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A Case Study on Model Fit and Performance

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Simulating a Homogeneous Product Merger: A Case Study on Model Fit and Performance

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Abstract

This paper studies Tesoro's 2013 acquisition of British Petroleum's Los Angeles refinery. We present a merger simulation model tailored to the gasoline market, which includes Cournot firms and a price-taking fringe. This hybrid model generates margins that are more plausible than those generated by the standard Cournot model. We also test the predictive accuracy of the models relative to empirical estimates of the acquisition's price effect. We estimate the effect of the acquisition using both difference-in-differences estimation and the synthetic control method. Both methods suggest the acquisition had little if any effect on Los Angeles gasoline prices. We can reject the price effect predicted by the standard Cournot model, but not that of the hybrid model.

[1] The views expressed in this article are those of the authors and do not necessarily reflect those of t(h)-4 leo-2. .umodel(

1. Introduction

This paper studies

(acquisition) city from our data. This form of exact inference contrasts with traditional hypothesis testing, where standard errors reflect sampling uncertainty under the assumption that the data are a sample from a larger population.

Neither empirical method provides robust evidence of a price change after the acquisition. All of our difference-in-differences estimates are statistically indistinguishable from zero. We can reject the 6% price increase predicted by the Cournot model, but not the 1% price increase predicted by the hybrid model. With the synthetic control method, the placebo exercise indicates that there is a better than 50% chance of finding as large an effect as that found in Los Angeles if we were to randomly select the treatment city from our sample.

Our results contribute to the merger retrospective literature, a growing body of studies that estimate the price effects of mergers. Recent examples on mergers in the petroleum industry include Hosken, Silvia and Taylor

The next section of the paper outlines the standard Cournot model and introduces our hybrid variant. Section 3 describes the California gasoline market and refinery production technology. Section 4 applies both models to industry data and demonstrates the superior *ex ante* fit of the hybrid model. Section 5 simulates the Tesoro-BP transaction under our baseline assumptions and Section 6 explores how the simulations change with alternative parameterizations. Section 7 presents the empirical analysis, which we use to assess the *ex post* accuracy of the simulation models. Finally, Section 8 concludes.

2. The Models

Consider a homogeneous goods market with inverse demand $P(Q)$ and N Cournot firms simultaneously choosing output. We can write firm i's first order condition, $P(Q) + q_i P'(Q) - MC_i(q_i) = 0$, in Lerner index form:

$$\frac{P - MC_i}{P} = \frac{s_i}{\varepsilon} \qquad (1)$$

where $Q = \sum_i q_i$ is total output, MC_i is the marginal cost of firm i at equilibrium, s_i is firm i's share and ε is the absolute value of the elasticity of market demand. In equilibrium, margins are proportional to market shares and inversely proportional to ε.

Less elastic market demand implies larger margins and larger differences in marginal costs between firms with different market shares. Firms with larger market shares operate at lower equilibrium values of marginal cost because marginal revenue is decreasing in q_i. This equilibrium relationship is true regardless of the functional form of demand or costs.

Now consider the same homogeneous goods market, with two sets of firms: k price-taking firms and $N-k$ strategic firms ($k = 0$). Price-taking firms choose output where price

equals marginal cost. We assume that strategic firms choose output in a Cournot fashion under the belief that price-takers expand production until their marginal costs equal the market price.

The mechanics of the hybrid model are analogous to those of a dominant firm model. The residual demand facing the strategic firm is the difference between market demand and the supply from price-takers, $S^{pt}(p) = S(p) - M(p)$. The following identity defines the price elasticity of residual demand:

$$\varepsilon^{r} = \varepsilon - \eta\frac{S^{pt}}{Q} \qquad (2)$$

where M is the

Assignment of firms to the strategic or price-taking groups is a challenge that dates at least as far back as Stigler's (1947) investigation of oligopoly pricing.[9] However, this assignment is in principle no more challenging than deciding when the textbook dominant firm model may apply.

of $105 per barrel, the average West Coast crude acquisition cost in 2012.[14] Similarly, consistent with prior literature we assume a demand elasticity of -0.3.[15]

Refineries produce multiple products, including gasoline of different grades, diesel fuel, jet fuel, heating oil, and other heavier products.[16] We focus on gasoline because it is generally the highest-valued product, and because it represents the plurality if not majority of production at California refineries.[17]

A typical refinery has thousands of production constraints, including the capacity of individual processing units, available tankage, and blending requirements of inputs and outputs. For a given stock of capital, the marginal cost of producing gasoline tends to increase as output expands and additional production constraints bind. Moreover, for a given amount of crude oil and other feedstocks running through the refinery

generally take prices as given. For example, a recent FTC investigation of gasoline pricing found that refiners typically "assume their short-run operational decisions do not affect market prices."[19]

By contrast, Borenstein, Bushnell and Lewis (2004) argue that despite evidence consistent with price-taking behavior, it would be surprising if producers did not consider the effect of their own production levels on California gasoline market prices. Our hybrid model allows for both price-taking and strategic behavior to exist simultaneously. This additional degree of freedom allows the hybrid model to better match plausible industry margins, given market shares and demand elasticity estimates.

4. Fitting the Models to the California Gasoline Market

In the standard Cournot model, a firm's margin is a function of its market share and the price elasticity of demand. Hence, we can calculate equilibrium marginal costs with information on market shares, price, and the price elasticity of demand. Again, we use crude distillation capacity shares as a proxy for gasoline output shares. Table 2 shows the quantity, implied margins, and implied marginal costs for each firm in California assuming Cournot equilibrium. The standard Cournot assumption implies equilibrium marginal costs that are lower than the cost of crude oil for all firms except Kern Oil.

[19] See Federal Trade Commission. (2006). The report does note that "although refiners state that they generally adhere to the LP model, some refiners occasionally deviate from the model if their internal analyses and judgment

TABLE 2—Implied Margins in the Standard Cournot Model

5. Simulating Tesoro's Acquisition of BP Carson

Tesoro acquired BP's Southern California refining, marketing and logistics business on June 1, 2013. The assets included BP's Carson refinery, marine terminals, land terminals, and pipelines that were adjacent to the refinery [illegible]

$$M_j = \frac{>G_{ij}}{>G_{ij} + 1} \quad (4)$$

$$M_j = \frac{=}{>} \; n \frac{>G_{ij}}{1 + \tilde{A}_{ij} \frac{>G_{ij}}{>G_{ij} + 1}} \; r \; .^{26}$$

It is straightforward to solve for the parameters of the demand function based on the market price, quantity, and assumed elasticity of demand. Simulating a merger occurs in two steps. First, we recover the G_{ij} using the first order conditions. Second, we calculate the post merger equilibrium M_j given the post-merger values of G_{ij}.

TABLE 4—Simulation Results from the Standard Cournot Model

Table 4 shows the results of the Cournot simulation. Tesoro's predicted post-merger output is 26% less than the combined output of BP and Tesoro before the acquisition. Equilibrium marginal costs are lower as the merged entity restricts output along its new marginal cost function. Conversely, all of the non-merging firms increase output in response, with their marginal costs increasing as they expand output. Overall,

To simulate the merger with the hybrid model, we assume a linear supply function from the price-taking firms, with parameters defined by the pre-merger equilibrium price, quantity and the same supply elasticity for each price-taking firm. From this, one can algebraically derive the residual demand function facing the strategic firms. The simulation proceeds under the standard Cournot model above, with the exception that we replace the overall market demand function with the residual demand function, and replace the overall market shares with the share of each strategic firm within the strategic group. Table 5 presents the results

TABLE 5—Simulation Results from the Hybrid Model

	Quantity*	C'	(P - C)/P
Chevron	27.60	105.67	0.18
Tesoro	24.83	107.97	0.16
ConocoPhillips	11.51	119.05	0.07
Valero	11.12	119.38	0.07
Shell	8.59	128.63	0.00
Exxon	8.21	128.63	0.00
ALON	6.37	128.63	0.00
Kern Oil & Refining	1.43	128.63	0.00
Total	99.66		

*Pre-acquisition total market output normalized to 100.

Tesoro reduces output less than predicted with the standard Cournot merger simulation: 7% rather than 26%. This difference reflects the more aggressive output expansion of the price-taking firms. In the hybrid simulation, strategic firms outside the merger increase output by 1%, while the non-strategic firms increase output by 2%. Overall, output falls by 0.3% and the hybrid model predicts that price increases by approximately 1%.

6. Alternative Parameterizations

In Table 6, we derive simulated price effects as we change the composition of the strategic group. The first column assumes the strategic group includes only Chevron, BP, and

Tesoro. Moving to the right, the strategic group includes additional firms, added in descending market share order. The middle column, which includes five strategic firms, is the baseline case presented in section 5. Notably, the order-of-magnitude of the simulated price effect does not change with the composition of the strategic group.

TABLE 6—Price Effect with Different Strategic Groups

One might expect that the price effect would increase as additional firms join the strategic group and the hybrid model ostensibly looks more like a standard Cournot model. However, note that the margin of the largest strategic firm remains constant as we move to the right in the table.[27] In order to maintain the level of margins, the elasticity of supply from the price-taking firms must increase, as defined by equations (2) and (3). Intuitively, as the share of the competitive fringe shrinks, the remaining price-taking firms must possess

proxy for the minimum marginal cost of producing gasoline. Relevant marginal costs may also include additional purchases of materials, labor, and capital, or the opportunity cost of forgone output of other products. Hence, equilibrium marginal cost likely falls somewhere between the cost of crude oil and the price of gasoline.

Figure 1 illustrates the relationship between the largest firm's pre-acquisition

FIGURE 1—Relationship between Assumed Margins and the Predicted Acquisition Effect

The choice of market demand elasticity does not affect the size of the merger's price effect in the hybrid model, given our strategy of identifying the model's parameters by restricting the largest firm's marginal cost to a plausible range. As long as the group of strategic firms is unchanged, equation (3) sets the relationship between the residual demand elasticity, market shares, and margins. In other words, assumed margins imply the residual demand elasticity facing the strategic firms. Changing the overall market demand elasticity will change the supply elasticity of the price-taking firms (and therefore their quantity response), but will not change the predicted price effect of the acquisition.

Changing the choice of demand elasticity will change the predicted prifo Td ( )e

implied marginal costs for the largest firm close to the cost of crude oil if one is willing to assume a demand elasticity of -1.3. In that case, the predicted price effect would be 1.2%. Hence, in some sense, the practical difference between the hybrid and standard Cournot model rests on the assumed elasticity of demand. However, we believe a market demand elasticity of -1.3 is implausible, and other researchers share this view. Covaglianese, Davis, Kilian, and Stock (2015) describe a price elasticity of -1.46 as "the upper end of the range of elasticity values that seem economically plausible and indeed is higher than many economists would be comfortable with."

7. Estimating Merger Price Effects

The standard Cournot and the hybrid model predict respective price effects of 6% and 1% using our baseline calibrations. To assess the accuracy of these predictions we estimate the actual effect of the acquisition on Los Angeles wholesale gasoline prices. The standard approach in the merger retrospective literature is to use a difference-in-differences model, comparing the evolution of prices in markets affected by the transaction with the evolution of prices in markets not affected. Lacking an ideal control for Los Angeles prices, we supplement the difference-in-differences approach with the synthetic control method.

We start by comparing the average post-acquisition price difference in Los Angeles with the same difference in all 18 cities for which we have data. This difference-in-differences regression analysis allows us to conduct traditional statistical inference and test the null hypotheses from the simulation models. In this approach, we assume the 18 controls cities are

sample drawn from a larger population, and that the conditional mean price change in that population is the same change that would have occurred in Los Angeles but for the acquisition.[29]

The primary drawback of this approach is that Los Angeles prices might have followed a different path than the average price in the control cities if the acquisition had not occurred. Unobserved variables that differentially affect Los Angeles and one or more control cities will lead to correlation between the error term and treatment dummy. We could select, based on our best judgment, a particular control city that we believe experienced the same time-varying shocks. Yet this approach may raise concerns about the objectivity of our choice of control city and the degree to which its prices are a credible proxy for Los Angeles's counterfactual prices

The synthetic control methodology, which selects a control group using a data-driven procedure, reduces the ability of the researcher to influence results and makes the selection process more objective. After finding the optimal synthetic control and estimating the effect of the transaction on Los Angeles prices, we conduct a placebo experiment that applies the synthetic control method to each of the control cities. We can then assess whether the estimated effect in Los Angeles is large relative to the distribution of placebo effects.

Section 7.1 describes our data set. Section 7.2 presents the difference-in-differences regression analysis. Section 7.3 describes the synthetic control methodology. Section 7.4 presents the synthetic control results.

[29] Assuming prices in Los Angeles are precisely measured and the price effect in Los Angeles is the relevant statistic, the standard errors reflect sampling uncertainty arising because we do not observe every control city in the population. Abadie, Athey, Imbens, and Wooldridge (2014) discuss how traditional standard errors can also reflect the fact that, even if the researcher observes outcomes for all subjects in the population, there are additional potential outcomes for each subject with different levels of treatment.

7.1. Data and Sample

We construct a panel dataset with 19 cities and 48 monthly observations from January 2011 to December of 2014. The variable of interest is the wholesale price of gasoline. We construct monthly averages using the daily average rack price of branded and unbranded gasoline published by Oil Price Information Service (OPIS). Gasoline retailers and distributors can purchase gasoline at distribution terminals referred to as racks.[30]

We include data on Metropolitan Statistical Area annual per capita personal income, from the U.S. Bureau of Economic Analysis, to capture demand. That these data are annual is not problematic as both the synthetic control method and the regression analysis use pre-acquisition and post-acquisition averages.[31]

Table 7—Control Variables and Pre- and Post-acquisition Prices, Averages by City

7.2. Difference-in-Differences Regressions

We estimate the regression models using time-differenced data that capture the change in each variable from the pre-merger period to the post-merger period. The regression equation takes the form:

ln

The goal is to capture the price effect from Tesoro's acquisition. We need a window of time long enough for firms to adjust output in response to the merger allocation of capital, yet short enough to avoid contaminating effects from unrelated events in the industry. The possibility that firms change their behavior before the actual transaction further complicates matters. For example, Kim and Singal (1993) find that merging airlines increase prices after the

on time-aggregated data include Tenn (2011), Tenn and Yun (2011), Thompson (2011), and Haas Wilson and Garmon (2011).[34]

TABLE 8—Difference-in-Differences Regression Models

Variables	1	2	3	4
Full Sample (Jan '11-May '13 pre period and Jun '13-Dec '14 post pe				
ACQUISITION	0.000	-0.002	0.001	0.003
	(0.015)	(0.016)	(0.015)	(0.017)
ΔINCOME		0.115		-0.2
		(0.475)		(0.539)
ΔCOST			0.106	0.125
			(0.089)	(0.106)
Constant	-0.081***	-0.0841***	-0.0755***	-0.0693***
	(0.003)	(0.013)	(0.006)	(0.018)
R-squared	0.000	0.004	0.081	0.089
12-month pre and post periods, no transition window				
ACQUISITION	-0.002	-0.003	-0.002	-0.004
	(0.011)	(0.012)	(0.012)	(0.012)
ΔINCOME		0.455		0.479
		(0.775)		(0.845)
ΔCOST			0.007	-0.006
			(0.064)	(0.069)
Constant	-0.037***	-0.039***	-0.037***	-0.039***
	(0.003)	(0.005)	(0.003)	(0.005)
R-squared	0.002	0.023	0.003	0.024
12-month pre and post periods, 12-month transition window				
ACQUISITION	-0.008	-0.01	-0.007	-0.008
	(0.014)	(0.015)	(0.014)	(0.015)
ΔINCOME		0.397		0.167
		(0.545)		(0.590)
ΔCOST			0.099	0.089
			(0.079)	(0.088)
Constant	-0.079***	-0.084***	-0.073***	-0.076***
	(0.003)	(0.008)	(0.006)	(0.012)
R-squared	0.018	0.049	0.106	0.111
N	19	19	19	19

*** p<0.01, ** p<0.05, * p<0.1

[34] Our time-differenced model is equivalent to a two-period city fixed effects model.

Table 8

and $\grave{U}$. is a diagonal matrix with elements that apply weights to the variables in and $\grave{U}$ determining their importance as relevant characteristics.

We choose $\hat{U}$ by minimizing the mean square prediction error (MSPE) of the synthetic control city relative to Los Angeles during the pre-acquisition period. That is, we choose $\hat{U}$

snm <05Dimcontrition

7.4. Synthetic Control Results

The optimal synthetic control city for Los Angeles applies

9) References

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