens even though none of the firms cheats on agreement.

[2] The results are based on a simple model with constant marginal costs.

first type allows for side payments. It requires all production to be reallocated to the most efficient firm. Then profits are shared with the rest of the firms. As the author notes, one should think of such technology as “a standard of comparison, rather than as a realistic possibility” (p.354). The second type involves market sharing arrangements, when firms produce according to pre-specified quotas. Obviously, this type of profit re-distribution is more likely to occur in the real world. However, question of quota assignment is not a trivial one. One way to proceed is to assign market quotas in a way that generates the same critical discount factor for every firm and maximize cartel sustainability. Such arrangements, however, do not guarantee joint profit maximization. More importantly, they would make “long and complex negotiations necessary, especially when firms are imperfectly informed about their rivals’ costs, and this may entail unacceptable antitrust risks” (p.357). Third technology implies market division, when each firm is assigned to a part of the market and charges its optimal monopoly price in this segment. One obvious difficulty in implementation of this technology is the possibility of arbitrage. Finally, the last type of rewards distribution is *proportional reduction*, when firms “maintain market shares at their non-collusive (Cournot) values and reduce the output of all sellers proportionally” (p.357). Although this technology may generate less profits than some or all of the alternatives discussed above, the simplicity of its implementation may be decisive.

The existing empirical IO literature provides several different ways of identifying market power. Most of the methods are based on equations that nest several types of market conduct depending on the value of a conjectural variation parameter. One of the most famous is the Bresnahan-type identification of market power using aggregate industry data, which is based on demand “rotators” controlling for demand “shifters” (see Bresnahan (1982)). The implication of including demand rotators is that the demand function is no longer separable in these rotators. As shown by Lau (1982), identification of conjectural variation is possible in this case.

The intuition is simple. Suppose that demand is rotated around the equilibrium point. Then for marginal cost pricing (perfect competition) this has no effect on market quantity or price. Under oligopolistic or monopolistic market structure, rotation of demand will change its slope and, hence, the slope of the marginal revenue, which would result in a new market equilibrium. Porter (1983) and Ellison (1994) use the Green and Porter (1984) model of collusion to identify market power based on theoretical predictions that price wars should occur as a part of equilibrium enforcement and that they should occur precisely when random demand shocks are negative. In particular, Ellison (1994) uses a model "that focuses on the regime transition probabilities to provide evidence for the existence of the trigger strategies that are central to the theory" (p. 56). One of the possible extensions of Bresnahan-type identification to a dynamic oligopoly model is suggested by Steen and Salvanes (1999). The authors suggest using an error correction model to account for "short-run departures from the long-run equilibrium in the data" (p.148).

An alternative approach to identifying market power can be found in Sullivan (1985), who suggests estimating the lower bound on the number of firms that is consistent with the observed market price and quantity. Intuitively, the model is built on "an extension of the familiar rule that a monopolist will not produce on the inelastic portion of his demand curve" (p.588).

Two other ways of identifying market power are based on entry decisions (e.g. Bresnahan and Reiss (1991)) and pricing strategies by multi-product firms (e.g. Bresnahan (1987)). The first approach might be particularly useful if one does not observe prices or costs. The intuition is based on the "demand entry threshold, a measure of the market size required to support a given number of firms" (p.978). Then the effect of entry on market conduct can be inferred from the ratios of the entry thresholds. The second approach is based on the fact that multi-product firms would maximize joint profits from their imperfectly substitutable products. If, in turn, two products belong to the competing firms, profit is maximized separately for each product. In other words, negative externalities from producing one product for the other are not endogenized. In the periods of competition this difference should be significantly larger than in the periods of collusion.

Nevo (1998) discusses two approaches to identification of collusion in a differentiated product industry. The first, "menu approach", is derived directly from theory. Under this approach a researcher estimates a finite set of models of firms conduct. The models are defined by matrices of zeros and ones, where zeros (ones) switch off (on) corresponding elements in the matrix of cross-partial derivatives within individual firms' first order conditions. Each of these "ownership matrices" is then consistent with a joint profit maximization for a given subset of products. The alternative models can be discriminated according to their fit. The second approach replaces zeros and ones in the ownership matrix with a set of parameters to estimate. The parameters determine to what extent the firms internalize the effect of their control variables on the market shares of their competitors. This approach has weaker theoretical justification and identification of the parameters may require a large number of exogenous demand shifters. For example, Ciliberto and Williams (2014) study the relationship between multi-market contact and the degree of collusion in the airline industry using exogenous variation in the number of airport gates leased to different airlines. As discussed by Berry and Haile (2013), identification in this literature may be based on observable demand and/or cost shifters and the change in the market environment (e.g., market size). In a complement paper, Shcherbakov and Wakamori (2015), we provide a detailed discussion of the method used in this paper and illustrate it using Monte-Carlo simulations and the well-known data from the Joint Executive Committee railroad cartel.

3 Institutional framework

Historically, the sugar industry was one of the core agricultural businesses in Ukraine, accounting for about half of the overall white sugar production in the former Soviet Union. Sugar production involves two stages: growing sugar beets and its refining. The market structure of the sugar beets growing industry is likely to satisfy assumptions of a perfectly competitive market. However, the degree of competition in the refining industry is of much greater concern.

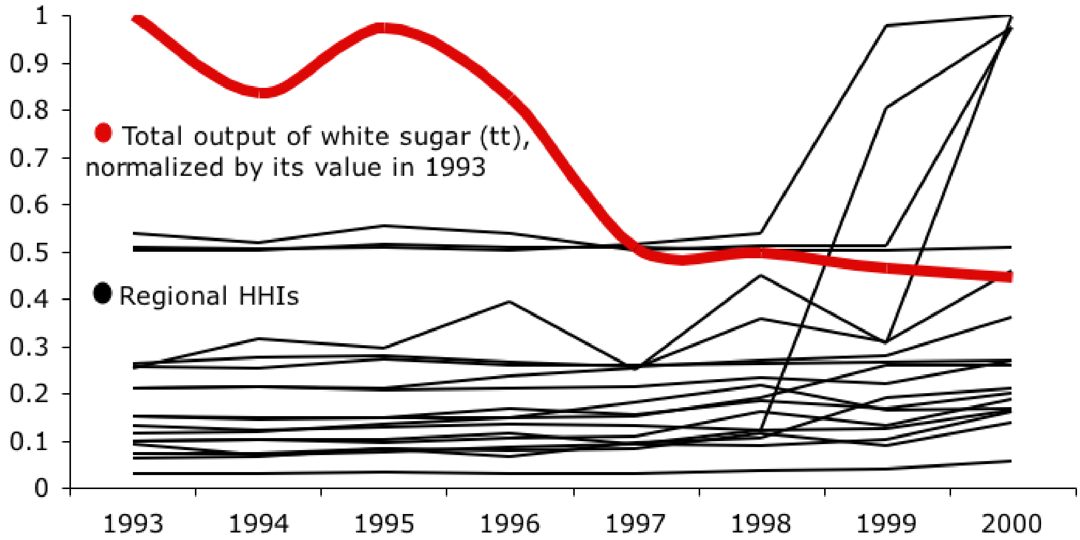
In the beginning of the transition, the refining industry included 192 sugar refining plants and accounted for about 120,000 employees. As an important part of Ukrainian economy, the sugar industry was subject to a considerable regulatory intervention by the government. Both wholesale and retail sugar prices were regulated either by central or by municipal authorities. Further, the industry was subject to protectionist measures that made import of sugar beets and sugar itself virtually ineffective in fostering competition in the domestic markets.

According to previous studies, the number and the density of sugar factories in Ukraine is excessive (see Zorya and Nivyevsky (2005)). For instance, the number of sugar refining firms in a single Ukrainian region (Vynnytska oblast) is 35, while the total number of sugar factories in Germany is only 26. This market structure was inherited since Soviet times when the Ukrainian sugar industry served about 50 percent of the overall white sugar demand in the former USSR. Given that all of the existing firms are mostly oriented to the domestic market, one could expect fierce competition between the factories. As a result of such competition, a considerable number of firms should have been forced to exit the industry in the early years of the transition period. However, in 1992-1998 almost all sugar refining plants reported positive levels of output.[3] Interestingly, although the aggregate output fluctuated considerably over the sample period, the market structure as measured by the regional HHI was much less volatile (see Figure 1). I believe that the evidence presented on Figure 1 is consistent with the proportional reduction technique of collusion, i.e. when all firms reduce their outputs (relative to the competitive level) by the same proportion. In this case, collusive and competitive market share remain the same and only the aggregate level of output decreases.

All sugar processing plants in Ukraine (regardless of whether they are privatized or not) are united by the association "Ukrtsukor", which represents a mechanism through which government has direct control over production and the wholesale market of sugar. Ukrtsukor allocated output quotas by directly assigning every refinery firm to a sugar beet

[3] According to several studies (e.g. Nivyevsky and Strubenhoff (2005), Zhosan (1999)), most of the Ukrainian sugar factories operate at much less than full capacity levels.

Figure 1: Evolution of regional HHI and total output in 1993-2000



Source: Own calculations, Ukrainian manufacturing register 1993-2000

producing farm(s).[4] Therefore, price control undertaken in this way represents *explicit* collusion.

4 Model

In order to identify collusion one usually assumes a particular objective function for the cartel, e.g. joint industry profit maximization. Then, the empirical version of the cartel's first-order conditions is derived. Most of the previous empirical work relies on game theoretic predictions about three possible competition regimes, i.e. perfect competition (or Bertrand-like scenario), Cournot, or perfect cartel (i.e. monopoly output). Whenever an industry is in one of these regimes, a conjectural variation parameter has clear interpretation. One, however, can rarely observe a pure monopoly outcome in an industry that is known to be collusive. In this case, the parameter estimates are usually interpreted "as if", e.g. $N-$firm industry produces output as if it is an industry with $M < N$ Cournot competing firms. Such interpretation is at best imprecise and can hardly be used to measure the welfare consequences of the collusion. More importantly, the empirical version of the cartel's first order conditions typically makes sense under a fairly strict assumption

[4] In Ukraine, all firms use the same sugar refining technology and the rate of conversion of sugar beets to sugar is known and relatively constant across refining firms.

of symmetric firms.[5]

In Ukraine, there is a particular reason for why joint industry profit maximization is not a reasonable assumption. Cartels often are created under the government umbrella and, hence, immune to the regulations by the antitrust authorities. Such cartels typically have more complex objective functions. For example, social welfare considerations may have nontrivial importance for output decisions.

An alternative to assuming an objective function of a cartel is to assume a way in which collusion is implemented. In particular, I assume that firms use a proportional reduction technique (PR) when the collusive market share of each firm is determined by its market share under a competitive regime and only overall level of output is adjusted. This approach has several advantages. First, with symmetric firms PR would be a natural outcome regardless of whether firms are maximizing joint industry profit or producing any other quantity in the interval between a monopoly and competitive one. Second, under asymmetric firms this is the simplest way of implementing collusion. Further, the resulting distribution of market shares would be observationally equivalent to the competitive case. The HHI would be the same under collusive and competitive regimes and collusion would be harder to detect. Third, the PR is appealing from the standpoint of fairness considerations and possesses some flexibility regarding difference in bargaining power among firms. Note that PR does not necessarily imply that more efficient firms will be favored. Since each of the asymmetric firms has its optimal monopoly output level, overall output could be set in a way that could favor any given firm in the industry.

Assumption 1: *In a collusive regime firms reduce their individual output proportionally to the baseline Cournot quantities*

The assumption about PR collusion technique allows the linkage of collusive outputs to competitive ones through a single parameter that has a straightforward interpretation. The discussion below shows how PR is profitable for all firms in the neighborhood of the Cournot outcome. This implies that there exists a common discount factor that would

[5]Some early models attempt to estimate firm-specific conjectures. Such approach did not get significant acknowledgment in the recent empirical literature on collusion.

sustain collusion in simple grim-trigger strategies.[6]

4.1 Profitability under PR collusive technology

A profit maximizing Cournot competitor's first order conditions (with respect to quantity) are given by

$$P'(Q_t)q_{it} + P(Q_t) - C'(q_{it}) = 0$$

Consider a Cartel, which sets overall industry output to $\bar{Q}_t = Q_t^{Cournot}$ and assigns market shares such that $\bar{Q}_t s_{it} = q_{it}^{Cournot}, \forall i = 1, ..., n$, where s_{it} is market share of firm i. Then the profit of such a cartel member is given by $\pi^m(s_{it}, \bar{Q}_t) = P(\bar{Q}_t)\bar{Q}_t s_{it} - C(\bar{Q}_t s_{it})$ and by construction is identical to the non-cooperative Cournot outcome.

Consider a derivative of this profit function with respect to $\bar{Q}_t$:

$$\begin{aligned}
\frac{\partial \pi^m \left(s_{it}, \bar{Q}_t\right)}{\partial \bar{Q}_t} &= P'\left(\bar{Q}_t\right)\bar{Q}_t s_{it} + P\left(\bar{Q}_t\right)s_{it} - C'\left(\bar{Q}_t s_{it}\right)s_{it} \\
&= C'\left(q_{it}\right) - P\left(\bar{Q}_t\right) + P\left(\bar{Q}_t\right)s_{it} - C'\left(\bar{Q}_t s_{it}\right)s_{it} \\
&= \left(C'\left(q_{it}\right) - P\left(\bar{Q}_t\right)\right)\left(1 - s_{it}\right) < 0
\end{aligned}$$

where the first equality is obtained by replacing $P'\left(\bar{Q}_t\right)\bar{Q}_t s_{it}$ with $C'\left(q_{it}\right) - P\left(Q_t\right)$ and the inequality follows from the fact that $P'\left(Q_t\right)q_{it} = C'\left(q_{it}\right) - P\left(Q_t\right) < 0$.

It is easy to see that in an infinitely repeated game with grim-trigger strategies there exists a common discount factor $\tilde{\beta} \in (0, 1)$ that supports the collusive equilibrium. In particular, from above it follows that $\pi_{it}^m > \pi_{it}^c$ where π_{it}^m and π_{it}^c are collusive and competitive profits respectively. Let $\pi_{it}^d \geq \pi_{it}^m$ denote deviation profit of firm i. Then for

[6] It is worth noting that a cartel controlled by the government may use other punishment schemes to enforce collusion.

the collusive equilibrium to be sustainable the following condition must be satisfied

$$\begin{aligned}
\pi_{it}^d - \pi_{it}^m &\leq \sum_{\tau=t+1}^{\infty} \beta^{\tau-t} \left(\pi_{it}^m - \pi_{it}^c\right) \\
\pi_{it}^d - \pi_{it}^m &\leq \frac{\beta}{1-\beta} \left(\pi_{it}^m - \pi_{it}^c\right) \\
\beta &\geq \frac{\pi_{it}^d - \pi_{it}^m}{\pi_{it}^d - \pi_{it}^c} \in (0,1)
\end{aligned}$$

Hence, $\tilde{\beta} = \dfrac{\pi_{it}^d - \pi_{it}^m}{\pi_{it}^d - \pi_{it}^c}$ would support a collusive equilibrium in simple grim-trigger strategies.

4.2 Recovering optimality conditions

Consider an n-firm industry producing a homogenous product. The industry operates through time indexed by $t = 0, 1, 2, ...$ In every period, firms either compete or collude by employing PR technique. Let q_{it}^m and q_{it}^c denote collusive and competitive quantities respectively. Let $Q_t^m = \sum_{i=1}^n q_{it}^m$ and $Q_t^c = \sum_{i=1}^n q_{it}^c$ denote total collusive and competitive quantities. Then

$$q_{it}^c = Q_t^c s_{it} = \frac{Q_t^c}{Q_t^m} q_{it}^m = \theta_t q_{it}^m \tag{1}$$

where $\theta_t \in [1, \infty)$ and is equal to the inverse of the share of potentially competitive output in period t.[7]

Given the relationship between competitive and collusive quantities it is possible to "restore" individual firms' first order conditions for quantity choice. In particular, in the stage game according to the Cournot scenario firms solve

$$\begin{aligned}
&\max_{q_{it}^c} \left\{P(Q_t^c) q_{it}^c - C_i(q_{it}^c)\right\} \\
&FOC : P(Q_t^c) + P'(Q_t^c) q_{it} - C_i'(q_{it}^c) = 0
\end{aligned} \tag{2}$$

where the FOC above must be satisfied at competitive quantities. If firms illicitly collude we observe collusive quantities, q_{it}^m and Q_{it}^m instead of q_{it}^c and Q_{it}^c. Using the relationship

[7] Upper bound on θ_t depends on the parameters of the cost function. For a simplified analysis see Appendix 3.

(1) I can write (2) in terms of observed quantities (Q_t^m, q_{it}^m) and parameter θ as follows

$$P(\theta Q^m) + P'(\theta Q^m)\theta q_i^m - C_i'(\theta q_i^m) = 0 \tag{3}$$

4.3 Empirical specification

In order to derive empirical version of individual first order conditions in terms of observed variables and parameter θ, I make the following parametric assumptions.

Assumption 2: *The inverse demand function is linear in total quantities and is given by*

$$P(Q_t) = \alpha_0 - \alpha_1 Q_t + \bar{\alpha}_2 \bar{Z}_t + \varepsilon_t$$

where $\alpha_0, \alpha_1 > 0$ *and* $\bar{Z}_t$ *is a vector of demand shifters.*

On the supply side of the market, firms are heterogeneous with respect to their cost functions.

Assumption 3: *Assume that total cost function of firm* i *in period* t *is given by*

$$C_i(q_{it}) = F_i + a_i q_{it}^{\delta}, \delta \geq 1 \tag{4}$$

i.e. cost functions are weakly convex and differ by a firm-specific shift parameter a_i*.*

A similar cost function was used in Porter (1983). Note that weak convexity allows for constant marginal costs, i.e. when $\delta = 1$. This however is unlikely to be found in the data because according to the official statistics sugar refinery firms worked at half-capacities, i.e. 40-45 days a year instead of optimal 90-100. Then marginal cost of firm i is $C_i'(q_{it}) = a_i \delta q_{it}^{\delta-1}$.

Using parametric assumptions on the demand and cost functions, the empirical version of the individual first order conditions can be derived. First, note that due to linearity, $P(\theta Q^m) - P(Q^m) = -\alpha_1(\theta - 1)Q^m$. Second, due to the form of total cost function defined by (4),

$$
\begin{aligned}
C'(q_{it}^c) &= a_i \delta \theta_t^{\delta-1} q_{it}^{\delta-1} \\
&= a_i \delta \theta_t^{\delta-1} \frac{q_{it}^{\delta}}{q_{it}} \\
&= \delta \theta_t^{\delta-1} \frac{C(q_{it})}{q_{it}} = \delta \theta_t^{\delta-1} AVC(q_{it})
\end{aligned}
$$

Then, the first order conditions (3) for each firm can be written in terms of observed (collusive) quantities and price

$$
\begin{aligned}
P(\theta_t Q_t^m) - P(Q_t^m) + P(Q_t^m) + P'(\theta_t Q_t^m)\theta q_{it}^m - C_i'(\theta_t q_{it}^m) &= 0 \\
-\alpha_1(\theta_t - 1)Q_t^m + P_t^m - \alpha_1 \theta_t q_{it}^m - \delta \theta_t^{\delta-1} AVC_{it}^m &= 0 \\
-\alpha_1(\theta_t - 1)Q_{-it}^m + P_t^m - \alpha_1(2\theta_t - 1) q_{it}^m - \delta \theta_t^{\delta-1} AVC_{it}^m &= 0 \\
&\Rightarrow \\
q_{it}^m = \frac{1}{\alpha_1(2\theta_t - 1)} P_t^m - \frac{\theta_t - 1}{2\theta_t - 1} Q_{-it}^m - \frac{\delta \theta_t^{\delta-1}}{\alpha_1(2\theta_t - 1)} AVC_{it}^m &= 0 \\
q_{it}^m = \gamma_{1t} P_t^m + \gamma_{2t} Q_{-it}^m + \gamma_{3t} AVC_{it}^m & \qquad (5)
\end{aligned}
$$

where $\gamma_{1t} = \dfrac{1}{\alpha_1(2\theta_t - 1)} > 0$, $\gamma_{2t} = -\dfrac{\theta_t - 1}{2\theta_t - 1} \geq 0$, and $\gamma_{3t} = -\dfrac{\delta \theta_t^{\delta-1}}{\alpha_1(2\theta_t - 1)} > 0$.

Let the empirical version of (5) be given by

$$
q_{it}^m = \gamma_1 P_t^m + \gamma_2 Q_{-it}^m + \gamma_3 AVC_{it}^m + \epsilon_{it}, \tag{6}
$$

where ϵ_{it} accounts for variables unobserved by the econometrician. Suppose that $\epsilon_{it} = w_i + \xi_t + v_{it}$, i.e. it can be decomposed into time-invariant firm-specific unobservable, w_i, a shock common for all firms that varies across time, ξ_t, and a random variable v_{it} that varies across both time and firms. The first component, w_i, may be unobserved by us but are likely firm-specific factors observed by the cartel. These factors could include differences in technology, the quality of management or location specificity of a particular sugar refinery firm.[8] The second component, ξ_t, stands for the industry-wide

[8]For instance, some firms may have better access to the input and output markets due to better infrastructure or geographic location.

cost shifters, like changes in input prices or taxation, also observed by the cartel. The last term, v_{it}, represents random deviations from the optimality conditions, like errors in the data, potential "miscalculations" of outputs or even random instances of cheating on the optimal quotas. I assume that v_{it} is not observed by the cartel at time when quotas are allocated.

4.4 Identification

The parameter of interest, θ_t, can be recovered from the estimate of coefficient γ_{2t}, i.e.

$$\theta_t = \frac{1 + \hat{\gamma}_{2t}}{1 + 2\hat{\gamma}_{2t}}$$

This sharp result is a consequence of the linearity assumption imposed on the demand function. Note that the accuracy of the parameter estimate depends on both the degree of convexity/concavity in the demand function and the degree of collusion. If collusive output is close to the Cournot level, then this simple first order approximation would be sufficiently precise even for non-linear demand systems. However, the higher the level of collusion, the more important the linearity assumptions becomes. In other words, identification of the structural parameter, θ_t, depends on the functional form assumptions.

In turn, in order to identify parameter γ_{2t} we need to consider several issues. First of all, some components of the error term in (6) are potentially observed by the cartel. This concerns the firm-specific time-invariant term w_i and the common "cost shifter", ξ_t, that varies across time but not across firms. Since these components of the error term ϵ_{it} are potentially observed by the cartel they clearly affect optimal quota allocation. In order to account for the persistent over time w_i component, I use a fixed-effect estimation technique. Since the data is pooled from several regional markets, to account for the region-specific time-varying cost shifter I use sugar beet yield at regional level, which is likely to affect input prices at the regional level. Other time-varying factors that are common across markets are captured by the year dummies. Finally, using observed price as an independent variable in the supply relationship (6) results in a well-known simultaneity problem.[9] To deal with this problem I use real income at regional level, which should influence sugar demand but not supply, to instrument for price.

4.5 Model adjustment for Ukrainian sugar market

The theoretical framework above can be used to identify illicit collusive behavior in an oligopoly with a complex objective function, when the collusion is implemented using a proportional reduction technique. It suggests a meaningful measure of collusion relative to some benchmark conduct scenario. Institutional peculiarities of the Ukrainian sugar refining industry make identification of collusion redundant as the way Ukrtsukor allocates output quotas defines it as a classical cartel. It is conceivable that the sustainability of the cartel was guaranteed by the centralized coordination where sugar beets producing farms were assigned to a particular refinery firms. Hence, the major target of this study becomes to quantify the degree of collusion.

The assumption that Ukrtsukor uses proportional reduction when allocate quotas seems reasonable for several reasons. Given that Ukrtsukor controls prices by allocating output quotas, there are no reasons to use complex collusive techniques that guarantee maximum cartel sustainability (i.e. "market sharing" technique). There is no evidence of inter-firm cash transfers. Besides, all firms produced nonzero output levels in 1993-1998, while each of them operate at much lower than full capacity levels. Hence, the perfect ("optimal") collusive technology was not likely to be implemented. Using market division would necessarily result in dramatic cross-regional price differences, which would not be consistent with the price control functions of the association. Finally, empirical evidence in the Figure 1 is consistent with stable market shares of individual producers even when aggregate output fluctuated considerably.

Interestingly, if the cartel indeed fulfills its price control functions, collusion should be implemented heterogeneously across regional markets. In order to reduce inter-regional price differences, Ukrtsukor should allow regions with greater number of firms to reduce outputs more than in the regions with fewer refinery firms. This suggests a testable

[9]Unobservables (or their distribution) ϵ_{it}, which affect aggregate quantity, affects price through the demand relationship, which results in $cov(P_t, \epsilon_{it}) \neq 0$.

implication that θ_t may vary across regions with different number of firms.

It follows that the most likely implementation of collusion in the Ukrainian sugar refinery market was a combination of market division with proportional reduction technique implemented separately in each market.

4.6 Parameter's value interpretation

An advantage of the suggested framework is that θ_t has meaningful interpretation for the entire range of its possible values. It is equal to the inverse of the share of potential Cournot quantity. Note that the model setup does not define Cournot as a low bound on competitiveness. Instead, firms could choose price competition in which case $\theta_t < 1$. Some numerical examples might be useful. Assume for simplicity that firms are symmetric with a constant marginal cost of c. Let inverse demand be linear, $P(Q) = \alpha_0 - \alpha_1 Q$. In this case, Cournot output per firm is given by

$$q_i^c = \begin{cases} \dfrac{\alpha_0 - c}{(n+1)\,\alpha_1}, & \text{if } \alpha_0 - c \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

and total output for the industry is

$$Q^c = \frac{n}{(n+1)} \frac{\alpha_0 - c}{\alpha_1} \tag{7}$$

Monopoly output (also total industry profit maximizing output) is given by

$$Q^m = \frac{\alpha_0 - c}{2\alpha_1} \tag{8}$$

and output per cartel member

$$q_i^m = \frac{1}{n} \frac{\alpha_0 - c}{2\alpha_1} \tag{9}$$

Finally, total Bertrand output when price is equal to marginal cost is

$$Q^b = \frac{1}{\alpha_1} (\alpha_0 - c) \tag{10}$$

with per-firm output given by

$$q_i^b = \frac{1}{n\alpha_1}(\alpha_0 - c) \tag{11}$$

Then the following ratios are easily computable

$$\frac{Q^c}{Q^m} = \frac{q_i^c}{q_i^m} = \frac{2n}{n+1} \tag{12}$$

$$\frac{Q^c}{Q^b} = \frac{q_i^c}{q_i^b} = \frac{n}{n+1} \tag{13}$$

Table 1 below summarizes different values of the parameter depending on the degree of competition chosen. Hence, the estimated parameter values suggest type of competition

Table 1: Hypothetical values of parameter θ for various conduct scenarios

Type of competition	θ	% of Cournot
Perfect cartel ($n = 2$)	4/3	75
Perfect cartel ($n = 3$)	3/2	67
Perfect cartel ($n = 10$)	20/11	55
Cournot ($n = 2, 3, 4, ...$)	1	100
Bertrand ($n = 2$)	2/3	150
Bertrand ($n = 3$)	3/4	133
Bertrand ($n = 10$)	10/11	110

and could be used to compare observed outcome to a hypothetical Cournot scenario.

5 Data

The data for the current project was composed from several sources (see summary in Table 2). Regional information on the sugar beet yield, overall production of sugar beets, and conversion rates of sugar beets to white sugar were obtained from online databases at *http://www.minagro.gov.ua/* (Ministry of Agrarian Policy of Ukraine). Real income and the dynamics of real wages across regions were retrieved from the online databases at *http://www.ukrstat.gov.ua/* (State Statistics Committee of Ukraine). White sugar output in natural units by regions was taken from the bulletin of State Statistics Committee on the regional manufacturing output levels (1990-2000). Firm-level data on revenues, capital stock, variable costs of production, power installed/used, etc. came from the

Ukrainian manufacturing enterprise register (1993-1998). Extension of the Ukrainian manufacturing enterprise register to 1999-2000 also known as Legis-Plus Fenix dataset provides information on these firm-level variables for later periods.

Table 2: Data sources

Source	Location
Ministry of Agrarian Policy of Ukraine	*http://www.minagro.gov.ua/*
State statistics committee of Ukraine	*http://www.ukrstat.gov.ua/*
Bulletin of SSC on regional production	hardcopy
Ukrainian manufacturing enterprise register	electronic DB
Legis-Plus Fenix dataset	electronic DB

There are several things worth noting. First, data on individual firms consists of 185 continuous establishments in 1993-1998. According to the official statistics, there were 190 sugar-refining firms at the beginning of the period, so the set of firms is fairly representative. These 185 sugar-processing firms are located in 19 regions of Ukraine. Second, the data on sugar prices at the regional level are not available. To construct the variable I used data on total revenues by region of 185 sugar-refining firms available in the manufacturing enterprise register. Using overall quantity of sugar produced at regional level, I computed the approximate price of sugar from the available variables. All variables that are measured in monetary units are expressed in USD 1995 prices. Data summary statistics is presented in the Table 3.

Table 3: Data summary statistic, 1993-2000

Variable	min	max	mean	median	std.dev.
q_{it}, tt	0.00	227.30	15.20	10.69	17.29
Q_t, tt	20.60	535.00	213.45	192.40	126.87
P_t, \$ per t	144.69	344.47	217.63	217.50	41.53
SBY, tt	84.80	321.60	188.25	191.10	38.04
RY, \$	37.13	78.00	56.49	55.15	8.22
$\#firms$	2.00	38.00	17.28	16.00	11.74

6 Estimation results

Table 4 summarizes results of the overall regression. Due to the simultaneity problem, price is negatively correlated with the supply shifter. Using a one-variable regression shortcut one can expect that the OLS parameter estimate would underestimate the true coefficient on price. As it follows from Table 4, both OLS and fixed-effect (FE) estimators without instrumental variables (IV) result in negative point estimates of the price coefficient (as it is shown in Section 4, $\gamma_1 > 0$). Both point estimates of the price coefficient in the IV specifications are positive. The remaining coefficients have expected signs. In particular, higher sugar beets yeild (SBY) at regional level has positive effect on individual quantity because it reduces input prices. According to the model, γ_{3t} has non-positive expected sign, which is confirmed by the estimates from the overall regressions.

Estimates of γ_{2t} suggest that on average firms produce at a level of about 0.89 to 0.95 of potential Cournot quantity.[10] The high statistical significance of γ_{2t} allows rejecting the null hypothesis of competition in the sugar refining industry of Ukraine. The magnitude of the findings in an economic sense requires some discussion. If Cournot competition is a target for the sugar industry conduct, then prices would be about 6 to 12 percent lower with a price elasticity of demand of -0.89 (this suggested by the aggregate supply-demand system estimation reported in Table 8 below).

On the other hand, if price competition is socially desirable, then losses due to collusive behavior are much higher. For instance, Table 5 provides a simplified analysis of potential price reductions due to competition that makes prices equal to the marginal costs. Here I assume symmetric firms and average underproduction of 5% relative to Cournot level. Price elasticity of demand is assumed to be -0.89.

In order to trace the dynamics of market power in the sugar industry I re-estimated the model by allowing the monopolization parameter to vary across time. Note that in this case coefficients on price and average variable cost must vary across time as well because θ enters reduced form parameters in (6). Table 6 presents the estimation results.

[10] Note that even though within (FE) IV specification is the most robust one, it also takes away a lot of variation in the data.

Table 4: Overall regression results, 1993-2000

Variable	OLS (1)	IV (2)	FE (3)	FE, IV (4)
P	-0.046**	0.651	-0.021	0.201
(s.e.)	(0.021)	(0.458)	(0.018)	(0.290)
Q_{-i}	-0.100***	-0.100***	-0.048***	-0.047***
(s.e.)	(0.010)	(0.016)	(0.009)	(0.016)
% Cournot	0.89	0.89	0.95	0.95
SBY	0.111***	0.253***	0.072***	0.117
(s.e.)	(0.024)	(0.098)	(0.020)	(0.076)
AVC	-0.161***	-0.164	-0.137***	-0.138**
(s.e.)	(0.031)	(0.117)	(0.028)	(0.070)
$const$	47.648***	-149.779	25.894***	-37.947
(s.e.)	(8.739)	(126.683)	(6.941)	(81.907)
Reg. Dum.	yes	yes	no	no
Year Dum.	yes	yes	yes	yes
Observations	1412	1412	1412	1412
Num. of firms	179	179	179	179

First stage regression results ($P_t = ...$); R^2=0.79

Const.	RY	SBY	Year dummies	FE
223.6***	1.102**	-0.206***	yes	yes
(26.134)	(0.436)	(0.029)		

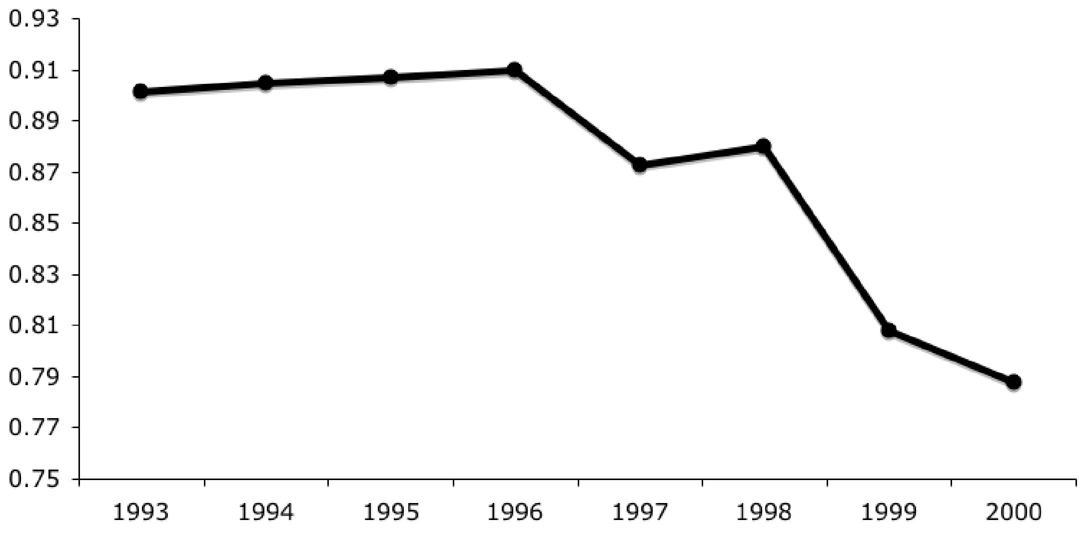
** significant at 10%; ** significant at 5%; *** significant at 1%*

Table 5: Counterfactual experiment, Bertrand assumption

# firms	# reg.	$\%Q \Uparrow$	$\%P \Downarrow$
2	3	55.00%	61.80%
3	1	38.33%	43.07%
4	2	30.00%	33.71%
5	2	25.00%	28.09%
6	1	21.67%	24.34%
9	1	16.11%	18.10%
10	1	15.00%	16.85%
11	2	14.09%	15.83%
12	1	13.33%	14.98%
16	2	11.25%	12.64%
20	1	10.00%	11.24%
38	1	7.63%	8.57%

Similar to the overall regression results, all coefficients have expected signs. The estimates of γ_{2t}, which are used to compute the PR parameter θ_t are very precise in statistical sense. Estimated percents of Cournot quantity for each year are described on Figure 2.

Figure 2: Evolution of market power in 1993-2000



Source: Estimation results in Table 6

The major conclusion is that the degree of monopolization was moderate in 1993-1996 with slight increase in 1997 and considerable increase in 1999 and 2000. A possible explanation could be given in terms of two effects, both working in the same direction.

Table 6: Time-specific parameter values, FE IV, 1993-2000

Year	Price	QMI	% Cournot	AVC
1993	0.702*	-0.090***	0.90	-0.327
(s.e.)	(0.379)	(0.023)		(0.511)
1994	0.312	-0.087**	0.90	-0.066
(s.e.)	(0.436)	(0.034)		(0.058)
1995	0.786**	-0.085***	0.91	-0.637
(s.e.)	(0.333)	(0.027)		(1.683)
1996	0.230	-0.083***	0.91	-0.732***
(s.e.)	(0.338)	(0.031)		(0.158)
1997	0.157	-0.113**	0.87	-0.077
(s.e.)	(0.348)	(0.053)		(0.327)
1998	0.132	-0.107**	0.88	-0.623*
(s.e.)	(0.354)	(0.048)		(0.326)
1999	0.277	-0.161***	0.81	-0.373
(s.e.)	(0.321)	(0.057)		(0.258)
2000	0.188	-0.175***	0.79	-0.333***
(s.e.)	(0.378)	(0.059)		(0.100)
SBY	0.121			
(s.e.)	(0.104)			
Cons	-146.449			
(s.e.)	(105.980)			
Year Dum.	yes			

** significant at 10%; ** significant at 5%; *** significant at 1%*

The first effect is related to the price control measures undertaken by the government. In the early years of hyper-inflation, prices of the essential goods were under careful control by the government, which possibly prevented Ukrtsukor from excessive monopolization. In 1997, with the introduction of a new currency and relative stabilization of monetary policy, government control over sugar prices might have become less restrictive. A slight increase in the "competitiveness" is observed in 1998, which may be related to currency crises and tighter control over food prices in this year.

Another explanation is related to the regulation of firms' exit from the industry. In the early years of transition period, Ukrainian bankruptcy procedure was not developed yet and many non-viable firms continued their operations. Besides, the government explicitly supported decaying firms viewing this support as a kind of social protection of the workers. Given the great asymmetry between firms difference in costs across firms may restrain Ukrtsukor ability to monopolize the market. Later in the period, many sugar refinery firms were allowed to shut down, which most likely reduces asymmetry amonth the remaining producers. This, in turn, enhanced collusive possibilities.

It is worth noting that collusion in the downstream market had an adverse effect on the upstream market, i.e. producers of the sugar beets. For instance, growing sugar beets was acknowledged to be less profitable than growing alternative agricultural products (see Cramon-Taubadel et al. (2001)). The effect of collusion in the downstream market could result not only in increased monopsony power but also may have directly harmed sugar beet suppliers as many of them at the same time were consumers of the refined sugar through toll and barter transactions. The gradual exit of the sugar beet producers from the market by switching to alternative agricultural products increased input prices for sugar refinery firms. This increase in the costs in turn reduced profits (increased losses) of all sugar refinery firms, thus increasing incentives to exit the industry. In other words, in 1993-1997 monopolization gradually (but persistently) eroded cartel's resource base by forcing sugar beet producing agricultural firms to change specialization. In 1998-2000 this process, exacerbated with the consequences of currency crisis, caused significant changes in the market structure in some of the regions. These changes nevertheless allowed the cartel to reduce asymmetry of its members and hence to increase the degree of monopolization.

One of the hypotheses of this study is that Ukrtsukor has a complex objective function, which in addition to profit-maximization also included price control. A testable implication of this hypothesis is that collusion was implemented in a heterogeneous across regions way, which would reduce cross-regional price differences.

To test for this possibility I split the sample into three groups: (1) regions with less than 10 refinery firms, (2) regions with 10 to 15 firms, and (3) regions with more than 15 producers. Estimation results for each of the sub-samples are presented in Table 7.

Table 7: Region-specific parameter values, FE IV, 1993-2000

	Number of firms		
	< 10	10 to 15	> 15
P	-0.565*	1.578**	1.514*
(s.e.)	(0.329)	(0.646)	(0.907)
Q_{-i}	0.033	-0.057*	-0.187***
(s.e.)	(0.072)	(0.032)	(0.068)
% Cournot	1.03	0.94	0.77
SBY	-0.093	0.411***	0.793**
(s.e.)	(0.086)	(0.124)	(0.330)
AVC	-0.636*	-0.297	-0.062
(s.e.)	(0.374)	(0.206)	(0.160)
const	180.344*	-436.645**	-451.353*
(s.e.)	(94.871)	(181.784)	(263.221)
Year Dum.	yes	yes	yes
Observations	352	351	709
Num. of firms	45	44	90

** sign. at 10%; ** sign. at 5%; *** sign. at 1%*

Results are consistent with the hypothesis. In particular, regions with less than 10 sugar refinery firms appear to produce at or even below the Cournot level (according to the point estimate, which is not statistically different from zero). In the regions with 10 to 15 firms, monopolization was at 0.94 of the Cournot (and coefficient is significant at 10 percent level). In the regions with a large number of refineries degree of monopolization is significant in both statistical (at 1 percent level) and economic sense, i.e. 0.77 of Cournot level. Hence, empirical evidence suggests that Ukrtsukor attempted to control the price differential across regions by implementing collusion in a non-uniform (across regions) way.

Finally, it might be interesting to compare estimates of monopolization obtained using a structural model developed in this study with the results produced by existing conjectural variation models. For comparison, I choose Bresnahan-type identification due to its estimation simplicity and similarity to the present model.[11] Unfortunately, Bresnahan-type identification requires availability of data for demand rotators. Justification of particular choice variables may be crucial to guarantee proper identification of the conjectural variation parameter. I choose the percent of sugar beets produced by individual households as a candidate for the demand rotator (Z). It is worth noting that the data on the Z variable was unavailable for 2000. Therefore, I have to restrict time-series observations in the data to 1993-1999. The coefficient of interest is one at the variable constructed as $\mathbf{Q}*(\alpha_1 + \alpha_3\mathbf{Z})^{-1}$. In the setup suggested by Bresnahan, this coefficient, λ, takes a value of 1 for a perfect cartel, 0 for perfectly competitive markets, and $\frac{1}{N}$ for Cournot oligopoly, where N denotes number of firms. The expected sign of the coefficient is negative; therefore, one should consider a value of $-\lambda$ in relation to the theoretically predicted outcomes. The details of the underlying theoretical model and estimation algorithm can be found in Bresnahan (1982). Table 8 summarizes the estimation results. Interestingly, the estimate of the conjectural variation parameter is -0.075, which implies that Ukrainian sugar industry behaved "as if" it is 13 Cournot competitors. Given that the mean and median number of firms in the regions are 17 and 16 respectively, this implies a slight degree of monopolization, which is consistent with the findings of the proposed structural model.

7 Conclusions

In this study I estimate the degree of collusion in the sugar refining industry of Ukraine. I develop a structural model of a cartel with an unknown objective function under the as-

[11] I use aggregate demand estimation results to compute price elasticity, which turns out to be about -0.89

Table 8: Bresnahan-type identification, 1993-1999

	Demand (Q), GMM	Supply (P), GMM
P	-0.731***	
(s.e.)	(0.166)	
$\mathbf{P} * \mathbf{Z}$	-17.715***	
(s.e.)	(6.059)	
Z	6.810***	
(s.e.)	(2.227)	
RY	18.392***	
(s.e.)	(2.771)	
Q		0.482**
(s.e.)		(0.200)
$\mathbf{Q}* \left(\alpha_1 + \alpha_3 \mathbf{Z}\right)^{-1}, \lambda$		-0.075*
		0.042
SBY		-1.380***
(s.e.)		(0.198)
Size		-0.316***
(s.e.)		(0.043)
K		0.063***
(s.e.)		(0.009)
const	-351.647**	-138.185
(s.e.)	(167.442)	(101.539)
Regional & year Dum.	yes	yes

** significant at 10%; ** significant at 5%; ***significant at 1%*

sumption of a proportional reduction collusive technique. The estimation results confirm a statistically and economically significant level of monopolization in the sugar industry. These findings are consistent with the results obtained using Bresnahan (1982) identification strategy.

According to the estimates, output of sugar refining firms was between 0.89 and 0.95 percent of the Cournot quantity. Under a counterfactual scenario of non-collusive quantity competition, white sugar prices would have been 6 to 12 percent lower than observed in the data. Competition in prices would suggest a more dramatic price decrease ranging between 9 and 62 percent depending on the number of firms in the region.

Dynamically, monopolization of sugar industry was relatively stable in 1993-1998 with a significant increase in market power only in 1999 and 2000. This increase can be explained by the reduction in the number of firms in the industry and less severe control over sugar prices by the Ukrainian government.

Finally, I found evidence that the Ukrtsukor association implemented collusion in a heterogeneous way across markets. The degree of monopolization was considerably higher in regions with a larger number of firms. This is consistent with the hypothesis that the cartel attempted to reduce the cross-regional price differentials.

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