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EDGEWORTH PRICE CYCLES, COST-BASED PRICING AND STICKY PRICING IN RETAIL GASOLINE MARKETS

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Abstract

This paper examines dynamic pricing behavior in Canadian retail gasoline markets. I find three distinct pricing patterns: cost-based pricing, sticky pricing, and sharp asymmetric retail price cycles that resemble the Edgeworth Cycles of Maskin & Tirole [1988]. I use a Markov switching regression to estimate the prevalence of the regimes and the structural characteristics of the cycles themselves. I find cycles are more prevalent when there are more small firms and are accelerated and amplified with very many small firms. In markets with few small firms, sticky pricing dominates. The findings are consistent with the theory of Edgeworth Cycles.

JEL Classification L13, L41, L81

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I Introduction

In a retail industry where many firms sell a homogeneous good, one might expect retail prices to correlate relatively closely with wholesale prices. However, in retail gasoline markets in Canada, three different pricing phenomena are observed. The first pattern is one in which prices cycle rapidly and in a strongly asymmetric way. The cycle begins with a large price increase from one week to the next, and is followed by a gradual decline in price over the next several weeks. It then repeats. These cycles, seldom documented empirically, appear similar to the theoretical "Edgeworth Cycles" of Maskin & Tirole[1988]. In contrast, the second pattern is one in which prices remain fixed for months at a time. A pattern in which retail prices more closely follow wholesale prices is the least common pattern of the three.

In this paper, I use a panel set of 19 cities over 574 weeks (January 1989 to December 1999) to explore these three phenomena in two stages.

The first objective is to develop an empirical framework to objectively separate out the three patterns, measure the prevalence of each, and measure their structural characteristics such as period, amplitude, and asymmetry. I argue that a Markov switching regression technique, adapted from Cosslett & Lee[1985] and Ellison[1994], is well suited to this and preferable to the bias-prone "eyeball" test. I find cycling activity in 43% of the sample, sticky pricing in 30% and cost-based pricing in 27%. The cycles are also strongly asymmetric.

The second objective is to show that not only do these cycles appear like Edgeworth Cycles but that their prevalence and characteristics vary in ways predicted by the theories of Edgeworth Cycles (Maskin & Tirole[1988], Eckert[2003]). Consistent with the theory, I show that the cycles are significantly more prevalent and are significantly taller, faster, and *less* asymmetric when there is greater penetration of small independents. The result is robust when controlling for market size and service outlet density, and under alternate measures of small firm penetration.

In Section II, I preview the results in graphs and preliminary statistics. Section III contains a discussion of the related literature and in Section IV, I lay out my empirical framework. A short discussion of the data is in Section V. In Section VI, I report results on the prevalence of retail price cycles, sticky pricing and cost-based pricing and construct estimates of the structural characteristics of the cycle. I examine the impact of small independent firms on cycle prevalence and structural cycle characteristics in section VII. Section VIII concludes.

II Data at a Glance

(Figure 1, panels A, B, and C about here)

Examination of wholesale and retail prices over time across Canadian cities reveals sharp differences in pricing behavior. To illustrate, Figure 1 shows the average wholesale price (the "rack" price) and the average tax-exclusive retail price series for three cities over subsets of the sample: Windsor, St. John's, and Ottawa.[1] The data are average spot prices recorded at the same time each week, in Canadian cents per liter, and the same wholesalers and the same retail service outlets are polled each time.[2]

The retail price series shown for Windsor exhibits a rarely documented but striking cyclical pattern that does not appear in wholesale prices. When the retail price gets too near the rack price, retail prices rise suddenly by more than three cents on average and often greater than five cents.[3] On average, it triples the rack-retail markup. The retail price then falls gradually again.

In St. John's, prices remain fixed for months at a time in spite of fluctuating rack prices. In Ottawa, we observe retail prices roughly following wholesale.

The asymmetry in the cycles cannot be explained by simple demand or inventory stories. There are no predictable and repetitive supply discontinuities that would generate such a cycle. There is also no evidence that demand in a given city would sharply increase at particular moments but then gradually decline at all other times.

Even nearby cities experience price spikes on different weeks, have cycles of different durations, and experience cycling spells at different times. This confirms there was not a single event that caused some general shift either to or from cycling. The experience of each city differs.

As a preliminary look at the extent of asymmetry in all sample markets, I report summary statistics on rack prices, retail prices, markups, per-week price changes and price "runs" in Table 1. A "run" is defined as the number of weeks of consecutive same-sign price changes.

Over the full sample, the average week-to-week retail price increase (2.01 cpl) is significantly greater than the average decrease (1.18 cpl). I report both the usual two-sample t-statistic and the P-value from the more comprehensive Kolmogorov-Smirnov distribution test.[4] There are highly significant asymmetries in retail prices but none in rack prices. Similarly, the mean length of a run down in retail prices (1.94 wks) is significantly longer than the mean length of a run up (1.36 wks). While runs up of more than two weeks are rare, runs down of four to eight weeks are common. Rack price runs show no signs of asymmetry.

While suggestive, these preliminary statistics cannot separate price movements within an Edgeworth-like cycle from those within a cost-based pricing pattern. Therefore, they cannot be used to compute the prevalence and characteristics of the cycles and test them against the theory of Edgeworth Cycles. I propose a framework later to do this.

III Theory and Literature

At a glance, the observed price cycles appear similar to the theoretical "Edgeworth Cycles" of Maskin & Tirole[1988]. Maskin & Tirole consider a dynamic Bertrand game with two identical firms producing homogeneous goods and setting prices alternately. The authors show that, under identical supply and demand conditions, two distinct sets of equilibria are possible – "Focal Price" equilibria and "Edgeworth Cycle" equilibria.

In the latter, firms repeatedly undercut one another until price falls to marginal cost and a war of attrition ensues. When one firm finally "relents", the other follows and the cycle repeats. Figure 2 shows an example of the prices along an Edgeworth Cycle in a duopoly situation.

The prediction of asymmetry in Edgeworth Cycles stands in contrast to traditional models of price wars, such as Green & Porter[1984], Rotemberg & Saloner [1986], or Abreu, Pearce & Stacchetti[1986], whose price wars are symmetric – prices fall as fast as they rise.

While the asymmetric cyclical pattern observed in many cities appears consistent with Edgeworth Cycles, the sticky pricing we observe in the data appears more consistent with a Focal Price equilibrium and the cost-based pricing could come from either a competitive or a "Focal" markup above rack.

(Figure 2 about here)

Eckert[2003] extends the model to the case of an unequal sharing rule at equal prices.[5] The author shows that a sufficiently small firm (i.e. one with a lower equal price share) has such a strong incentive to undercut that only Edgeworth cycling can exist. A focal price equilibrium cannot. Moreover, when the small firm undercuts, the large firm is more likely to match rather than further undercut in response since it would serve most of the market at that price anyway. As a result, the downward portion of the cycle grows longer and the cycle appears more asymmetric.

In practice, retailers are capacity constrained and an undercut by a single small firm (with few retail outlets) is unlikely to warrant a response from the large firm. Only when there are many such small firms will widespread undercutting steal enough market share to invoke a response and generate a cycle. And the greater the number of small firms, the more likely that the response will be another undercut rather than a match.[6,7].

In this article, I will test whether the pattern of pricing in these markets and the shape of the cycles are consistent with these predictions of the model. I test for a greater prevalence of Edgeworth Cycles when there are more small firms. Conditional on cycling, I test for more rapid and *less* asymmetric cycles when there is greater penetration of small firms.[8]

Few empirical papers have specifically addressed asymmetric Edgeworth-like price cycles in retail gasoline markets. Allvine & Peterson[1974] note cycles in some western U.S. cities in several episodes in the 1960s and early 1970s and Castanias & Johnson[1993] present simple summary statistics (like Table 1) for the cycles in Los Angeles from 1968 to 1972. For Canada, Eckert[2002] shows how a cycle leads to rack price increases being passed through to retail prices more quickly than decreases in Windsor.[9] And Noel[2004] shows that major firms initiate higher prices and independents initiate undercutting to perpetuate the cycles in Toronto. Other recent work has begun to document in more detail the cyclical pattern in Vancouver, Canada (Eckert[2004]) and newly found cycles in Perth, Australia (Wang[2005]).[10]

Most closely related to this work is Eckert[2003] who motivates his theoretical model (described above) with some interesting correlations between overall price rigidity and concentration ratios in Canadian retail gasoline markets.

The current article improves upon this in several important respects. First, I am able to isolate price changes resulting from asymmetric Edgeworth-Cycle-like behavior from prices that are not rigid for other reasons, such as would occur in a symmetric, cost-based pricing regime. I can therefore directly estimate cycle prevalence. Secondly, I can estimate the detailed characteristics of the cycles which are of interest in their own right. Thirdly and most importantly, this allows me to design a multi-pronged test of the relationships predicted by the theory: with increasingly more small independent firms, 1. Edgeworth Cycles (as opposed to moving prices) should be more prevalent, 2. the upward portion should be unaffected, 3. the downward portion and therefore 4. the cycle itself should progress more rapidly and finally 5. the cycle should be less asymmetric.

IV Empirical Framework

(Figure 3 about here)

The first objective is to build measures of the prevalence of each pattern and of cycle characteristics from model parameters. I do this by taking nonlinear transformations of the parameters produced from a Markov switching regression.

The Markov structure is important in identifying cycles since it allows for serial correlation in the estimated regimes. The challenge is that the true underlying regimes are unobservable and cycle and non-cycle price movements can look identical to the econometrician, even in the absence of sampling error. The regime history contains valuable additional information. For example, an observed price decrease is more likely to be considered part of the undercutting phase of a cycle if we believe the market was in an undercutting phase in the previous period and less likely if it was a cost-based pricing regime. A regular switching regression has no such memory feature.

Of course, it would necessarily be subjective to classify cycles and their characteristics by eyeballing the price series or selecting minimum and maximum cutoffs. That in mind, eyeballing the results ex post confirms the model categorizes data well.

Guided by the time series, I model each given market as being in one of three top-level regimes at a given point in time. The regimes are

1. the relenting phase of the cycle (regime “R”),
2. the undercutting phase of the cycle (regime “U”),
3. the non-cycle price regime (regime “F”, for focal).

I further subdivide the non-cycle price regime “F” into two subregimes:

3a the non-cycle price regime – cost-based pricing (subregime “C”)

3b the non-cycle price regime – sticky pricing (subregime “S”)

Placing non-cycling activity into a single top-level regime makes parameter estimation manageable and allows me to focus on the asymmetric price cycles which are of primary interest.[11] Figure 3 outlines the model structure.

A. The Regimes

The first two regimes capture price evolution within the cycle: the relenting phase (regime “R”) and the undercutting phase (regime “U”). The portion during which I anticipate finding prices that rise sharply in a short time I call the relenting phase and the portion during which I anticipate finding prices that gradually fall I call the undercutting phase. However, the form of these within-regime regression equations is completely symmetric and no *a priori* restrictions are imposed on the sign or minimum size of price changes.[12]

Specifically, in periods of cycling, I model market m at time t as evolving according to the function

$$\Delta RETAIL_{mt} = X^i_{mt}\beta^i + \varepsilon_{mt}, \quad i = R, U \tag{1}$$

Setting the X^i to a vector of ones allows a simple estimation of the average price changes in each phase of the cycle (since non-cycle periods have now been isolated and excluded) and will contribute to measuring the vertical characteristics. When I include variables that capture the penetration of small independent firms and other demand variables into X^i in section VII, the vertical dimension is allowed to evolve with changes in these variables.

In the cost-based pricing subregime (subregime "C") of the non-cycling regime, I anticipate retail prices following wholesale prices, perhaps with a lag:

$$RETAIL_{mt} = X^F_{mt}\beta^F + \varepsilon_{mt} \tag{2}$$

where $RETAIL_{mt}$ is the retail price, $(X^F_{mt})'$ is a $K^F \times 1$ vector of explanatory variables, β^F is a $K^F \times 1$ vector of parameters and ε_{mt} is normally distributed. In all specifications, the rack price, and dummies for city, month, and year are included in the X^F. In the sticky price subregime (regime "S"), prices do not change from the previous week, so simply

$$RETAIL_{mt} = RETAIL_{m,t-1} \tag{3}$$

B. The Switching Probabilities

There are nine Markov switching probabilities, from and to each of three top-level regimes. Let I_{mt} be the indicator function equal to "R", "U", and "F" when market m at time t is in the relenting phase, the undercutting phase, and the non-cycle regime respectively. The probability that a market switches from regime i in period $t-1$ to regime j in period t is given by

$$\begin{aligned} \lambda^{ij}_{mt} &= \Pr(I_{mt} = j \mid I_{m,t-1} = i, W^i_{mt}) \\ &= \frac{\exp(W^i_{mt}\theta^{ij})}{1 + \exp(W^i_{mt}\theta^{iR}) + \exp(W^i_{mt}\theta^{iU})}, \quad i = R, U, F, \quad j = R, U \end{aligned} \tag{4}$$

and $\lambda^{iF}_{mt} = 1 - \lambda^{iR}_{mt} - \lambda^{iU}_{mt},\ i = R, U, F$ to satisfy the adding up constraint. Call Λ_{mt} the 3×3 switching probability matrix whose ij^{th} element is λ^{ij}_{mt}. Each $(W^i_{mt})'$ is an $L^i \times 1$ vector of explanatory variables that affects switching out of regime i and θ^{ij} is an $L^i \times 1$ vector of parameters.

Setting the W^i to a vector of ones yields average switching probabilities which I use to measure prevalence and the horizontal characteristics of the cycle. When I include variables that capture the penetration of small independent firms and other demand variables into W^i, penetration and the horizontal dimension of the cycle are allowed to vary with these variables.

Within a non-cycle regime, let the indicator variable J_{mt} equal to "C" and "S" when the market is in the cost-based and sticky pricing subregimes respectively. The probability of subregime "S", conditional on "F", is given by:

$$\Pr(J_{mt} = \text{``}S\text{''} \mid I_{mt} = \text{``}F\text{''}, V_{mt}) = \gamma_{mt} = \frac{\exp(V_{mt}\zeta)}{1 + \exp(V_{mt}\zeta)} \tag{5}$$

where $(V_{mt})'$ is a $Q \times 1$ vector of explanatory variables and ζ is an $Q \times 1$ vector of parameters.

The parameters $(\beta^i, \theta^{ij}, \zeta)$ in each specification are simultaneously estimated by maximum likelihood. Newey-West standard errors are calculated. Estimates of the switching probabilities, prevalence and cycle characteristics are derived from the core parameters and standard errors are calculated by the delta method or via simulation as noted.

C. Prevalence and the Anatomy of a Price Cycle

From these primitives, I derive formulae for the prevalence of each regime and the structural characteristics of the cycles.

For example, the prevalence of the three top-level regimes is simply $z = (z^R, z^U, z^F)'$ where z solves

$$\Lambda' z = z, \quad z \neq 0 \tag{6}$$

and Λ' is the transpose of the switching probability matrix. It is easy to see that z is the eigenvector of the transposed switching probability matrix corresponding to an eigenvalue of one. The prevalence of sticky pricing is just γz^F and of cost-based pricing it is $(1 - \gamma) z^F$.

The expected period of a cycle is the sum of the expected durations of a relenting phase and an undercutting phase. Expected duration of regime i is

$$E(duration\ of\ regime\ i) = \frac{1}{1-\lambda^{ii}} \tag{7}$$

and so the expected period of the cycle as

$$E(period) = \frac{1}{1-\lambda^{RR}} + \frac{1}{1-\lambda^{UU}} \tag{8}$$

To derive the amplitude of a cycle, I multiply the expected duration of the relenting phase with the expected relenting phase price change. One could also use the undercutting phase to calculate the vertical fall (rather than the vertical rise) and the long term stationarity of prices over the sample period ensures these measures are about the same. Therefore, expected amplitude is

$$E(amplitude) = \frac{\alpha^R}{1-\lambda^{RR}} \text{ or } \frac{-\alpha^U}{1-\lambda^{UU}} \tag{9}$$

where $\alpha^R = E(\Delta RETAIL_{mt} \mid X^R_{mt})$ is the expected per week price change in a relenting phase and α^U is similarly defined.

One of the most interesting characteristics of the cycles is their asymmetry. There are two dimensions on which to measure this: horizontally and vertically. I define "horizontal asymmetry" as the ratio of the duration of the undercutting phase to the duration of the relenting phase:

$$E(horizontal\ asymmetry) = \frac{1-\lambda^{RR}}{1-\lambda^{UU}} \tag{10}$$

and "vertical asymmetry" as the (negated) ratio of the average price change in an relenting phase to the average price change of the undercutting phase:

$$E(vertical\ asymmetry) = \frac{-\alpha^R}{\alpha^U} \tag{11}$$

Again, the long run stationarity of prices ensures these are roughly the same.

Finally, one might also be interested in the average duration of a complete cycling spell, which I calculate as

$$E(spell\ duration) = \frac{z^R + z^U}{z^R * \lambda^{RF} + z^U * \lambda^{UF}} \tag{12}$$

and the expected number of consecutive cycles that make up the spell:

$$E(\#\ consecutive\ cycles) = \frac{E(spell\ duration)}{E(period)} \tag{13}$$

V Data

I examine 19 major Canadian cities from the first week in 1989 to the last week 1999. Data were collected on retail gasoline prices, rack prices, outlet populations and other ancillary information.

Retail gasoline prices, $RETAIL_{mt}$, are the tax-exclusive prices for regular unleaded 87 octane gasoline, in Canadian cents per liter, as reported by the Ministry of Natural Resources of Canada, M.J. Ervin & Associates, and by the Ontario Ministry of Energy. The same set of service outlets in each city are surveyed at the same time each Tuesday morning and the average spot price is recorded.[13] The rack price, $RACK_{mt}$, is the average spot rack price for unbranded regular gasoline across wholesalers, reported by Bloomberg Oil Buyer's Guide.[14] Measures of small firm penetration were constructed from bimonthly data on firm-specific outlet counts, which were obtained from Kent Marketing Ltd. Populations and land areas are from Statistics Canada.

I mention a few data issues. First, if the relenting phase is short but occurs over a Tuesday, one may observe an average of some firms that have relented and others that have not, prolonging the relenting phase to two weeks. Second, if the relenting phase is generally completed in less than a week, the duration of that phase will be somewhat overestimated and the amplitude underestimated. These issues work against a finding of strong, asymmetric cycles.[15] Missing very fast cycles entirely does not appear to be a problem, however. The extremely rapid cycles known to exist in Toronto (Noel[2004]) are still virtually completely captured in this framework.

Finally, for my largely urban sample, the wide majority of prices at major branded and independent chain outlets are centrally controlled by the firm. Hence, concepts of "large" and "small" firms are meaningful.

VI A Description of Retail Price Cycles

For the first objective, I estimate the prevalence and characteristics of asymmetric retail price cycles and show they are consistent with Edgeworth Cycles. Table 2 shows the within-regime results and switching probabilities for three descriptive specifications, and Table 3 shows the corresponding prevalence and characteristics estimates.

Specification (1) can be thought of as the "summary statistics" of the cycle post regime-categorization. In this specification, the expected price changes in the two cycle regimes ($\alpha^i,\ i = R, U$), all switching probabilities ($\lambda^{ij},\ i, j = R, U, F$), and the probability of sticky pricing conditional on not cycling (γ) are all constants (i.e. the X^R, X^U, W^i, and V are all vectors of ones). This yields a single average measure of the prevalence vector z and of cycle characteristics. In this and every non-cycle cost-based pricing regime, the retail price depends on the current rack price and city, month, and year dummy variables.

Specification (2) is the base specification carried forward to later sections. It allows the switching probabilities to vary with the market's position in a cycle. As undercutting pushes the retail price closer to rack, the incentive to relent grows. That is, λ^{UU} should fall and λ^{UR} should rise. Conversely, when relenting pushes the price high above marginal cost, the switching probabilities should favor a shift to a new undercutting phase (λ^{RR} falls, λ^{RU} rises.) I measure cycle position as $POSITION_{mt} = RETAIL_{m,t-1} - RACK_{mt}$, the difference between lagged retail price and current rack price. I add "$POSITION$" to the W^R and W^U matrices in specification (2).

Specification (3) is similar to (2) but adds city, month, and year dummy variables to the switching probabilities out of the cycle regimes and the price change equations (i.e. in X^R, X^U, W^R and W^U) for additional flexibility.

Table 2, which shows within-regime results and switching probabilities, already hints at the asymmetry. All three specifications give similar results. In specification (1), the expected price change in the relenting phase is almost twice as large as that in the undercutting phase (2.40 cpl versus −1.26 cpl). Moreover, the probability of remaining in a relenting phase a second consecutive period is only 23% ($\lambda^{RR} = 0.23$) but the probability of remaining in an undercutting phase for a second period is 59% ($\lambda^{UU} = 0.59$). Switching between relenting and undercutting phases is common but rarely does a market switch from one of the cycle regimes to a non-cycle regime. Similarly, when in a non-cycle regime, a market continues in the non-cycle regime the next week with a 95% probability and sticky pricing prevails just over half the time.[16,17]

Specifications (2) and (3) further show that continued undercutting becomes decreasingly likely as prices get close to marginal cost ($\frac{\partial \lambda^{UU}}{\partial POSITION} = 0.04$). The probability of relenting as $POSITION$ falls increases a similar amount. If starting in a relenting phase, the probabilities change only slightly, as the probability of having two consecutive relenting phases is always quite small.

Using the formulae and results above, one can estimate the prevalence of cycles and their characteristics. I report results in Table 3.

In specification (1), price cycling is prevalent in 43% of sample periods. The relenting phase accounts for 13% and the undercutting phase for 30%. Sticky pricing is also very prevalent, occurring in 30% of the sample. The latter result is not simply due to flat rack prices: conditional on sticky pricing, the rack price changed over 70% of the time, by 0.54 cpl on average. Cost-based pricing is in 28% of the sample. Specifications (2) and (3) again yield similar results.

But are these cycles asymmetric and repetitive as the theory of Edgeworth Cycles would suggest, or is it simply volatile prices that are being captured? To differentiate, I describe the shape of the cycles along three main dimensions of interest – cycle period, amplitude, and asymmetry.

Along the horizontal dimension, the period of a typical cycle at 3.75 weeks using specification (1). This consists of a relenting phase of 1.30 weeks followed an undercutting phase of 2.44 weeks on average. The relenting phase duration is close to one as predicted.[18]

Vertically, the amplitude of the cycle is 3.13 cpl (relenting phase calculation).[19] This represents a large impact on firm margins: the amplitude of this price cycle is 60% of the average retailer markup in cycles, or 86% of the average markup at the bottom of the cycle.

The asymmetry of the cycles is their most defining feature. The asymmetry measures are significantly different than one at a high level of significance. Undercutting phases are almost twice as long as relenting phases and average price increases in cycles are almost twice as large as decreases.

Cycles are also repeated over and over – the average cycling spell lasts 14.51 weeks. The average duration of a non-cycle price regime, for comparison, is 19.3 weeks. Specifications (2) and (3) again find very similar results.

I conclude that the price cycles are tall (relative to markups), relatively fast, and highly asymmetric in the direction consistent with Edgeworth Cycles.

Beyond the descriptive national averages, we observe much heterogeneity across cities and over time. Based on specification (1), I report in Table 4, for each city, the prevalence of cycling activity over the full sample (column 1), each of its component phases (columns 2 and 3), cost-based pricing (column 4) and sticky pricing (column 5). In the last two columns I report the prevalence of price cycling in the most active year (maximum) and least active year (minimum). Cycling ranged from a high of 84% in Toronto to a low of 15% in St. John's. There is also heterogeneity in the prevalence of sticky and cost-based pricing and in cycle characteristics.[20] In the following section, I address this heterogeneity.

VII Industry Structure and Price Cycles

The theory of Edgeworth Cycles suggests that a greater penetration of small firms will 1. increase the prevalence of Edgeworth Cycles, 2. not affect the duration of the relenting phase, 3. shorten the undercutting phase, 4. shorten the cycle period, and 5. make the cycle less asymmetric. The second objective of this article is to establish each of these empirical relationships exist.

Since there are four large integrated firms in most markets (that differ across markets), variation in the penetration of small firms is well captured by the fraction of stations *not* operated by the largest four firms.[21] I call this measure $SMALLINDEX$, equal to one minus the four firm concentration ratio.[22]

Demand side factors may also be important to the "success" of price cycling activity. Greater local market size increases the short term demand gain from undercutting and should lead to more prevalent cycling. Where retail outlets are densely situated, consumers can more easily search on price, which again increases short term gain and should lead to more cycling. I include the driving age population (in thousands) per retail outlet, POP/RO, and the spatial density of retail outlets (per square km.), $DENSITY$, to capture these effects.

Summary statistics for these variables are reported in Table 1.

In specification (4), I add $SMALLINDEX$, POP/RO, and $DENSITY$ to the base specification (2), which recall includes $POSITION$.[23] The competitive variables enter three ways: 1. into the X^R and X^U matrices in the price change equation (1) so they covary with the expected price changes α^R and α^U and the vertical dimensions of the cycle, 2. into the W^i matrices in the switching probability equation (4) so they covary with the λ^{ij}, with the horizontal dimensions of the cycle and with regime prevalence, and 3. into V in the non-cycle regime switching equation so they covary with γ, the fraction of sticky prices.

Because $POSITION$ always changes along the cycle path, simulation techniques are used to calculate the impact of the competitive variables on cycle prevalence and characteristics. In each cell of Table 5, I report the partial derivative of the characteristic listed in the given *row* with respect to the competitive variable listed in the given *column*. Bootstrapped standard errors are in parentheses.[24] I also report the pseudo P-value equal to the fraction of simulation runs (out of 1000) that resulted in the opposite sign. All estimates in the table are taken from specification (4).

First, I find when there is a *greater* penetration of small firms, there is a substantially *higher* prevalence of asymmetric price cycles. The coefficient on $SMALLINDEX$ is statistically significant and all 1000 simulations reported the same sign. An increase in $SMALLINDEX$ of 0.035, or 10% from its mean, is associated with an increase in the prevalence of price cycling by 0.036, or 8.6% of its mean. Cost-based pricing also becomes a little more common. Sticky pricing, in contrast, is much less common with more small firms. As predicted, Edgeworth-like price *cycles* are more prevalent and sticky prices less common when there is a greater penetration of small firms.

In terms of cycle characteristics, each result is consistent with the theory of Edgeworth Cycles. I find a statistically significant and negative relationship between $SMALLINDEX$ and the duration of the undercutting phase – that is, more rapid undercutting phases with more small firms. I find *no* relationship between $SMALLINDEX$ and the length of the relenting phase. As a result, I find a significantly shorter cycle period with more small firms.

The defining feature of the price cycles is their asymmetry. As predicted by the theory, I find a negative relationship between $SMALLINDEX$ and both measures of asymmetry significant at the 5% level.

The theory does not predict how small firms affect the amplitude of the cycles, and many different amplitudes are possible. In my sample, I simply note that amplitude is positively related to the penetration of small firms.

As expected, greater market size and higher outlet density are associated with a significantly greater prevalence of cycling activity and significantly less sticky pricing. A 10% increase in the driving age population per outlet from its mean is associated with an increase in cycling prevalence of 0.024 (5% from the mean) and a decrease in the prevalence of sticky prices by a similar amount. A 10% percent increase in outlet density from its mean is associated with an increase in cycling prevalence by 0.012, or just 2.8% from the mean.

I find that greater market size is also associated with significantly faster and less asymmetric cycles. The relationship between density and cycle characteristics all have the correct sign but are generally insignificant and (adjusting for means) much weaker than $SMALLINDEX$ or POP/RO.

To get a sense for what typical price cycles look like under different environments, I report predicted cycle and non-cycle characteristics in Table 6 for different values of $SMALLINDEX$ and (POP/RO). Given its small effect, $DENSITY$ is set equal to its mean in each case. As one reads left to right, $SMALLINDEX$ and POP/RO each increase by one standard deviation per column. Column (b) corresponds to the means.

As markets become larger and less concentrated, there is a much higher prevalence of retail price cycles, from only 29% of periods in the first column up to 64% of periods in the last. Sticky pricing activity falls as rapidly.

The duration of the relenting phase is roughly constant while the undercutting phase grows shorter. As a result, retail price cycles that are sharply asymmetric when markets are small and concentrated become less asymmetric as markets grow and small firms become more influential. Cycles also become faster and taller.

Checking for robustness, I reestimated the model with other measures of concentration including the five and six firm concentration ratios, the Herfindahl index, and the actual percentage of major operated outlets in place of CR_4 in the $SMALLINDEX$ calculation. Results are similar in each case. I also find similar results for midgrade and premium gasoline, as these prices are generally set a standard amount above regular. I find no cycles in diesel fuels in any market, however, consistent with the nearly zero market share independents have in diesel in urban markets. Finally, I do not find an additional impact on cycling by department or convenience store chains over and above that of traditional independents, but power is limited due to the high cross-sectional correlation between these and traditional independents.

VIII Conclusion

In this article, I present evidence that retail price cycles, similar to the theoretical Edgeworth Cycles in appearance and behavior, are a real and prevalent phenomenon in Canadian retail gasoline markets. I identify repeated, asymmetric price cycling behavior in 43% of periods in the sample, sticky pricing in 30%, and cost-based pricing in 27%.

The theories of Edgeworth Cycles further suggest that a greater penetration of small firms should lead to more cycling activity and less sticky pricing. Moreover, the duration of the relenting phase of the cycle should be unaffected, the duration of the undercutting phase shortened and therefore the cycles should be more rapid and less asymmetric. Allowing the horizontal and vertical dimensions of the cycle to vary with a small firm concentration variable, I confirm each of these relationships. My results are robust when controlling for market size and outlet density and when using alternate measures of concentration.

The cycles in these markets have previously not been well understood. The large price jumps are often widely reported in the popular press but, given the lack of obvious justification in wholesale prices, have led to a popular impression that firms are covertly colluding. Meanwhile, the many small price decreases that bring prices back down each time easily go unnoticed. In this article, I bring the full path of the cycle into focus and analyze its entire structure, rather than just the most easily visible component. I find the phenomenon, consistent with an Edgeworth Cycles explanation, is commonplace in many Canadian cities. Whether or not cycles will return to the U.S. or to other markets remains to be seen.

Notes

[1]The cities and time periods are chosen as good examples of each pattern. The different period for St. Johns is chosen to emphasize price stickiness in a period of volatile rack prices.

[2]Consistent with the literature, I use the average spot rack price for unbranded regular gasoline across major wholesalers as my measure of the wholesale price. Although only independents buy at rack, the rack price represents the wholesaler's opportunity cost of wholesale gasoline (Lerner[1996]) and, given close and readily available U.S. sources of wholesale gasoline, can reasonably be modeled as exogeneous (Hendricks[1996]). Any discounts off the rack price are small and, more importantly, not time variant or keyed off retail prices.

[3]On average over the sample period, CDN$1 = US$0.70.

[4]The null hypothesis of the K-S test is that the distribution of retail price increases is the same as that of (the absolute value of) retail price decreases.

[5]This model is appropriate if, for example, consumers randomize across equally-priced retail outlets (or choose the closest one) but those stations are owned in different numbers by firms.

[6]The setting lends well to Canadian gasoline retailing markets. Gasoline is relatively homogeneous, frequently purchased, and firm level demand is highly-elastic. Switching costs and menu costs are very low. Discussions with regional managers also suggest that an alternating moves description is appropriate. Like previous work and consistent with regular consumer behavior, I treat gasoline as a nondurable good to the end user.

[7]Like most models involving multiple equilibria, unanticipated shocks that switch firms from one equilibria to another come from outside the model. Here, a shock that increases the asymmetry in firm size by enough to make focal prices unavailable will necessarily force a switch to Edgeworth Cycles, but the reverse is not necessary. Since the only renegotiation-proof equilibrium is a focal price one, it is plausible in practice (but still outside the model) that shorter periods of cycling and non-cycling may occur when firm asymmetry approaches the lower bound of what would just allow a focal price equilibria, as firms noisily attempt to move between the two equilibria.

[8]The theory does not make a strong prediction as to how small firm penetration impacts amplitudes. Many "top-of-the-cycle" prices are possible.

[9]While the large literature on asymmetric rack-retail passthrough in the U.S. and elsewhere (Borenstein, Gilbert, & Cameron[1997] and many others) typically assume reversion to a single long-run steady-state retail price (unlike what occurs in an Edgeworth Cycle) and are conducted for markets known *not* to exhibit retail price cycles, the existence of cycles suggests a new potential source for passthrough asymmetry.

[10]Slade[1987, 1992] examines an isolated price war in Vancouver in the summer of 1983, postulated to have been triggered by a shift in demand. I limit my review here to papers about repeated, asymmetric Edgeworth-like price cycles.

[11]Also to reduce computational burden, I do not elect a separate regime for adjustments in sticky prices. An examination of the data suggests that adjustments are triggered by movements in the rack price and reestablish a standard markup by market and year. Thus, placing cost-based and sticky pricing into a single regime helps classify these adjustments into cost-based pricing. The model does this very well. The three-top-level framework reduces the number of free switching probabilities from 20 to 7 vis-a-vis a five-top-level regime model and reduces the number of parameters by as much as 299. The largest specification has 212 parameters. Convergence on a 700MHz processor takes approximately three days.

[12]The model is free to classify, for example, a (small) price increase or zero price change as part of the undercutting phase if the history of play suggests it.

[13]M.J. Ervin & Associates continued the survey the week after the federal ministry discontinued it using mostly the same methodology and stations. The stations are branded self-service stations and number from from four to ten depending on the city. Rarely, a station is replaced because of exit or other reasons. The Ontario Ministry of Energy survey is more comprehensive but the stations are again the same each week.

[14]Rack price data from Oil Price Information Service yields similar results. There are between one and four wholesalers for any rack point. For cities that are not rack points, the nearest rack point is used.

[15]Any bias would work towards a negative correlation between small firm penetration and amplitudes. I find the opposite, and take my results as conservative. Note that the theory is silent on the effect of small firms on amplitudes so I do not rely on this finding as evidence of any hypothesis.

[16]I test for serial correlation in the errors as suggested by Hamilton[1994]. The test statistic for serial correlation is 4.56, below the $\chi^2(3)$ critical value of 7.81.

[17]I reestimated the model with the current rack price and six lags of it in each within-regime equation

(except sticky prices). This controls for possible lags in the rack-retail passthrough rate, although Hendricks[1996] shows rack-retail passthrough occurs quickly. The sum of the rack coefficients is not significantly different from zero in each of the two cycle regimes. In the cost-based subregime, the coefficient is 0.937 showing that 80.0% of rack price shocks is passed through in the same week and an extra 13.7% is passed through in the following six. See Borenstein & Shepard[2002] and references for a discussion of passthrough lags in the U.S.

[18]Due to averaging across firms, one cannot expect to find an estimate equal to one.

[19]As the two measures of amplitude are never significantly different from one another in any given specification, I report only the relenting phase calculations in the table.

[20]A form of price regulation existed for short periods in three of the sample cities. Beginning at the end of 1996, a below cost selling law was instituted in Montreal and Quebec under which retailers were prohibited from selling at a price below the rack price (adjusted for taxes and transportation costs). The law followed an extremely unusual downward price spike where markups went negative. I do not find evidence of a structural change in the prevalence of cycles or their characteristics attributable to the regulation, although characteristics were changing on a longer term trend. Also, Halifax was deregulated in mid-1991 but continued to experience sticky pricing for over a year later. It is unlikely then that the regulation actively prevented cycles. I report results using the full sample but the main results on the influence of small firms do not change when the regulated periods are dropped. Descriptive measures of average prevalence of cycles and sticky prices are marginally lower with the restricted sample as expected. Data was also available for Charlottetown but was not included in the analysis, since this market was regulated throughout the sample period.

[21]A large firm is one with many retail outlets in a given market and time.

[22]There is little concern over endogeneity of the concentration variable in this setting. SMALLINDEX is an explanatory variable only of price changes, never of price levels.

[23]Adding a full lag structure on rack prices does not appreciably affect results.

[24]The standard errors capture both the error in the MLE estimates and also the error inherent in the price generation process. The former is relevant. To test the degree of intrusion of the latter, I compare estimates from the core estimation that do not depend directly on switching probabilities with those from the simulations (such as within-regime price changes α^i and sigma σ). The standard errors in the simulation

(at 100,000 periods) are slightly larger than those from the core parameters and therefore standard errors reported in the tables are taken as conservative.

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