Staff Paper

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Abstract. The orange juice market is a "weather market" because of its high geographical concentration and the natural characteristics of orange trees. A few hours of a freeze in Florida is enough to cause a supply shock to the orange juice market. How do oligopolistic firms react to supply shocks – do they become more collusive or more competitive? This paper empirically examines the proposition and finds that the level of market power of orange juice firms decreases significantly, and the market becomes more competitive during supply shocks even though prices rise.

Key words: market power, supply shock, orange juice market

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1. Introduction

The orange juice market is characterized by high concentration not only because nearly 90 percent of the orange juice in the US market is produced in Florida, but also because few associations and firms control the supply chain. In addition, the natural characteristics of orange trees and freezes make supply shocks possible and cause price fluctuations in the orange juice market (Roll, 1984). How do oligopolistic firms react to supply shocks – do they act more collusively or more competitively? In other words, how does the firms' market power change while prices rise due to supply shocks from a freeze? Market power is usually consider to be manifested when firms charge higher prices than prices in competitive markets; however, a higher price does not necessarily mean higher market power, since other factors such as supply shocks could shift prices. Few scholars disagree with the statement that a firm will charge a higher (than competitive market) price if a firm is a monopoly in a market. According to this logic, many markets are served by a small number of firms with non-negligible market power (Tirole et al., 1988). However, not all models support the proposition. In the Cournot model of non-cooperative oligopolistic competition on quantity, oligopolistic firms tend to charge a higher-than-competitive-market price and exhibit some market power. But in the Bertrand mode of non-cooperative oligopolistic competition on price, firms compete in prices and they have no reason to cooperate with each other if they want to maximize

their profit; the market would be a perfect-competition market even though just two firms share the market.

In the early empirical "structure, conduct, performance" (SCP) studies in the 1950s to the 1970s on oligopolies' market power, researchers used industry-level data to draw inferences about the relationship between the structure of an industry (in particular, its concentration) and its profitability. However, as has been frequently noted in the past decade, the use of that methodology is on the wane because it lacks rigorous microeconomic foundations.

The next generation of empirical studies began in the early 1980s. The new empirical industrial organization (NEIO) school started with researchers' use of structural econometric modeling to identify the oligopoly solution to distinguish Cournot, Bertrand, and collusion situations (Bresnahan, 1982). Porter (1983) employed this framework to study the cartel stability of JEC (the Joint Executive Committee, a 19th century railroad cartel) from 1880 to1886. His model tried to distinguish what caused the unexpectedly low prices: deviation from collusion or demand shocks. However, the study did not explain why the firms deviate from previous collusion. Bresnahan (1987) examined the price war in the (concentrated) American automobile industry in 1955 and found collusion in 1954 and 1956, but competition in 1955. But he did not explain the latter, thus what triggered the price war in 1955. The common points of this class of studies are: (1) specifying and estimating structural demand and supply equations and econometric detection of market power that depends on estimation of a term for the demand elasticity in supply functions.(Bresnahan, 1987); (2) the assumption of Cournot competition during the cooperative periods and Bertrand competition otherwise (in non-

cooperative periods); identification of these two periods is a prerequisite to estimating market power; (3) failure by most of the studies to give reasons why the firms deviate from the equilibrium (collusive or competitive).

In the past decade, estimating supply and demand systems with product differentiation based on the Bertrand model became the "heart and soul" of NEIO research. This methodology started from BLP (Berry, Levinsohn and Pakes,1995) developing techniques to estimate demand and cost parameters for a class of oligopolistic differentiated products in US automobile markets. The key idea is the derivation of the demand function from the consumers' indirect utility function for a small number of product characteristics to avoid the requirement of too many observations to estimate demand functions. Nevo (2001) employed the BLP framework to measure market power in the American ready-to-eat cereal industry and found that firms' behavior in the industry is consistent with a non-collusion regime despite the high price-cost margin (PCM). The reasons for a high PCM are the firms' abilities to maintain a portfolio of differentiated products and influence the perceived product quality.

Sutton (1991) notes that producing differentiated products means a single firm could have some monopoly power in a particular product market (differentiated in space, brand, taste, or quality). Substitution goods would restrict the level of the market power if product differentiation is not so large (like different brands of orange juice). Thus, elasticities of substitution are crucial to a firm's market power. For a firm to maintain a portfolio of differentiated products, it must reduce the elasticities of substitution of its rivals' products and gain more power in the particular market. The more a firm can differentiate its products from others, the higher market power the firm achieves.

Meanwhile, firms could get even higher markups if they agree to collude in an aggregate market (including many differentiated but similar products[2]). However, distinguishing whether the markup increase is from product differentiation or from collusion is not straightforward.

In this paper, we focus on supply shocks to identify the market power change in the orange juice market[3] since potential collusion could be broken up or weakened during the supply shocks. The main difference between this study and Porter's study is that we consider freezes as implicit indicators and reasons for changes in firms' behavior. In addition, we believe firms would deviate from the Nash-Cournot equilibrium only if something happened like a freeze[4]. We focus on estimating the market power change, while in Porter's study the market power level is constant over the collusive regime (θ) and the non-collusive regime (0). We estimate market power change by introducing the interaction term of freeze and an indicator for market power, controlling for other factors. We identify the change and get our main conclusion: the level of market power in the

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[2] For example, the fruit juice market includes orange juice, apple juice etc.; they are different but similar. The products are always different: different brands, locations, package, flavor, materials even timing. Each differentiation could be taken advantage of by firms to gain quasi-monopoly power in a specific market.

[3] Here, we assume the orange juice market is a homogenous market and the difference between the different oranges for processing is relative little.

[4] We also assume the supply shocks only come from the freezes. However, other market circumstance changes (for example tariff reduction) could cause supply shocks; however, we assume the effect of supply shocks is relatively small compared with freezes.

orange juice market decreases significantly during the supply shocks even though prices rise. The main difficulty in estimation of the simultaneous functions is they are nonlinear in endogenous variables. We use 2SLS to estimate the simultaneous functions and get consistent estimators.

2. The Orange Juice Industry

The US is the number two producer, and the number one market of orange juice in the world; it accounts for 40% of world consumption. The second largest market is Europe, accounting for 30% (USDA, 2004). US consumers mainly drink their oranges: in 2000/01, about 85% of all oranges in the United States were consumed as juice. Orange juice is 60% of all fruit juice consumed in the US. 80% of oranges produced go into juice. In turn, Florida makes 80% of that juice (Pollack et al. 2003). Around 95% of orange production in Florida is purchased by processors to make juice (Florida Department of Citrus, 2003).

Since orange juice production is highly concentrated geographically, the supply of orange juice is very sensitive to the weather of the production area (southern and central Florida). Orange trees can not withstand a few hours of hard freezing temperatures[5]. From 1835 to 1996, there were 36 recorded freezes in Florida, including four catastrophic freezes (1835, 1895, 1899, and 1962), 20 severe freezes, and 12 moderate freezes (Attaway, 1997, 2004). Most freezes caused supply shocks. For instance, in 1895, almost all orange trees in Florida were killed to the ground on February 8, production declined

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5. Hard freezes are defined as 3 hours or more of temperatures below 27°F.

by 97% and 16 years passed before it recovered to its previous level (Roll, 1984). The worst freeze in the past century occurred in 1962, when Florida orange production dropped from 113.4 million boxes (1961-1962) to 55.1 million boxes (1963-1964) and orange production had not recovered to previous level until 1967[6]. Several serious freezes occurred in the 1980s[7] and caused the orange production to decrease from 206 million boxes (juice production, 1200 million gallons) in the 1979 to 104 million boxes (juice production, 622 million gallons) in 1984 (USDA, 2003).

Orange processing into juice is concentrated economically, while the orange farming sector is concentrated organizationally. There were 7,653 citrus farms in Florida in 2002. Most of the growers are members of a few associations such as FCM (Florida Citrus Mutual) which represents Florida citrus growers on issues affecting their business. FCM is the largest and exerts a strong influence on the conditions of the market. FCM started in 1948 with 6000 members; in 1949/50 it established minimum orange prices, but this price fixing was denounced as a violation of the spirit of the Sherman Antitrust Act in 1952, and thenceforth it shifted its role to providing market information and forecasts, and lobbying at state and federal levels on behalf of growers. In 1963 and 1970, FCM was instrumental in preventing tariff reductions on oranges, amid rising competition from Argentina and Brazil. In the 1970s FCM negotiated for a higher price for juice with the Nixon Price Commission during the wage-price controls. In the 1980s and 1990s FCM continued this active role. For example, in 1987 FCM convinced the US Department of

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[6] Orange production recovery after hard freezes usually takes 3-7 years.

[7] Hard freezes occurred in 1983, 1985, 1989.

Commerce that Brazil had been dumping FCOJ in the US market. FCM lobbied to maintain tariffs in NAFTA and GATT in the late 1980s and 1990s (www.flcitrusmutual.com).

By contrast, there were 18 processors in Florida in the 2000-2001 season (Spreen and Fernandes, Jr., 2000). To the extent processors cooperate, it offsets FCM (growers) market power, and vice versa. Among the processors, bulk processors dominate the market; the other kind of processors are called marketing processors which buy bulk juice and pack it under their own label. The next stage of the supply chain is shipping bulk "frozen concentrated orange juice" (FCOJ) (a product form introduced in the mid 1940s) to the local packers which then identify and ship to targeted markets. Before packing, the concentrated juice is usually reconstituted by adding the same amount of water. Then the distributors are responsible for shipping the packaged juice to wholesalers or retailers. The other kind of juice, "not from concentrated juice" (NFC) (introduced in the mid 1990s), usually is packaged in producing areas and shipped to wholesalers and retailers directly. The cost of shipping FCOJ is much cheaper than shipping NFC[8], so it is not surprising that NFC is more expensive than FCOJ.

The industry is quite concentrated at the wholesale and retail levels (Binkley et al. 2002). Many grocery marketing areas had four-firm concentration ratios near or above 90 percent in both the wholesale and retail stage of the grocery marketing system.

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[8] Most orange juice is transported in the form of bulk FCOJ to packing plants throughout the United States, since shipping volumes are 5-6 times smaller with concentrate than with reconstituted juice.

A final contextual point is that the industry is protected by a tariff. It was introduced in the early 1930s as a part of the Smith-Hawley Act. It successfully prevented the foreign (mainly Brazilian) orange juice from entering the US market; that tariff is under fire by the Brazilians in FTAA and WTO negotiations. In 2004 the tariff level was 29.7 cents per SSE gallon for FCOJ and 17 cents for NFC (Hart, 2004)

3. The Model

In the very short term, in the space of time of a supply shock and its immediate aftermath, cost efficiency and product differentiation are assumed to be fixed, and so one could not posit that market power could change based on the efficiency or differentiation factors. However, the firms' behavior (more collusive or more competitive) could change because of supply shocks. We can identify the firms' reaction by specifying the proper econometric model based on official time series data. We construct a simultaneous demand and supply model based on Bresnahan (1982) to reflect the structure of the orange juice market by using yearly price and output data.

Let us suppose that demand and marginal cost are linear in the industry. Denote the period t by subscript t. The demand function is assumed to be a linear function of prices and total income:

(1) Demand function: $Q_t = a_0 + a_1 P_{1t} + a_2 Y_t + a_3 P_{1t} P_{3t} + a_4 P_{2t} + a_5 P_{3t} + \varepsilon_t$

where Q_t denotes orange amount processed in Florida each year, P_{1t} is the average on-tree price of processing oranges in Florida each year (the price being generally a per box price for fruit which does not include costs of harvesting and transporting to the packing house). P_{2t} denotes average on-tree price of fresh oranges using oranges in California[9], P_{3t} denotes the price of grapefruit for processing in the US. Yt denotes the real GDP in US each year. ε_t is a zero mean stochastic term.

The key issue here is that P_{3t} (an exogenous variable) enters interactively with P_{1t}, so that a change in Y and P_{3t} both rotates and vertically shifts demand, so it makes λ to be identified in the supply function (Bresnahan, 1982).

Let us suppose the marginal cost of producing oranges for processing is a linear function of quantity, weather, and the tariff[10].

(2) $MC_t = \beta_0 + \beta_1 Q_t + \beta_2 W_t + \beta_3 T_t + \eta_t$

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[9] In the 2003 season, 83% of oranges in California were fresh-use oranges, versus 5% in Florida. Overall, in the US, 23% of oranges are consumed fresh, while 77% of oranges are processed for juice. We consider fresh-use oranges in California and grapefruit for processing in the US are substitution goods for orange juice.

[10] Here we extend the demand and supply for processing oranges to demand and supply of orange juice. The difference between these two is just the mechanical processing procedure. The ratio of transforming from orange to juice is assumed to be constant (just for interest, that ratio happens to be roughly 2:1).

Here, W_t is a dummy variable which denotes hard freezes, 0 means no hard freeze, 1 means hard freeze. Tt denotes the tariff level on imported frozen concentrated orange juice. η_t is also a zero mean stochastic term.

From equation (1), we get

(3) $MR = P_{1t} + \partial P_{1t}(Q_t) / \partial Q_t \cdot Q_t = P_{1t} + Q_t / (a_1 + a_3 P_{3t})$

From the Cournot and Bertrand Nash equilibrium model, combining the equation (2) and equation (3), we get

(4) $P_{1t} + \lambda_t Q_t / (a_1 + a_3 P_{3t}) = \beta_0 + \beta_1 Q_t + \beta_2 W_t + \beta_3 T_t + \eta_t$

Here λ indicates the level of market power, $\lambda = 0$, means firms compete in a Bertrand model, perfect competition. $\lambda = 1$ implies monopoly, $\lambda = 1/N$, implies N firms compete in a Cournot model.

We use Q^* to denote the term $Q_t / (a_1 + a_3 P_{3t})$, and introduce the interaction term WQ^* to capture the change of market power because of freezes. The equation (4) then becomes

(5) $P_{1t} = -\lambda_1 Q_t {}^* + \beta_0 + \beta_1 Q_t + \beta_2 W_t - \lambda_2 W_t Q_t {}^* + \beta_3 T_t + \xi_t$

Thus, when a supply shocks occurs, $\lambda = \lambda_1 + \lambda_2$, Otherwise, $\lambda = \lambda_1$. By introducing the interaction term of supply shocks and Q^*, we can estimate the market power change

during the supply shock, so we identify how the firms react to supply shocks, whether more collusive or competitive even though prices increase.

4. Data and Estimation

4.1. Data

The prices and output data from 1946 to 2003 come from the Florida Agricultural Statistics Service (FASS), Citrus Summary (various years) published by the Florida Department of Citrus. The consumer price index (CPI) was used to deflate the prices and GDP. The Summary statistics for the main variables are listed in Table 1, with main points as follows.

The quantity of oranges for processing increased in a general trend even though it varied dramatically over the sample period because of freezes and demand. The amount increased by four times in the past five decades while the bearing acreage increased nearly twice, thus suggesting that half of the production increase is from productivity increases, such as from technology adoption. After the 1962 catastrophic freeze, orange output decreased to half of previous level; a similar situation occurred after the 1980s several hard freezes. The major trend of the deflated price is downward in recent years, mainly reflecting imports of cheap orange juice bringing downward pressure on prices while the juice tariff was reduced step by step. In the 1930s, the citrus tariff level was 70 cents per single strength equivalent (SSE) gallon on imported citrus juice. By 2004, the level was only 29.72 cents. So the real tariff level today is just 3% of the tariff in 1930 if we consider the inflation factor.

Here we should add more information about the pattern and levels of freezes. The freeze information comes from the "West Central Florida Freezes History" (NOAA, accessed 2005) in which hard freezes are defined as three hours or more of temperatures below 27°F and "A history of Florida citrus freezes" (Attaway,1997). In general, a widespread killing freeze is defined as several hours of readings below the mid 20s, relatively low humidity values sufficient to prevent frost formation, and little or no temperature difference between flat and hilly terrain. In the "West Central Florida Freezes history", five hard freezes (1962, 1977, 1983, 1985, and 1989) were listed. Fourteen hard freezes and six soft freezes were listed by Attaway (1997), and Attaway (2004) lists the six years with most destructive January freezes. But it did not mean freezes just affected the production of these years - because the recovery of orange trees requires 3-7 years. So the years affected by freezes are even more. However, moderate freezes did not decrease the orange production for juice, on the contrary, soft freezes could increase juice orange supply a little bit because the quality of fresh use oranges became worse, and what would have gone for fresh (higher quality fruit) instead is processed. Since most oranges in Florida are for juice, soft freezes are not regarded as supply shocks to orange juice production.

4.2. Identification and Estimation

From the empirical framework, we construct simultaneous equations to reflect the demand and supply in the orange juice market.

(5) Demand: $Q_t = a_0 + a_1 P_{1t} + a_2 Y_t + a_3 P_{1t} P_{3t} + a_4 P_{2t} + a_5 P_{3t} + \varepsilon_t$

(6) Supply: $P_{1t} = -\lambda_1 Q_t^* + \beta_0 + \beta_1 Q_t + \beta_2 W_t - \lambda_2 W_t Q_t^* + \beta_3 T_t + \xi_t$

Since the simultaneous functions include the interaction term of endogenous variables (P1, Q*) and exogenous variables (P3 and W), the functions become non-linear functions in endogenous variables even though they are still linear in parameters. Also, we may treat the interaction terms as new endogenous variables (Wooldridge, 2001). These make the identification and estimation more complicated than the usual linear simultaneous equation models. However, treating interaction terms as new endogenous variables does not mean we have to get more exclusive exogenous variables to make the equations identified. According to Fisher (1965), we can get the equations identified by applying rank condition to the original system without increasing the number of equations. If the rank conditions are satisfied, the system is identified. According to this principle, Wooldridge (2001) shows that a model with interactions between exogenous variable and endogenous variables can be identified when the model without the interactions is identified (Wooldridge, 2001). So our simultaneous equations are identified even just having one exclusive exogenous variable in each equation. Essentially, we have three exogenous variables: Y, P_2, and P_3 in the demand function, which make the supply function identified. We have two exogenous variables W and T in the supply function which make the demand function identified.

To non-linear simultaneous functions in endogenous variables, we should apply the instrumental variable procedure directly to the two equations. Otherwise, we might make the mistake called a "forbidden regression" which involves replacing a nonlinear function of an endogenous explanatory variable with the same nonlinear function of fitted values from the first stage estimation. The forbidden regression attempts rarely produce

the consistent estimation in nonlinear equations (Wooldridge, 2001). However, the choice

of instruments for non-linear in endogenous variables is different from the usual linear

functions. After Wooldridge (2001), we employed instruments such as the interaction

term of P_2 and P_3 in estimating the demand function and P_2P_3, P_3^2 and Tax^2 in estimating

the supply function. The results are in Table 3.

Before applying 2SLS, we tested the validity of instruments variables for each

equation; these instrument variables all significantly correlated with targeted endogenous

variables after netting out other variables' effects. Thus, they are proper instrument

variables for estimating the simultaneous equations.

5. Results and Interpretation

Table 3 lists the 2SLS estimation results and marginal effects of the main

variables. The objective of this study is to find out how the firms react to supply shocks.

So the most interesting estimators are λ_1 and λ_2, the estimators are 0.82 and -0.53

respectively. The t test of them both reaches 1% significant level.

Thus, without the supply shock, the average market power of the growers

association is 0.82 over the sample period (1946-2003); in other words, the associations

(like FCM) of growers have heavy influence in the market.   However, it has not reached

the monopoly level. That result is not surprising if we look at the history of FCM. In the

early 1950s, the FCM set a minimum price for the citrus market in Florida since most

growers are members of FCM. At that time, the FCM can be considered as a monopoly in

the market. However, in 1957, the FTC announced that fixing prices prior to 1952 was a

violation of antitrust laws. After that, FCM still kept strong influence on the orange market in representing growers' interests as noted above. .

With supply shocks, the model tell us that market power decreased significantly, dropping to $\lambda = \lambda_{1+} + \lambda_2 = 0.29$. This makes sense. When a shock occurred, the old equilibrium in the market was broken, new rules had not been established, and the price was set more freely, unconstrained by earlier accords. Another factor could be imports entering into the market when the price rose from the supply shock. The importers would not be restricted by existing accords on pricing. The price did rise, but it was just the result of the supply curve shifting left to reach the new equilibrium at a higher price. In the retail market, a similar phenomenon was observed by Binkley et al. (2001) and Dutta et al. (2002), who found that when a supply shock occurred (1989), the orange juice retail market appeared very competitive.

In estimating the demand function, the estimators of prices are all reasonable and significant, indicating that the Q* is generated based on solid ground. In estimating the supply function, most of the estimators are the same as we expected, except the sign of Q. But that sign is consistent with the phenomenon that supply increases even though the price declines. It could be interpreted as given that market power exists in the industry, the industry is still profitable despite the price decline. More and more firms enter the market despite the price decrease.

6. Conclusions

In this paper, we employed a simultaneous model to study how the orange juice market reacts to exogenous shocks. We found that when shocks occurred, the market

became more competitive even though the price rises. An implication is that consumers receive some compensation for natural disasters through the market reaction: firms become more competitive(and cede part of their profit), which dampens the potential price increase, even though the price is still higher than usual. .

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Table 1: Summary Statistics for the Main Variables

Variables	Observations	mean	Standard deviation	Minimum	Maximum
Q	58	118163	58875	19220	232900
P_1	58	0.64	0.35	0.23	1.90
P_2	58	1.11	0.46	0.27	2.15
P_3	58	0.27	0.20	-0.027[11]	0.906

Note: P_1, P_2, P_3 are prices deflated by CPI. (1934 is the base year)

Table 2: Historic Freezes in Florida (Orlando area)

Year	Low temperature	Level	Year	Low temperature	Level	Year	Low temperature	Level
1940	22°	S	1970	24°	S	Dec,1985	26°	M
1947	24°	M/S	1971	22°	S	1986	27°	M
1957	21°	M/S	1977	20°	S	Feb,1989	29°	M
Jan,1958	26°	S	1981	18°	S	Dec,1989	25°	S
Feb,1958	24°-26°	S	1982	23°	S	Jan,1996	29°	M
1962	19°	Ca	1983	24°	S	Feb,1996	26°	M
1966	23°	M	Jan,1985	19°	S			

Source: "A history of Florida citrus freeze" (Attaway, 1997)
M means the damage level is moderate, S means severe, Ca means catastrophic damage.

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[11] The price is on-tree price of grapefruit in the US, The definition of on-tree price is price minus costs of harvesting and transporting to the packing house. So a negative price means the price which growers got is too low to offset the costs. This situation happened in 1998 and 2003. (Source: Florida citrus summary)

variables	Demand function	Marginal effect	Supply Function	Marginal effect
P_1	-96065***	-87692		
	(2.29)			
GDP	220.3***	220.3		
	(8.82)			
P_1P_3	30667			
	(0.57)			
P_2	21833	21833		
	(1.55)			
P_3	9734	29514		
	(0.21)			
Q*			-0.82**	
			(1.95)	
Q			-7.2e-06	-1.4e-05
			(1.61)	
weather			1.09***	2.20
			(4.75)	
WQ*			0.53***	
			(3.04)	
Tariff			0.03***	0.03
			(3.61)	
constant	53229		-0.10	
	(2.20)		(0.39)	
R^2	0.79		0.728	

Table 3 Estimation Results

Absolute t value in brackets.
*** indicates the 1% significant level, ** indicates the 5% significant level,
* indicates the 10% significant level.