Learning to coordinate: A study in retail gasoline*

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Abstract

Theories of collusion have long focused on how collusive agreements are implemented, yet are silent on how they are initiated. This paper presents a novel empirical study of the initiation of tacit collusion. We exploit a unique dataset from a metropolitan retail gasoline market that contains the universe of station-level prices for 15 years. We study the long-run evolution of conduct and uncover the initiation of a tacitly collusive pricing structure. The structure involves focal points that coordinate stations? daily price changes. We document a series of price experiments used by the market leader, BP, to create the focal points. The experiments allow BP to communicate its collusive intentions and facilitate learning among its competitors over their collective willingness to coordinate. Once implemented, the pricing strategy eventually improves margins by 75%, creates price stability, and enhances firms? ability to resolve conflicts.

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1 Introduction

Few research programs in economics have had as large a policy impact as the program on collusion. At least since Stigler (1964), theories of collusion have proven invaluable for anti-trust policy. They shed light on market primitives that facilitate collusion, and help identify situations where cartels breakdown. Ultimately, these insights inform the design of immunity and leniency programs used to detect collusion. Theory also provides an essential lens for interpreting findings from retrospective, in-depth case studies into prosecuted cartels. Such studies reveal how colluding firms behave in practice, which in turn motivate the development of richer theories of collusion, and spur policy innovation.

While the literature has produced numerous policy-relevant insights, there remains an important yet uninformed question: in the absence of direct communication, how is collusion initiated? Indeed, the following quote from Green and Porter (1984) is still relevant today:

> *"It is logically possible for this agreement to be a tacit one which arises spontaneously. Nevertheless, in view of the relative complexity of the conduct to be specified by this particular equilibrium and of the need for close coordination among its participants, it seems natural to assume here that the equilibrium arises from an explicit agreement."* (Green and Porter, 1984 p.89)

That is, Green and Porter (1984), like virtually all theoretical and empirical studies of collusion, are largely silent on where collusive agreements come from. Green, Marshall and Marx (2015) conclude this in their recent review of the literature on tacit collusion. In their words, while much is known both in theory and in practice about how collusive agreements are *implemented*, little is know about how they are *initiated*.

In this paper, we study the initiation of a tacitly collusive pricing structure. We exploit a novel dataset that consists of the universe of station-level price data from a metropolitan retail gasoline market for 15 years, from 2001 to present day. The richness of these data, and the length of time they span, permit a unique opportunity to study the evolution of oligopoly pricing, coordination, and conduct in an industry that is constantly subject to anti-trust investigations into price fixing and collusion.

We provide an overview of the market and data in Section 2. We characterize a concentrated urban market whereby the largest four firms own and operate two-thirds of the stations. The remaining one-third of stations are independently operated. Such asymmetry is common across gasoline markets worldwide (Eckert, 2013). In our market, there is a dominant retailer, British Petroleum (BP), who runs more than 20% of the stations. We document the evolution of margins from 2001 to 2015, which exhibit remarkable growth starting in 2010. Retail margins eventually grow to being 75% higher between 2010-2015 relative to 2001-2009 levels.

Section 3 establishes key facts regarding the evolution of firms' pricing strategies around the time when margins start growing. We document the emergence of coordinated, cyclical pricing strategy that is characterized by two focal points: (1) Thursday price jumps, whereby stations' prices in the market collectively rise by 15-20 cents per litre (or roughly by 20%) every Thursday; and (2) -2 cpl daily price cuts, whereby stations coordinate on -2 cpl daily price cuts for 6 days in a row between the Thursday price jumps. These focal points emerge around the start of 2010, precisely when profit margins begin to rise. The focal points are stable for more than five years after they emerge.

In Section 4, we exploit the richness of the data to uncover the mechanisms through which the tacit price coordination is initiated. We show how the market leader, BP, uses price experiments to test Thursday price jumps and -2 cpl price cuts before implementing them as focal points. We argue that the experiments facilitate learning among the retailers over their collectively willingness to coordinate on daily price changes. They also allow BP to communicate its intentions to implement the focal points to coordinate market prices. We further empirically show that beyond retail margin enhancement, the initiated coordinated pricing strategy yields price stability, and allows them to easily resolve conflict.

The timing of BP's experiments also yields a new insight for the literature on collusion. In particular, we show that BP's experimentation is used to resolve a price-war between BP and its main rival, Caltex. To our knowledge, our finding of experimentation, and not punishment, as a response to price wars among oligopolists engaged in tacit price coordination is novel.

Overall, the experimentation process spans two and a half years. Given the gradual nature of experimentation and implementation of the focal points, we believe that the experiments tacitly initiated price coordination. A maintained caveat, however, throughout our study is we cannot rule out unobserved forms of explicit communication among the firms (e.g. phone calls) that may have also helped initiate price coordination.

Section 5 concludes. Here, we discuss new insights arising from our study for policy. This includes how firm size asymmetry can help facilitate price leadership and experimentation, and hence tacit collusion. This contrasts with conventional anti-trust concerns regarding firm size symmetry and incentives to collude (Ivaldi et al., 2003). Our paper also highlights how Big Data can be used to detect collusion at the initiation stage. This again yields an interesting contrast with conventional policy practice, where the focus is on collusion detection during the implementation phase, more specifically through cartel breakdown and price wars.

Related literature. This paper adds to a collection of case studies that examine the practices of prosecuted cartels using court documents and data. These ex-post studies on cartel implementation include Clark and Houde (2013) (gasoline price fixing in Quebec), Asker (2010) (bidding ring with stamp dealers), Genesove and Mullin (2001) (U.S. Sugar Institute), Roller and Steen (2006) (Norwegian Cement), Pesendorfer (2000) (bidding ring with milk suppliers), and Porter (1983) (railroads).[1] Like these studies, we develop an in-depth, forensic examination of pricing practices of an oligopoly engaged in competition-reducing behavior. We differ, however, in terms of our focus on tacit and not explicit collusion, and our unique ability to study cartel initiation from an ex-ante perspective.

We also relate to empirical studies that use more aggregate and lower-frequency data to test for tacit collusion and coordinated effects, and that identify aspects of market structure that give rise to them. These papers include Miller and Weinberg (2016) (mergers), Lewis (2015) and Knittel and Stango (2003) (focal points), Lewis (2012) and Wang (2009) (price leadership), Ciliberto and Williams (2014) and Busse (2000) (multi-market contact), Borenstein and Shepard (1996) and Slade (1992) (demand fluctuations and price wars). Our focus on the long-run transition from competition to collusion, and dominant firms' use of price leadership and experimentation to initiate tacit collusion, represents a significant departure from this prior work.

Finally, we relate to experimental, lab-based studies on the dynamics of learning and coordination in oligopoly. These include Huck et al. (1999), Offerman et al. (2002), Apesteguia et al. (2007), among others. An overarching theme of this work is that lab participants engaged in repeated Cournot games tend to converge to perfectly competitive outcomes. However, a recent study by Friedman et al. (2015), which permits a much longer time horizon of repeated interaction, shows that repeated lab-based Cournot games eventually transition from competition and converge to collusion. Our field-based study of learning and coordination in oligopoly most closely relates to this recent paper.[2] In the context of price competition, we also highlight a long-run convergence to a collusive outcome, that is preceded by ten years of comparatively competitive pricing.

2 The market and data

The context is Perth, Australia, a city of 1.7 million people. As with many cities worldwide, Perth has a concentrated retail gasoline market. Four major oil firms (BP, Caltex, Mobil and Shell) dominate refining, importing and distribution of fuel. Moreover, the oil majors directly or indirectly exert control over retail pricing across their large gasoline station networks. Two nationally-dominant supermarket chains, Coles and Woolworths also compete in the market

[1] See Levenstein and Suslow (2006) for an overview of many other ex-post studies of prosecuted cartels.

[2] The only other studies from the field on learning in oligopoly that we are aware of are Doraszelski, Lewis and Pakes (2016) and Yan (2016). These papers develop structural models of competition and learning with lower frequency (e.g., monthly) data. They do not consider issues of leadership, experimentation or transitions between competitive and collusive conduct.

and directly set their stations' retail prices.[3] The remaining stations are operated by independent station owners.

The market has a gasoline price transparency program called Fuelwatch. It was introduced by Western Australia's state government on January 3, 2001. The program requires firms to submit, via CSV web-uploads, all of their station-level prices to the government each day before 2pm. When stations open at 6am the next day, they are required by law to post the submitted prices from the previous day. Prices are then subsequently fixed at these posted levels for 24 hours.

Using the station-level price data, the government posts online today's prices for every gasoline station in the market. In addition, starting at 2:30pm each day, the government posts online tomorrow's prices for all stations.[4] The program aims to reduce consumers' costs of searching for gasoline prices. However, in Byrne and de Roos (2015), we document that only 0.5%-1% of households in the market use the website. Demand-side search frictions likely remain an important market primitive despite the policy.[5]

Fuelwatch has important implications for our study of tacit collusion. The program's design implies that price competition occurs at daily frequencies, and that firms effectively set prices simultaneously. Moreover, the program allows firms to perfectly monitor each others' prices over time. Finally, firms faces common cost shocks each day arising from fluctuations in crude oil prices on the world oil market. These features of the market together imply that our setting maps well into the benchmark repeated games framework for studying collusion: simultaneously Bertrand price competition with perfect monitoring.[6]

2.1 Data overview

Our dataset consists of the universe of daily station-level price observations from January 3, 2001 to December 31, 2015 for 661 stations in the Perth metropolitan area. These data are freely available for download from www.fuelwatch.gov.au. In total, we have 1,760,805 retail gasoline price observations for regular unleaded fuel. Importantly, each retail price is linked to a station and brand. This allows us to accurately track station entry/exit and the evolution of oil majors' and supermarkets' station networks over time.

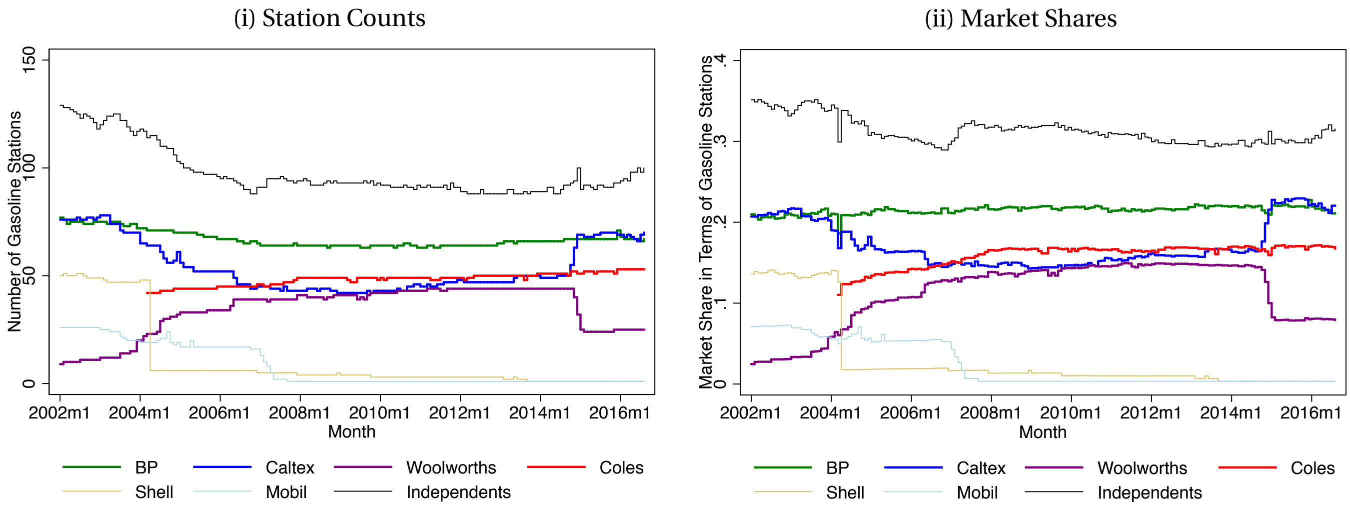
[3]For the majority of our sample, the supermarkets offer 4 cents per litre gasoline price discounts in the form of "shopper dockets" that apply if a customer purchases at least $30 in groceries.

[4]Between 2pm and 2:30pm, submitted prices undergo a verification check. From our discussions with the state government we understand that compliance with the Fuelwatch program is nearly perfect. Figure A.1 in the Appendix provides a snapshot of the Fuelwatch website.

[5]See Chandra and Tappata (2011) or Schmidt-Dengler et al. (2016) for evidence on the importance of search frictions for generating price dispersion in retail gasoline markets.

[6]In contrast, repeated pricing games where firms have private information of their actions like Green and Porter (1984) are less applicable in our setting.

Figure 1: Size and Market Shares of Oil Majors, Supermarkets and Independents



We match the daily terminal gate price (TGP) for wholesale gasoline to the retail price data. The TGP is a local spot price for wholesale gasoline which includes a margin for upstream suppliers. We use the lowest TGP each day across Perth's six gasoline terminals as a proxy for stations' marginal costs.[7] Daily TGP data are also available from the Fuelwatch website from January 19, 2002.

Figure 1 illustrates the evolution of market concentration. The figure plots firms' size and market shares from 2002-2015, where both measures are constructed from station counts. From 2001-2004, BP, Caltex, Shell and Mobil dominate that market, operating 65% of all stations. The distribution of market shares changes dramatically in March 2004 as Caltex, Shell and Mobil begin to sell off their stations to the supermarkets, Coles and Woolworths. As the figures show, Coles is a new entrant in 2004. From 2005 onwards, market shares are relatively stable with BP emerging as the largest firm (22% share), followed by Caltex, Coles and Woolworths (16%, 16% and 13% shares, respectively).

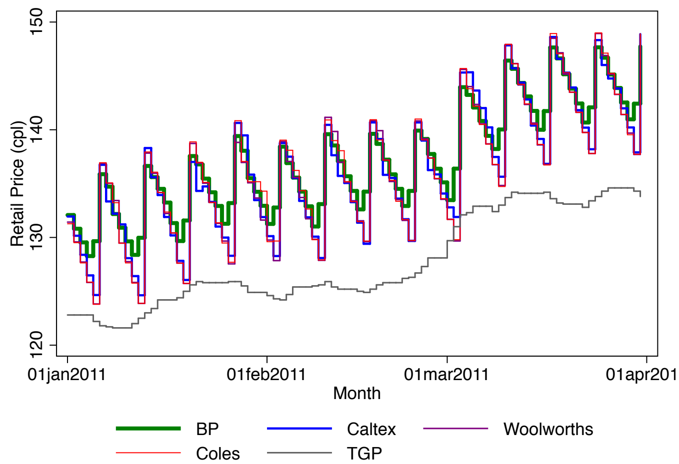
Turning to retail pricing, Figure 2 depicts an asymmetric cycle that characterizes retail pricing for much of our sample.[8] Prices infrequently jump (the *relenting* phase), with daily price cutting ocuring between the price jumps (the *undercutting* phase). The figure also shows that the level of the price cycle trends over time with wholesale fuel prices (TGP).

For the analysis that follows, it is helpful to define price jumps and cycles at the station and

[7]We abstract from time-invariant marginal cost components related to quantity discounts, shipping costs, wharfage fees, and insurance. In using TGP to measure price-cost margins, we follow the standard practice in the empirical literature on gasoline retailing of using a market-specific marginal cost measure. Firm-specific cost data are highly proprietary and unavailable (e.g. Borenstein and Shepard (1996), Noel (2007), Lewis (2009)).

[8]Retail gasoline price cycles exist in many cities around the world, including those in U.S., Canada, Australia, and Europe (Noel, 2011).

Figure 2: Retail Price Cycle



market-level:

(i) A *station-specific price jump* occurs at station i on date t if $\Delta p_{it} \geq 6$ cpl, where p_{it} is the retail price and $\Delta p_{it} = p_{it} - p_{it-1}$.

(ii) A *station-specific price cycle* commences on date t if $\Delta p_{it} \geq 6$ cpl. This is denoted as "day 1" of the station-specific cycle. Days $2, 3, 4 \ldots$ of the cycle correspond to the relenting phase until the next station-specific price jump occurs and a new cycle begins.

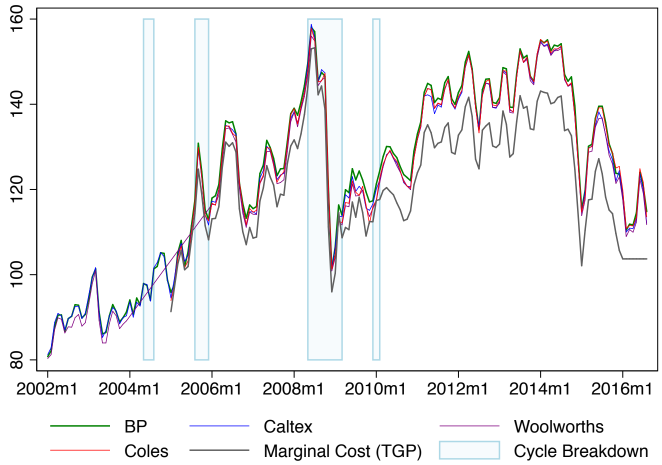
(iii) A *market cycle* commences on date t if either $\text{median}_i(\Delta p_{it}) \geq 6$ cpl, or $\Delta p_{it} \geq 6$ for at least one station and the 60^{th} percentile of Δp_{it} is positive. This is denoted as "day 1" of the market cycle.

(iv) Station i is a *cycling station* in year y if $\Delta p_{it} \geq 6$ cpl at least 15 times in year y.

Part (iv) of the definition acknowledges that not all stations in the city's metropolitan area are cycling stations. However, the majority of stations exhibit price cycles: 505 of the 661 stations are cycling in at least one year in the sample. All of our main empirical results below are robust to variations on the definitions of price jumps and price cycles at the station and market level.

Among cycling stations, the average station-level daily price jump is 11.88 cents per litre (cpl) (s.d.= 3.77 cpl), while the average daily price cut during the undercutting phase is -1.48 cpl (s.d.=2.06 cpl). The average retail margin on price jump days is 15.09 cpl (s.d.=4.74 cpl), and is 6.59 cpl (s.d.=5.36 cpl) on price cut days. Cycle length, which is the number of days between price jumps, is 11 days on average (s.d.= 3.7 days).

Figure 3: Monthly Retail Prices, Costs, and Margins



3 15 years of retail pricing

This section documents the evolution of retail pricing between 2001 and 2015. It establishes a set of key facts regarding a substantial rise in margins, and a remarkable shift in tacit price coordination, at the start of 2010.

3.1 Retail prices, costs, and margins

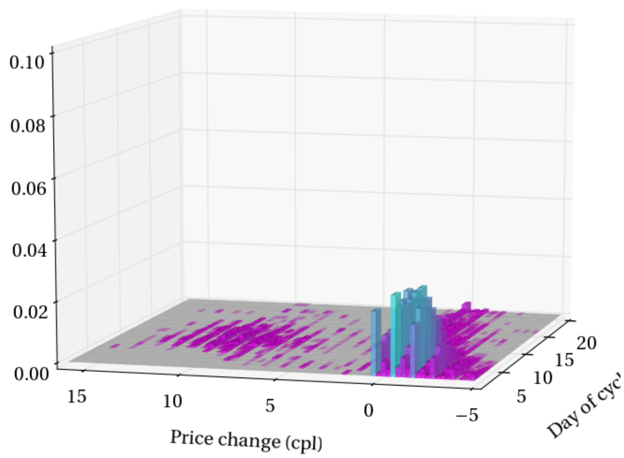
We begin with Figure 3, which plots monthly average prices for BP, Caltex, Coles and Woolworths, and the wholesale TGP. The figure has two distinguishing features. First, price-cost margins start growing at the start of 2010. Visually, this can be seen from the widening gap between retail prices and TGP. Before 2010, the average monthly margin in months with a stable price cycle is 4.96 cpl (s.d.=1.23 cpl). After 2010, it is 9.99 cpl (s.d.=2.48 cpl), which represents a 100% increase in price-cost margins. This growth partly reflects an upward trend in retail gasoline margins across the country. However, in Appendix B, we show that the difference-in-difference estimate of Perth's retail margin before and after January 2010 relative to other major cities in Australia with cycles is 3.65 cpl (s.d.=0.97). That is, margins grew locally in Perth by 74% at the start in 2010.

The figure's second notable feature is that the price cycle collapses four times between 2001 and 2010, as indicated by the shared blue areas. Three of the collapses correspond to aggregate shocks: Coles supermarket entry (2004Q1), Hurricanes Katrina and Rita (2005Q3), and a global crude oil demand shock (2007Q4-2008Q3).[9] The fourth, short-lived, cycle collapse occurs at

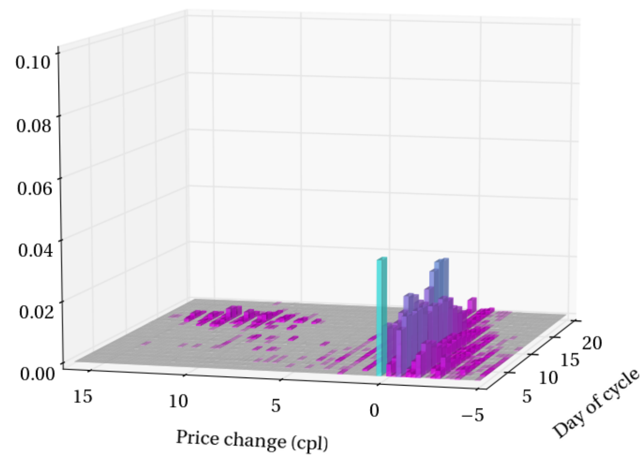
[9]See Hamilton (2009) for an extensive discussion the drivers of the 2007-08 global crude oil demand shock. These include a fall in Chinese oil demand, and the influence of speculators on crude oil markets.

Figure 4: Distribution of Price Changes Across BP, Caltex, Woolworths and Coles Stations

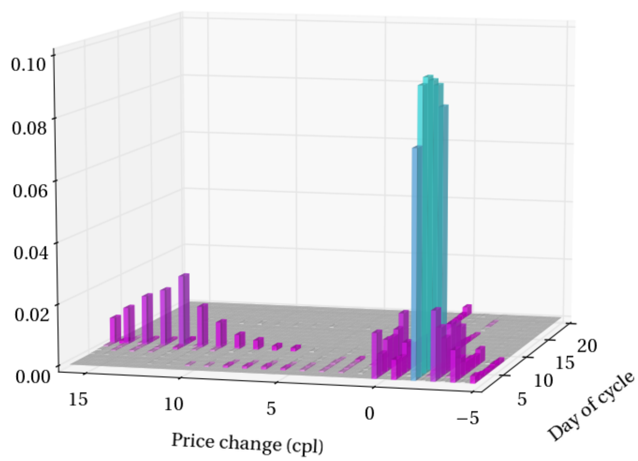
(i) 2001-2003



(ii) 2006-2007



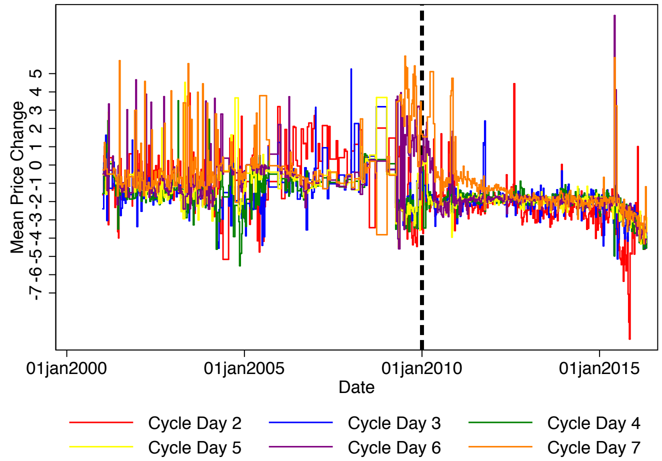
(iii) 2009-14



the start of 2010. This corresponds to a price war between BP and Caltex. Below, we discuss the price war in detail; it precipitated the large rise in price-cost margins and shift in tacit price coordination (discussed momentarily in Sections 3.2 and 3.3).

Finally, we note that in contrast to the pre-2010 period, the price cycle is stable for the entire 2010-15 period. Importantly, this includes another crude oil price shock in 2015 due to a global oil supply glut. Unlike the similar-magnitude 2007-08 oil price shock, the cycle remains stable around the 2015 oil price shock. In this sense, Figure 3 also highlights enhanced pricing stability in the 2010-15 period.

Figure 5: Average Daily Price Cuts Across BP, Caltex, Woolworths and Coles Stations



3.2 Coordination on price cuts and jumps

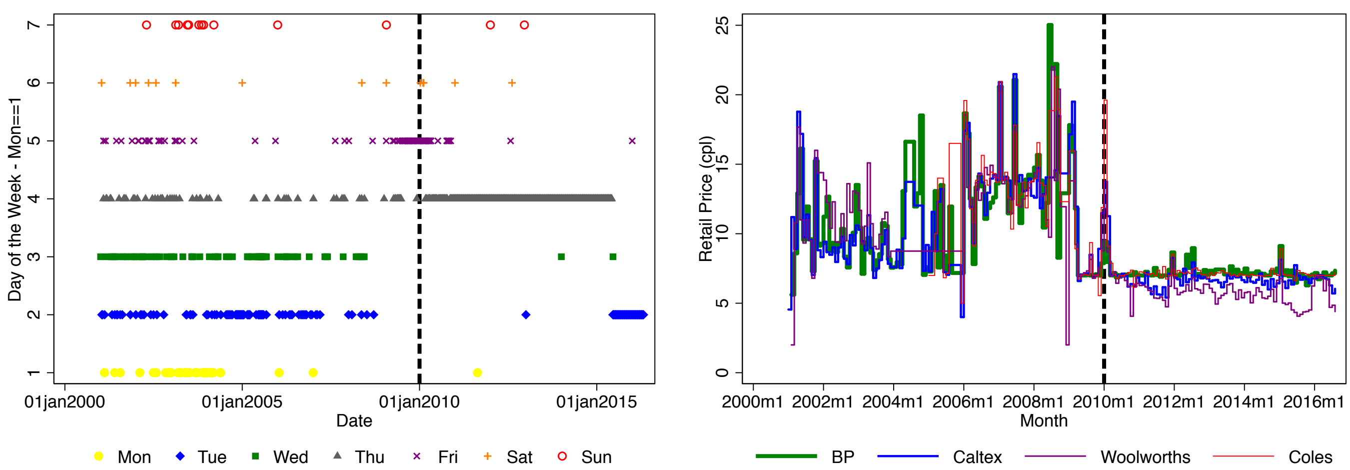
The next set of facts relate to the evolution of price coordination. We start by plotting the joint distribution of daily price changes and day of the price cycle for the dominant firms, BP, Caltex, Woolworths and Coles. Panels (i)-(iii) of Figure 4 present the joint distributions for three periods when the price cycle is stable: 2001-03, 2006-07, and 2009-14. In each panel there are two probability masses in the distribution. The bottom right mass corresponds to the distribution of price cuts. The top left mass corresponds to the distribution of price jumps.

The figure reveals a dramatic change in price coordination in 2009-14. The change in the distribution of price cuts immediately stands out. In both 2001-03 and 2006-07, price cuts are relatively disperse between -1 cpl and -4 cpl. In 2009-14, however, the mass of price cuts spikes at -2 cpl. This reveals our first focal point of interest: **-2 cpl price cuts.**

Figure 4 further reveals two important differences in the distribution of price jumps in 2009-14. First, there is a leftward shift in the distribution of price changes among price jumps in panel (iii). That is, price jumps tend to be larger in 2009-14. Second, the dispersion in price jump timing (by cycle day) collapses in panel (iii). Whereas panels (i) and (ii) exhibit dispersion in price jump timing, panel (iii) exhibits virtually no dispersion in the timing of price jumps. They all occur on day seven of the cycle, implying one-week price cycles. As we will see, this change in the distribution of cycle length is due to the emergence of a second focal point in 2010: **Thursday price jumps**.

Figure 6: Evolution of the Timing of Price Jumps and Cycle Length

(i) Timing of Market-level Price Jumps by Day of Week (ii) Monthly Average Cycle Length by Firm



3.3 Inter-temporal dispersion in price cuts and jumps

Further inspection of inter-temporal dispersion of price cuts and price jumps confirms the emergence of -2 cpl price cuts and Thursday price jumps as focal points starting in 2010. Figure 5 highlights the former focal point. It plots the daily average price cut across all stations for each day of the undercutting phase. In computing these daily average price cuts, we focus on days 2-7 of station-level price cycles. Or in other words, the first 6 days of the undercutting phase. The dashed black line in Figure 5 marks the start of 2010, when retail profit margins begin to grow rapidly.

The figure reveals a sharp decline in inter-temporal dispersion of price cuts at the start of 2010. Prior to this decline, we find relatively large dispersion in price cuts within each cycle day for ten years between 2001 and 2010. In addition, we see the magnitude of price cuts differ across days 2-7 of the cycle. However, within a matter of weeks at the start of 2010, we find inter-temporal dispersion in price cuts collapses. At this point, price cuts across days 2-7 of the cycle converge to -2 cpl focal point, and remain stable for the next five years.

Figure 6 presents inter-temporal dispersion in the timing of price jumps. Panel (i) plots, for each day of the week, a dummy variable that equals one if a market-wide price jump occurs that day of the week. As with price cuts, we again find a rapid decline in inter-temporal dispersion in the timing of price jumps at the start of 2010. Prior to 2010, market-wide price jumps are dispersed across all the days of the week. Between 2010 and 2015, however, we see that virtually all price jumps occur on Thursdays. We further find that mid-way through 2015 a rapid shift in Thursday price jumps to Tuesday price jumps. This corresponds to another price war, which we discuss in detail below.

Panel (ii) of the figure further shows the corresponding collapses in inter-temporal dispersion in cycle length at the start of 2010. Between 2001 and 2010, cycle length varies considerably, ranging from 7 to 14 days. When the Thursday price jump focal point emerges in 2010, we see cycle length rapidly converges to 7 days and remains stable thereafter.

4 Initiating tacit collusion

Section 3 reveals that two focal points emerge after 2010: -2 cpl price cuts and Thursday price jumps. These focal points are unrelated to market primitives, and are associated with a 74% rise in retail margins. On this basis, we interpret the pricing structure that evolves as tacitly collusive.[10] In this section, we investigate the mechanisms used to initiate this tacitly collusive pricing structure.

Our analysis consists of four parts, which naturally order chronologically. Sections 4.1 and 4.2 provide context for the establishment of the focal points. Section 4.1 highlights the importance of price leadership by BP and Caltex in determining pricing conduct in the market to 2009, in re-initiating the price cycle after it collapses in 2004, 2006 and 2008-09 following aggregate entry, supply, and demand shocks. Section 4.2 documents the onset of a BP-Caltex price war in the second half of 2009 that led to a collapse in the cycle and margins.

Section 4.3 describes how BP resolves the price war at the start of 2010, and initiates a new tacitly collusive pricing structure. Here, we emphasize price leadership and experimentation as key mechanisms for establishing focal points (e.g. -2 cpl price cuts and Thursday price jumps), which facilitate tacit collusion. Finally, in Section 4.4, we document three outcomes from collusion: profit margin enhancement, price stability, and firms' improved ability to resolve conflict.

4.1 Aggregate shocks and price leadership

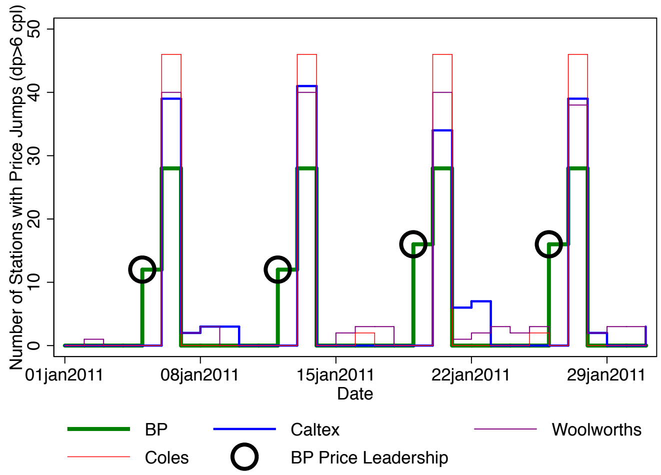
Defining price leadership. Price leadership plays a central role in retail pricing throughout our 15-year sample period. It is fundamental to coordinating price jumps week-to-week, and in re-initiating the price cycle after its multiple collapses between 2001 and 2010.

Before we get into formal definitions of price leadership, we discuss a simple illustrative example in Figure 7 from 2011 that motivates our definition. The figure tabulates, for each date and major retailer, the number of stations engaging in station-level price jumps.[11] The figure highlights weekly price cycles. At this point in time, market-wide price jumps occur on Thursdays. We also see, however, that a subset of 12 to 14 BP stations engage in price jumps on

[10] We are unable to rule out unobserved explicit communication, but the time taken to establish and fine tune the pricing structure argues against direct communication.

[11] Recall from Section 2.1 that a station-level price jump occurs at station i on date t if $\Delta p_{it} \geq 6$ cpl.

Figure 7: Average Daily Price Cuts Across BP, Caltex, Woolworths and Coles Stations



Wednesdays each week. These stations are engaging in price leadership on Wednesday as they initiate market-wide price jumps on Thursdays.

In line with the example, we adopt the following definition of station-level price leadership.

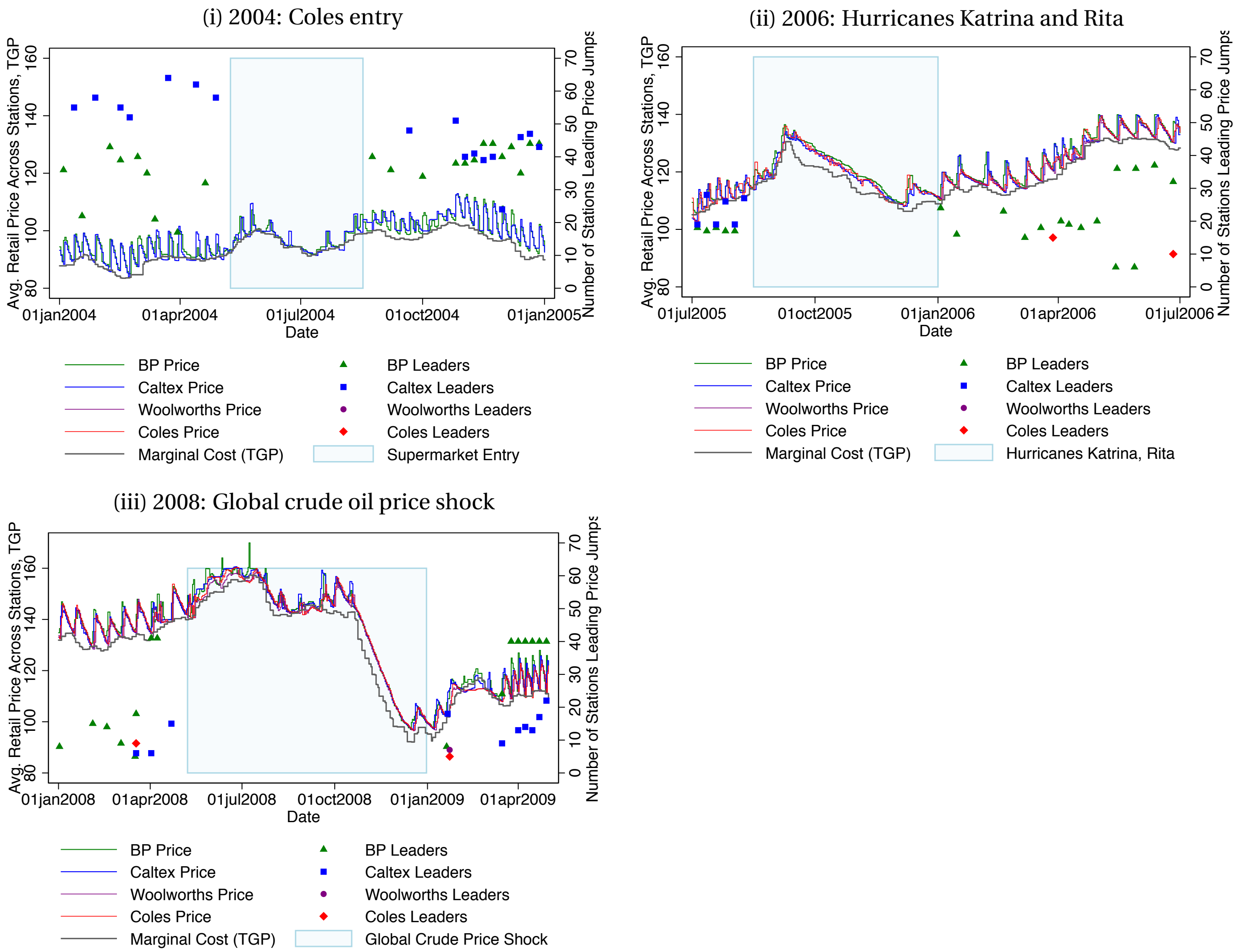
Definition. (v) Station i is a *price leader* on date t if: (1) it engages in a station-specific price jump on date t; (2) a market cycle begins on dates t, $t+1$, $t+2$ or $t+3$; and (3): less than 5% of all other stations engage in station-specific price jumps on date $t-1$.

Notice that the definition (v) makes use of the definitions (ii) and (iii) for station-specific price jumps and market cycles from Section 2.1. This definition of price leadership identifies instances where a station engages in a price jump that ultimately leads to successful market-wide price jumps within one, two or three days.

Aggregate shocks and the evolution of price leadership. Using our definition, we now document how aggregate shocks, price cycles, and price leadership coevolve around the entry of Coles in 2004, Hurricanes Katrina and Rita in 2005, and the global crude oil price shock of 2008-09. Figure 8 depicts the cycle collapses, cycle re-initiation, and price leadership for each shock. The left vertical axis in each panel is the average daily retail price, with the colored lines graphing the price cycles for each firm. The right vertical axis is the number of price leader stations on each date, with the colored shapes indicating the number of price leader stations for each firm. For example, the green triangles correspond to the number of BP price leader stations on each date.

Panels (i)-(ii) reveal an interesting evolution in price leadership between 2004 and 2010. Panel (i) shows that BP and Caltex had price leadership roles prior to Coles' entry in 2004, and in

Figure 8: Cycle Collapses, Re-initiation, and Price Leadership



re-initiating the price cycle after its collapse. During this period, they used nearly every station to lead market-wide price jumps week-to-week. Panel (ii) again highlights shared price leadership between BP and Caltex before the 2006 cycle collapse. Following the aggregate shock, we find that BP is the sole price leader in re-initiating the cycle. Rather than sharing the leadership role with BP, Caltex starts following BP by one day each week in implementing station-level price jumps. This highlights a competitive tension: by delaying its price-jumps by one day and allowing BP to be the sole price leader in the post-shock period, Caltex is likely able to steal business from BP during price jumps.

We observe a similar dynamic in price leadership in panel (iii). Here, both BP and Caltex again share the price leadership role prior to the 2008 global crude oil price shock. In contrast to earlier periods, however, they now use less than half of their station networks to lead price jumps week-to-week. In re-initiating the price cycle after the shock in April 2009, BP takes an extreme approach to price leadership and leads price jumps with its entire station network. Caltex exhibits price leadership in re-initiating the cycle as well; however, it leads with less than half of its stations. We again find a competitive tension emerge between BP and Caltex following the aggregate shock.

4.2 The 2009 Price war

Having re-established the price cycle in April 2009, BP would soon find itself in a price war with Caltex. We document this in Figure 9, which plots daily average retail prices for BP and Caltex between April 2009 and April 2010.[12] Panels (i) and (ii) of the figure yield relatively stable pricing between April and August 2009. During these months, BP leads price jumps with its entire station network week-to-week. Caltex delays price jumps by one-day relative to BP at the majority of its stations. Visually, this is highlighted by the one day gap in price jumps between the green and blue lines in the figure.

Starting in August 2009, the gap between BP and Caltex price jumps widens to two days. This is highlighted in panel (ii). Caltex now delays price jumps by two days and the rest of the market (not plotted) follows Caltex. Because prices are fixed for 24 hours each day, BP stations are exposed for two days as they have prices that are 10-15 cpl higher than all other stations in the market. Given this, Caltex's defection to delay price jumps by two days effectively represents a substantial price cut.

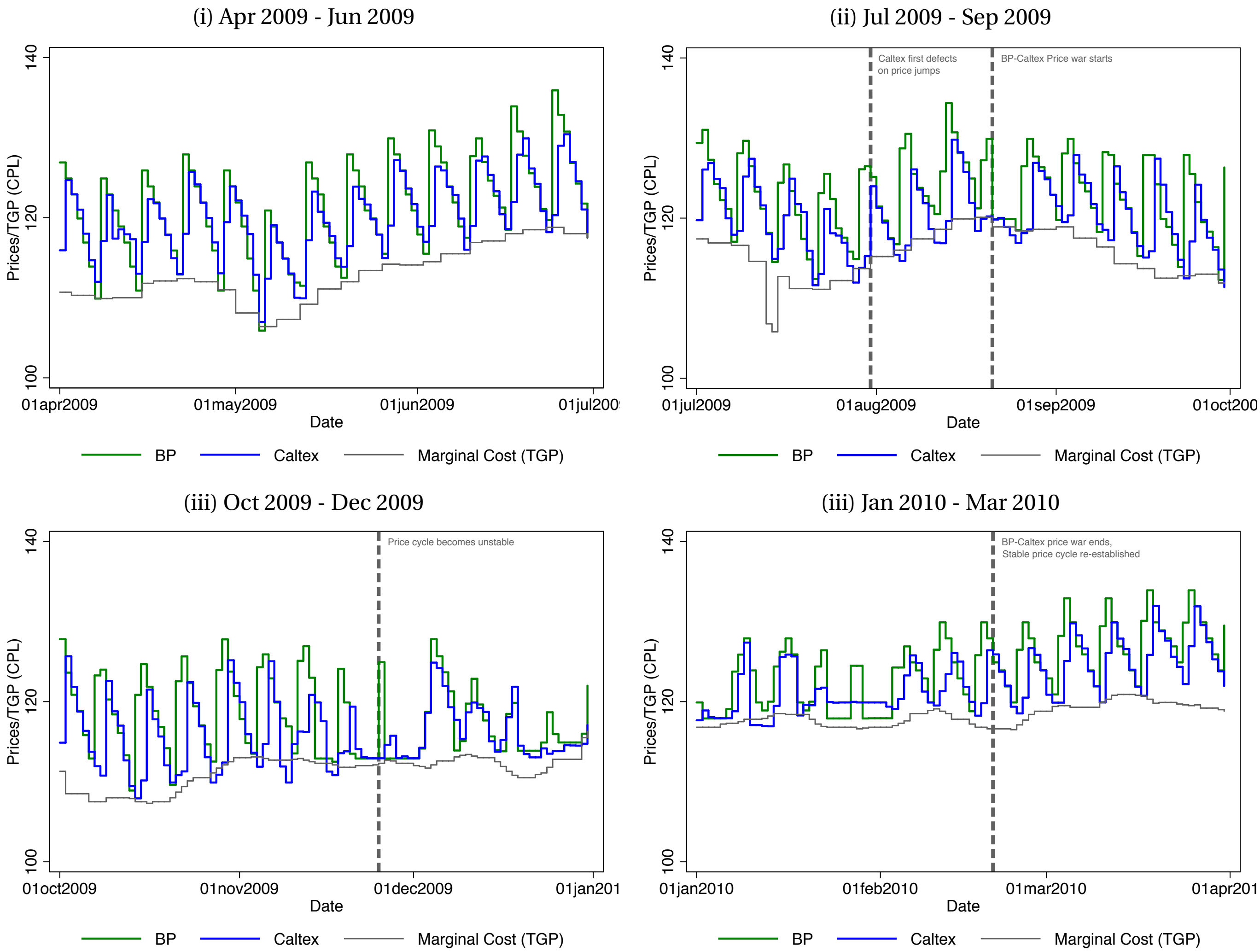
Panels (ii) and (iii) show that BP remains exposed as a two-day price leader for four months until mid-November 2009. At this point the cycle begins to destabilize. Between November and December 2009, Caltex exhibits an unwillingness to engage in price jumps week-to-week. BP continues to engage in price jumps with its stations, but is now unsuccessful in coordinating market-wide price jumps. In the last week of 2009 (panel (iii)), and the first week of 2010 (panel (iv)), BP also stops engaging in price jumps with most of its stations and the cycle collapses.

Panel (iv) further highlights initial and unsuccessful attempts by BP to re-initiate the cycle between January and February 2010. However, in the last week of February, we see the cycle is re-initiated and is stable. Like the price cycle from April 2009, the cycle that emerges involves BP leading price jumps, with Caltex (and all other firms) delaying price jumps by one day.

Discussion. Having identified pricing behaviour as tacitly collusive, the price war we document poses a challenge for the theory of collusion. At least since Friedman (1971), that a detected deviation should be met by punishment has been a central premise.

[12] That is, panel (i) in Figure 9 starts from where panel (iii) in Figure 8 ends. We focus on BP and Caltex for the sake of brevity. All other stations in the market tend to follow Caltex's pricing in Figure 9.

Figure 9: 2009 BP-Caltex Price War



The Caltex 2-day price jump delay represents a clear deviation from the pricing structure prevailing until August 2009. However, BP did not respond to Caltex's deviation with punishment. Rather, as evidenced by BP's attempts to re-initiate the cycle in early 2010, and the price experiments that we document next in Section 4.3, we find that BP exhibits a certain degree of patience in responding Caltex's defection. BP ultimately resolves conflict through price leadership and price experiments, not punishment.[13]

Our result also echoes findings from Genesove and Mullin (2001). They found that the Sugar Cartel responded to defection through meetings that resolved conflicts, and that these meetings did not necessarily involve punishing defecting cartel members. The key distinction between our findings and theirs is that our results suggest that dominant firms in markets with asym-

[13] Other empirical examples highlight that price wars may reflect bargaining or negotiation rather than punishment. See, for example, de Roos (2004), Gupta (1997), and Levenstein (1997).

metric firms can resolve conflict tacitly through their prices. While we cannot rule out explicit collusion (e.g. an unobserved conversation between BP and Caltex in February 2010 that resolves the conflict), the history of price leadership by BP in re-initiating price cycles throughout 2004-2010 after recurring collapses, and in managing Caltex's defection in coordinating price jumps, suggests that price leadership plays a central role in BP's ability to communicate its collusive intentions and resolve conflict.

4.3 Mechanisms for initiating tacit collusion

How did -2 cpl price cuts and Thursday price jumps emerge as focal points for tacit collusion out of the price war? In this section, we investigate the mechanisms through which BP established these focal points.

4.3.1 -2 cpl price cuts

We begin with -2 cpl price cuts. In Figure 10, we plot for each retailer the probability that a given station sets exactly a -2 cpl price cut on undercutting days of its station-specific cycle (e.g. cycle days 2, 3, 4, ...) in each month (panel (i)) and week (panel (ii)). The plots include the four major retailers, as well as an independent retailer, Gull, as a contrast.[14]

Panel (i) highlights rapid convergence by the four major oil to the -2 cpl price cut focal point. It occurs within the first 6 months of 2010, immediately after the BP-Caltex conflict is resolved. At this time, approximately 60% of stations in each of BP's, Caltex's, Woolworths's and Coles's station networks are setting -2 cpl price cuts on undercutting days. By the start of 2011, this grows to 80% of stations for BP, Woolworths and Coles; 60% of Caltex stations continue to set -2 cpl price cuts. For the next *four years*, this degree of coordination on the -2 cpl price cut focal point is stable. Making this level of coordination even more remarkable is that it obtains despite the fact that stations set prices simultaneously once each day.

Gull's propensity to conform to the -2 cpl price cut yields an interesting contrast. Panel (i) shows Gull stations exhibit a gradual rise in the propensity to set -2 cpl price cuts between 2010 and 2013. The propensity is roughly 20% between 2010 and 2013, and then rapidly rises to 60% at the start of 2013.

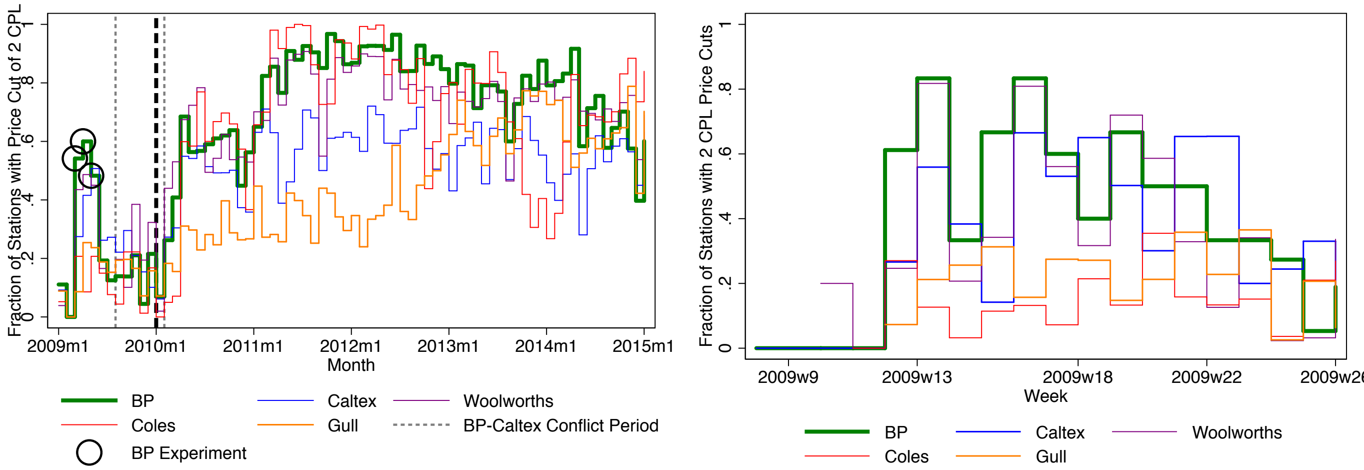
This difference in results for Gull and the major retailers is consistent with heterogeneity in firm learning about focal points. Gull, as a smaller, less organized and potentially less sophisticated competitor took longer to learn about the existence of a -2 cpl focal point, and hence took longer to tacitly coordinate on -2 cpl price cuts. Alternatively, there could exist unobserved explicit communication among the oil majors, but not Gull, around the start of 2010 regarding the

[14] Gull has 10 stations in the market over the 2010-15 period.

Figure 10: BP Price Leadership in 2011 and 2013

(i) Fraction of Stations with Daily 2 CPL Price Cut (Monthly, 2009-2015)

(ii) Fraction of Stations with Daily 2 CPL Price Cut (Weekly, Feb-Jun 2009, BP Experiments)



-2 cpl focal point. However, the prolonged one-year transition toward the focal point among oil majors, and the heterogeneity between the oil majors in their propensity to adhere to it, points to tacit and not explicit collusion among majors in forming common beliefs about coordinating on -2 cpl price cuts.

Experimentation. Figure 10 also provides evidence on experimentation as a mechanism for initiating tacit collusion. This is highlighted in panel (i) by the three black circles in 2009, two months prior to the BP-Caltex conflict. Panel (ii) provides greater resolution for these experiments, zooming into the firms' propensities to set -2 cpl price cuts at weekly frequencies between March and June 2009. The latter panel shows two instances where BP ramps up and then down its stations' propensities to set -2 cpl price cuts. For instance, in 2009 week 12 BP sharply moves to having 60% of its stations set -2 cpl price cuts. The following week, it ramps up to 80%, and then drops back to less than 40% the week after. BP repeats this pattern in weeks 15-17, before it stops coordinating its stations' price cuts at -2 cpl.[15]

Through these price experiments, BP achieves two things: learning and communication. First, it is able to learn about its rivals' willingness to coordinate on a -2 cpl focal point. In panel (ii) of the figure, both Woolworths and Caltex reveal that they are willing and able to quickly coordinate on -2 cpl price cuts, while Gull and Coles are not. Moreover, the experiments likely have an indirect learning effect, whereby BP's rivals also learn about each others' collective will-

[15]We have examined these ramping up-and-down patterns at daily frequencies as well. The results are precisely the same as those presented at weekly frequencies: BP leads all other firms in infrequently but repeatedly coordinating -2 cpl price cuts, with its rivals following its trials by one day. The visualization is better at weekly frequencies, and we therefore present these without losing any additional insight.

ingness to coordinate on price cuts.

Second, the experiments enable BP to communicate its intention to coordinate on price cuts to its rivals. From Green et al. (2015), we know that a necessary condition for initiating tacit collusion is firms having common beliefs on a collusive pricing strategy. BP's price experiments effectively serve as a form of communication in helping establish common beliefs on -2 cpl price cuts. This communication, combined with any learning from the experiment, are likely key to BP's ability to confidently take a leadership role in rapidly establishing the -2 cpl focal point at the start of 2010.

4.3.2 Thursday price jumps

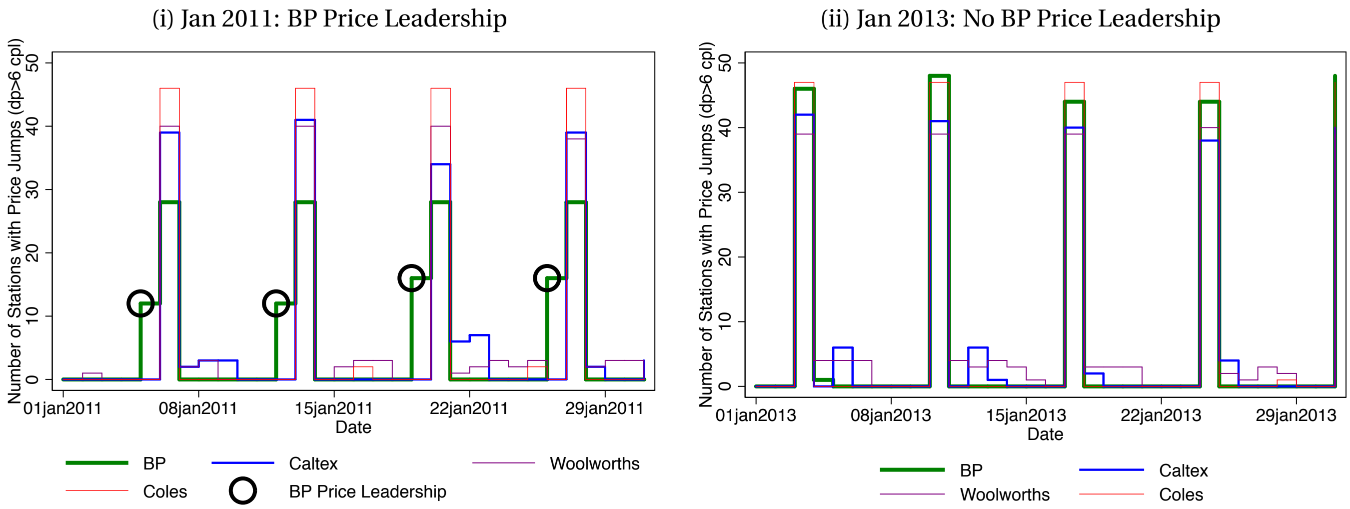
Similar patterns of price leadership, experimentation, and focal point formation exist with Thursday price jumps. Before documenting these dynamics, we discuss a simple example based on cycles from 2011 and 2013 to foreshadow an important shift in price cycle leadership after 2010. Figure 11 presents the example. Panel (i) reproduces our figure for price cycle leadership from above. It reiteraties how BP uses a subset of stations to lead price jumps each week in January 2011. In this figure, the subset of leading stations move on Wednesdays, and the rest of the stations in the market move on Thursdays.

Panel (ii) presents the same picture for January 2013. Here, we see that BP no longer engages in price leadership on Wednesdays. Instead, all firms are able to coordinate on market-wide price jumps with nearly their entire station networks on Thursday. In other words, all firms are able to simultaneously lead price jumps week-to-week. We again emphasize that the firms are able to eventually achieve this remarkable degree of price coordination despite having to set their prices simultaneously each day.

Forming the focal point. Figure 12 illustrates the rate with which the major retailers in the market converge on Thursday price jumps. Panels (i)-(iv) plot for each major retailer and month, the percentage of station-level price jumps that occur on a given day of the week. For instance, panels (ii)-(iv) show that Caltex, Woolworths, Coles rapidly converge on engaging in Thursday price jumps with their station networks starting in March 2010. 90% of Caltex stations engage in Thursday price jumps month-to-month between 2010 and 2015; 80% and 100% of Woolworths and Coles stations engage in Thursday price jumps over this period.

The dynamics for BP in panel (i) of the figure are different. In this figure, the transition in BP stations' propensity to engage in Thursday price jumps (green triangles) and Wednesday price jumps (orange circles) is important. Starting with the latter, panel (i) shows that in March and April 2009 nearly 100% of BP stations engage in Wednesday price jumps. As per our discussion in Section 4.1 above, and as indicated in the figure, this is when BP re-initiates the cycle after its

Figure 11: BP Price Leadership in 2011 and 2013



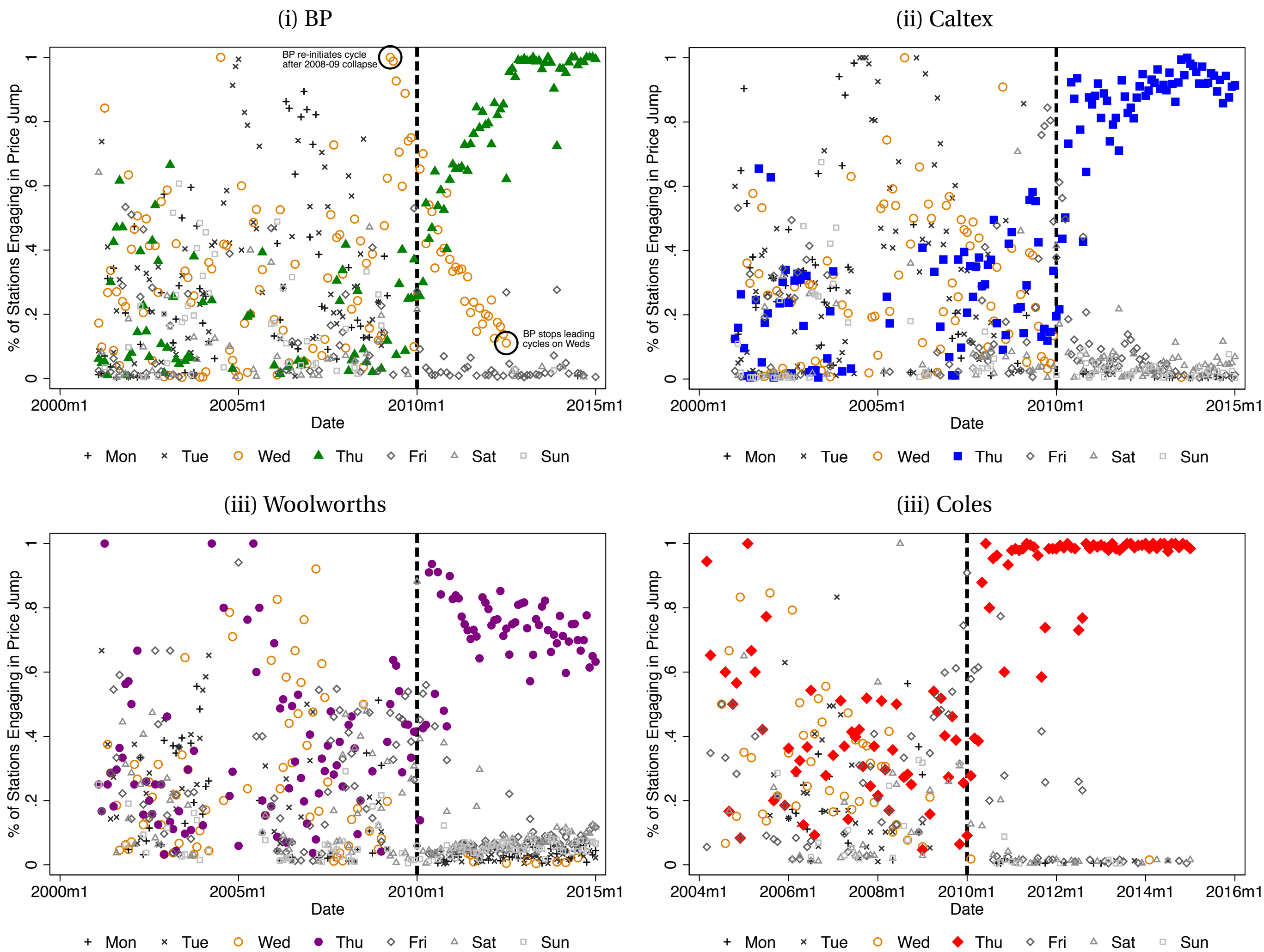
collapse due to the 2008-09 crude oil-shock. From this point through to 2012, the figure reveals a downward trend in BP stations' propensity to engage in Wednesday price jumps. Midway through 2012, we see that eventually no BP stations engage in Wednesday jumps.

Contrasting with this downward shift in Wednesday jumps is an upward shift in Thursday price jumps for BP stations. In sum, the respective downward and upward sloping orange circles and green triangles in panel (i) reflect BP gradually substituting away from Wednesday jumps to Thursday jumps over a two and half year period. This transition allows BP to scale back its price leadership role until eventually it begins coordinating solely on Thursday price jumps with its rivals. This is precisely the shift in price leadership we observed in Figure 11.

Price leadership. As with the -2 cpl price cuts, the richness of the data allow us to dig deeper into the mechanisms used by BP to establish the Thursday jump focal point. A different type of price leadership by BP (e.g. apart from weekly price jump leadership) plays a key role in sparking the market's convergence toward Thursday price jumps. Figure 13 contains the evidence. Panels (i) and (ii) of the figure zoom in on the transition to Thursday price jumps around the start of 2010. The panels respectively plot, by firm, the number of stations engaging in Wednesday and Thursday price jumps between July 2009 and July 2010.

The downward trend in Wednesday price jumps among BP stations is again clear in panel (i). In each week, a subset of BP stations lead price jumps. There are, however, two critical exceptions which we denote "Gap 1" and "Gap 2". We interpret Gap 1 as a form of BP price leadership. In panel (i), we see that no BP stations engage in Wednesday price jumps in Gap 1. Instead, as panel (ii) shows, nearly all BP stations engage in Thursday price jumps in Gap 1. Panel (ii) further shows that prior to Gap 1, the market as a whole initially struggles to coordinate

Figure 12: Price Leadership with Thursday Price Jumps

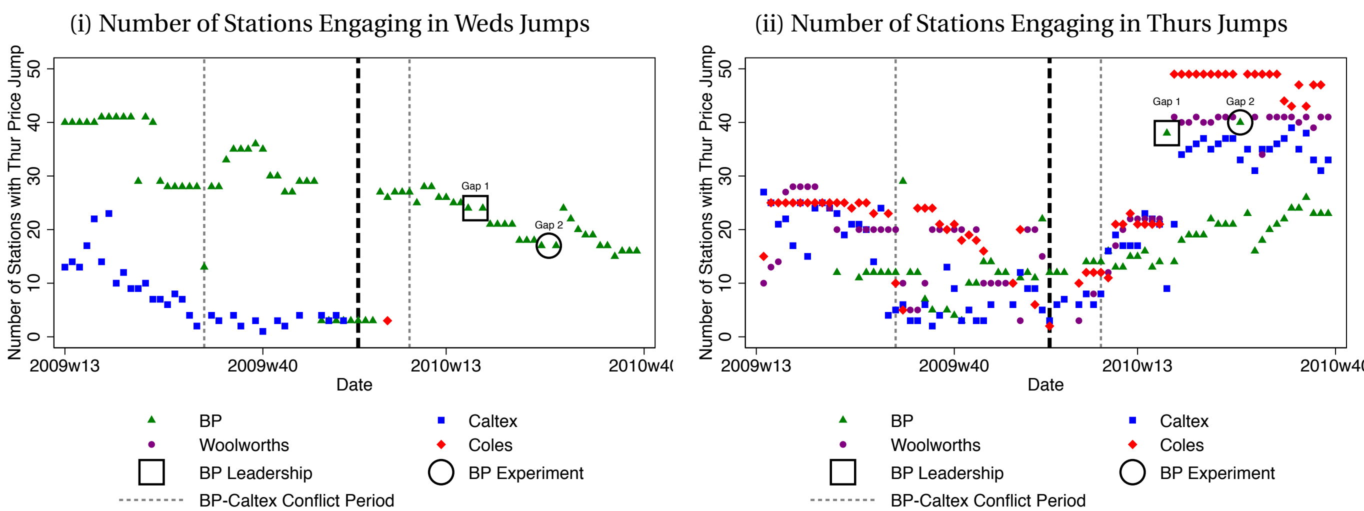


on Thursday price jumps at the start of 2010, despite the fact that BP was leading jumps week-to-week on Wednesdays. The week following Gap 1, however, Caltex, Woolworths and Coles dramatically shift their behavior and immediately start coordinating on Thursday price jumps. At the same time, BP reverts back to engaging in price jump leadership on Wednesdays with a subset of its stations the following week.[16]

It is in this sense that Gap 1 is a form of price leadership by BP: through it, BP is able to communicate its intentions to coordinate on Thursday price jumps with its rivals. In doing so, it dramatically tips the equilibrium to coordinating on Thursday price jumps, thereby creating

[16]The restriction to simultaneous price setting once each day is important for interpreting the shift. When BP engaged in Thursday price jumps with nearly its entire station network in Gap 1, its rivals would not have been able to respond in that week. Observing Gap 1, the rivals would first have a chance to coordinate on Thursday jumps the following week. They do so nearly perfectly with their first opportunity the week following Gap 1.

Figure 13: Evolution of Weds and Thurs Price Jumps
(Weekly, 2009-2011)



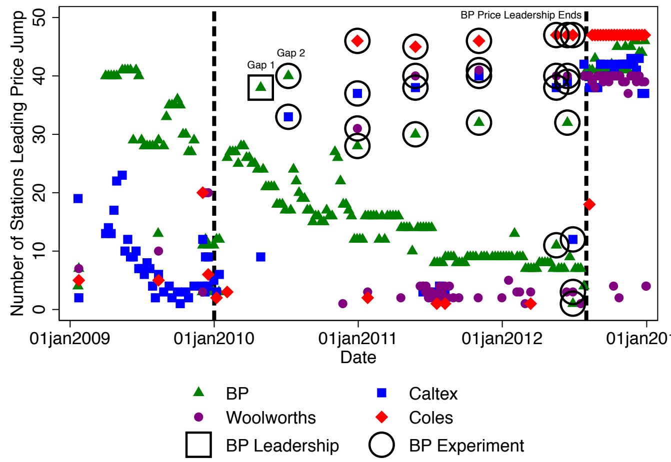
the focal point. An important caveat to the interpretation of Gap 1 representing price leadership by BP is that we cannot rule out unobserved explicit communication as another mechanism for the stark shift to coordinated Thursday price jumps.

Experimentation. In addition to price leadership, experimentation by BP plays an important role in forming the Thursday jump focal point. Returning to Figure 13, we focus on Gap 2, which is the second week of note where BP breaks from past behavior. Panel (i) shows that in this week, BP again does not engage in price jump leadership on Wednesday. Instead, as panel (ii) shows, it engages in price jumps on Thursday with nearly its entire station network. From this one-off experiment, BP learns a critical piece of information: both Woolworths and Coles do not hold common beliefs regarding the stability of Thursday price jumps. This can be seen in panel (ii) as neither Coles nor Woolworths engages in price jumps during Gap 2. In contrast, Caltex continues to engage in Thursday price jumps in Gap 2 despite BP not engaging in price leadership.

The structure of the price transparency law plays an important role in interpreting Gap 2 as an experiment. From 2:30pm onwards on the Wednesday of Gap 2, Caltex, Woolworths and Coles would have all immediately observed BP not engaging in Wednesday price leadership. As evidenced in panel (ii) of Figure 13, this information was sufficient for Woolworths and Coles to defect from the Thursday price jump in Gap 2. In sum, the experiment reveals to BP that the Thursday jump focal point was not stable at this point. It still required price jump leadership week-to-week.

If Thursday price jumps were unstable, how did BP eventually completely scale back its

Figure 14: BP Experiments with Price Jump Leadership



Wednesday price jump leadership? Figure 14 reveals how: more price experiments. The figure is similar to Figure 13, except that it simply plots for each firm and date the number of stations engaging in price jump leadership between 2009 and 2013.[17] To help provide context, we highlight Gap 1 and Gap 2 in the figure.

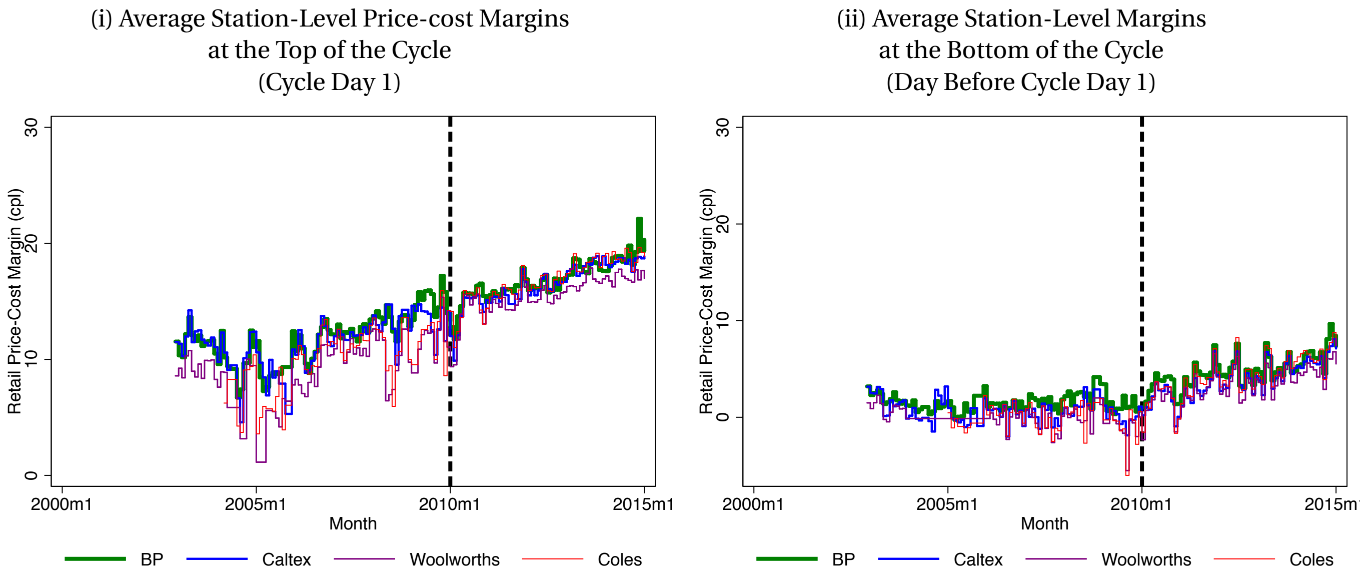
The figure has a number of important features. First, we again see BP scaling back its role in engaging in price jump leadership week-to-week by the downward sloping green triangles. Second, the figure highlights 6 dates after Gap 2 where all 4 major retailers simultaneously lead price jumps. These dates correspond to BP price experiments, where again there are one-off weeks where no BP stations engage in Wednesday price jumps, and instead only engage in Thursday jumps. It turns out that Gap 2 represents the first such experiment in the sample, and that BP engages in similar experimentation 6 additional times after Gap 2.

Finally, the figure shows that the last 3 sets of experiments occur within a few weeks of each other midway through 2012. After these experiments, there is a dramatic shift in price leadership. Specifically, as noted in the figure, BP price jump leadership ends. BP no longer engages in price jump leadership on Wednesdays, and instead simultaneously coordinates on Thursday price jumps week-to-week with all other firms in the market. In effect, the Thursday jump focal point is cemented, and price leadership is no longer needed to ensure cycle stability.

Discussion. Overall, the results from Figures 13 and 14 provide novel, and we believe important, evidence on experimentation as a mechanism for initiating tacit collusion. Through its experiments, as the market leader BP is able to learn about its rivals' willingness to coordinate on price jumps, and also communicates its intentions to its rivals. While the initial experiment

[17] Recall that we define station-level price jump leadership above in Section 4.1.

Figure 15: Evolution of Price-Cost Margins at the Top and Bottom of the Cycle



in Gap 2 reveals an unstable focal point, the remaining experiments reveal its eventual stability. This stability may, in fact, result from the original Gap 2 experiment, which reveals BP's and Caltex's intentions to coordinate on Thursday price jumps. This again speaks to Green et al. (2015), specifically that experimentation can help facilitate communication among oligopolists to help form common beliefs regarding collusive pricing structures.

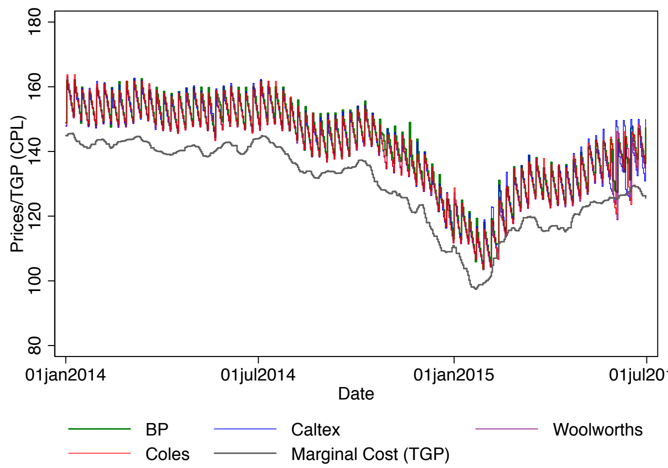
We find the length of time it took for the market to converge on Thursday price jumps interesting. It took more than two years for BP to escape price jump leadership through its series of experiments. The gradual nature of BP's convergence to Thursday price jumps and its repeated experimentation suggest that tacit and not explicit collusion is the primary driver of these dynamics. This is not to say, however, that there was no communication among rivals over this period in coordinating on price jumps. It is simply that BP appears to use price experiments to communicate its intentions, not phone calls.

4.4 Collusive outcomes

4.4.1 Price-cost margins

Having now characterized the tacitly collusive relationship, we further describe its outcomes. We begin with margins. Figure 15 plots the average price-cost margin across stations for each month and retailer at the top and bottom of the cycle. The plots highlight sustained growth in margins over time at both points in the cycle, with higher rates of growth between 2010 and 2015. The enhanced margin growth is more noticeable in panel (ii). This implies that the -2 cpl

Figure 16: Pricing Stability Around the 2015 Global Oil Price Shock



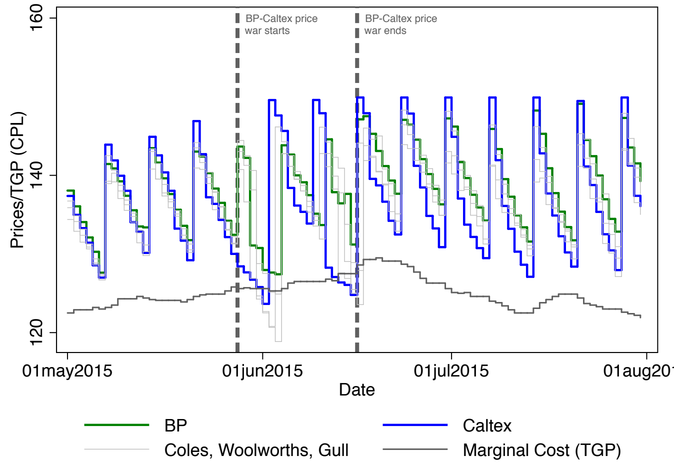
price cuts over a weekly cycle with Thursday price jumps ultimately lead to less aggressive price undercutting after the tacitly collusive pricing structure was formed.

The other interesting finding from Figure 15 is that inter-temporal dispersion in margins is noticeably lower at the top of the cycle after 2010. Over time between 2010-2015, the firms were better able to coordinate on increasingly large price jumps. In contrast, inter-temporal margin dispersion is similar at the bottom of the cycle before and after 2010. During the tacitly collusive period, each week there would be -12 cpl price cuts total (6 days × -2 cpl per day) regardless of weekly changes in crude oil prices. Hence, the dispersion in margins at the bottom of the cycle during the tacitly collusive period reflects weekly variation in marginal costs.

4.4.2 Price stability

Figure 16 highlights another key outcome from tacit collusion: price stability. The figure depicts the price cycle in the first half of 2015. At this time, the international crude oil market experienced another major aggregate price shock due to a global supply glut of oil. This shock is similar to the 2008-09 oil price shock both in terms of its size and rapidity. Unlike the shock of 2008-09, however, we do not see the price cycle collapse around the 2015 shock. The focal points that characterize the tacitly collusive pricing structure are likely responsible for this enhanced pricing stability. Regardless of movements in world oil prices, during the 2015 shock period the firms' pricing behavior was governed by two simple pricing rules: -2 cpl price cuts and Thursday jumps. Given firms' common beliefs about these rules, their form of tacit collusion ultimately created price stability in the presence of macroeconomic instability and cost volatility.

Figure 17: Conflict Resolution With the 2015 BP-Caltex Price War



4.4.3 Conflict resolution

The final collusive outcome of note is conflict resolution. At the end of May 2015, another Caltex-created price war broke out. We depict the war in Figure 17. The figure shows a week just before June 1, 2015 where Caltex did not engage in a Thursday price jump. Instead, it engaged in a Tuesday price jump.[18]

This BP-Caltex conflict lasted all of three weeks. This stands in stark contrast to the prolonged 6-month BP-Caltex conflict of 2009. In 2015, BP quickly responded to Caltex's defection by matching it on Tuesday price jumps. Moreover, the firms quickly shifted the magnitude of price cuts from -2 cpl to -3 cpl, also inline with Calte'x Caltex's defection. This rapid degree of conflict resolution, and the way in which BP resolved the conflict, highlights the importance of focal points and common beliefs among the tacitly colluding firms regarding pricing strategies. Resolving the war was relatively simple in that there were only two easily-understood focal points to re-establish: the magnitude of price cuts and day of the week for price jumps. The contrast with the previous 2009 war is evident; six years earlier the firms engaged in noisy price coordination day-to-day, and did not have focal points with which to coordinate prices and resolve conflict.

[18]The cause of the war is not exactly known. However, in our conversations with the Western Australian government, the only major Caltex-specific change prior to the 2015 war was a change in ownership. Specifically, one-month prior to the war, Chevron sold its 50% share in Caltex and got completely out of gasoline retailing. This may have lead to a change in management who wanted a break from the past 5 years of pricing in the market.

5 Conclusion

This paper has provided a novel study on the initiation of tacit collusion. Using a uniquely rich dataset in retail gasoline, and a market context that maps well into the standard repeated games framework for collusion, we have shown how price leadership and experimentation can be used to initiate tacit collusion.

In our setting, we found the market leader, BP, was able to use experiments to communicate its collusive intentions to its rivals. Moreover, the experiments enabled BP's competitors to collectively learn about their willingness to engage in tacit price coordination. With the market informed by the experiments, BP engaged in price leadership to establish focal points to coordinate price jumps and cuts. Over time, firms adhered to these focal pricing rules, and were able to substantially enhance their retail margins. We further found that the simplicity of the pricing structure helped ensure stability in the presence of aggregate shocks, and enabled firms to quickly resolve conflict.

Our study has a number of implications for research on collusion and anti-trust policy. Most notably, we have provided some of the first evidence on the mechanisms through which tacit collusion arises: price leadership and experimentation. The fact that firms appear to be able to communicate through prices in our setting provides an interesting contrast with the presumption from Green and Porter (1984) that collusion is likely initiated through an explicit agreement. Similarly, our findings complement the "Need to Meet Principle" from Green, Marshall and Marx (2015) that stipulates oligopolists require higher-order knowledge of their rivals' intentions to collude, and that such higher-order knowledge cannot be attained in practice without an explicit meeting. Through price leadership and experiments, BP was able to ensure that its competitors developed common beliefs regarding pricing focal points, which were fundamental to initiating the tacitly collusive pricing structure that we found.

The timing of BP's use of price leadership and experimentation also provides a new insight for future research on collusion. Specifically, we found that rather than engaging in punishments in response to Caltex's defection on price coordination in 2009, BP used price leadership and experiments to resolve conflict. This finding contrasts with many theories of collusion that commonly assume some form of punishment or renegotiation to resolve conflict. This is thus another avenue for future research on collusion suggested by our results.

The final notable research-relevant point is that the collusive pricing structure that BP initiated was, ultimately, a simple one: price jumps on Thursdays, and -2 cpl price cuts on all other days. Despite the simplicity of the structure, the price dynamics in Figure 2 at first glance, appear complex. Given that firms can perfectly monitor fluctuations in each others' prices and costs day-to-day in our setting, it is intriguing that BP chose to initiate such a simple collusive pricing structure. With perfect monitoring, one might expect more sophisticated structures to emerge. Our results indicate that firms may adopt simple tacitly collusive pricing structures, despite perfect monitoring on rivals' actions, because simple structures are easy to experiment with, and communicate to rivals.

Moreover, with simple, standardized pricing structures, price transparency is enhanced and miscommunication is minimized. Ultimately, enables firms to identify defections from simple pricing focal points, thereby facilitating punishments and enhancing the stability of the collusive pricing structure. In this sense, the standardization of pricing practices by BP is reminiscent of the standardization of rules documented in the Sugar Institute cartel by Genesove and Mullin (2001).

Policy implications. There are at least three policy implications stemming from our study. Our analysis emphasizes the role of firm size asymmetry in generating coordinated effects. We found asymmetry to be essential to initiating collusion: as the largest player in the market, BP was able to exploit the size of its station network to signal the timing and magnitude of price changes to its rivals and establish focal points for tacit price coordination. That asymmetry, and not symmetry, is fundamental to generating coordinated effects contrasts with conventional anti-trust worries of firm size symmetry in merger cases, since symmetric firms have great incentives to collude (Ivaldi, 2003). A takeaway from our study is that mergers that generate asymmetric firms may also facilitate collusion by enabling price leadership and experimentation.

We believe that our ex-ante approach to collusion detection is also policy relevant. Our complete history of daily station-level retail prices for 15 years is what enabled us to track the distribution of prices and firms' strategies at daily frequencies. The ability to observe these distributions, effectively in real-time, is what allowed us to uncover tacit collusion and the price leadership and experiments that initiated it. It is possible that in emerging 'Big Data' environments, anti-trust authorities will be able to construct remarkably rich pricing datasets similar to ours.[19] With these data, pricing conduct can be monitored in real time, and the initiation of tacit price coordination can be identified. That is, future ex-ante studies of cartel initiation like ours can complement conventional ex-post studies of prosecuted cartels and cartel breakdowns to further enrich authorities' menu of cartel detection policies.

Finally, we found tacit collusion emerged in a market with a price transparency policy. Conceptually, the policy originally well-intentioned, focusing on the demand-side of the market: by making prices more easily comparable, demand elasticity would rise, thereby promoting re-

[19]For instance, the IRI Academic Database (Bronnenberg et. al, 2008), which provides weekly price and quantity panel data for a selection of products across a wide range of grocery stores in the U.S. from 2001-2011, is readily available for both researchers and policymakers to pursue forensic high frequency analyses of the long-run evolution of tacit price coordination in various retail markets.

tail competition. However, with hindsight, we know that the policy made retail prices perfectly observable to consumers *and* firms. When viewed through the lens of a collusive model, the policy facilitated communication among firms through prices, and monitoring of rivals' conduct. Ultimately, the policy may have been fundamental to the initiation of tacit collusion.[20] As such, one may interpret our study as a cautionary case for authorities considering such policies. Much work remains to be done both theoretically and empirically to inform governments about the short and long-run trade-offs in using information technology to make prices transparent to both the demand and supply side of markets.

[20]Indeed, we do not observe such price coordination and profit margins across other markets in Australia emerge between 2010 and 2015.

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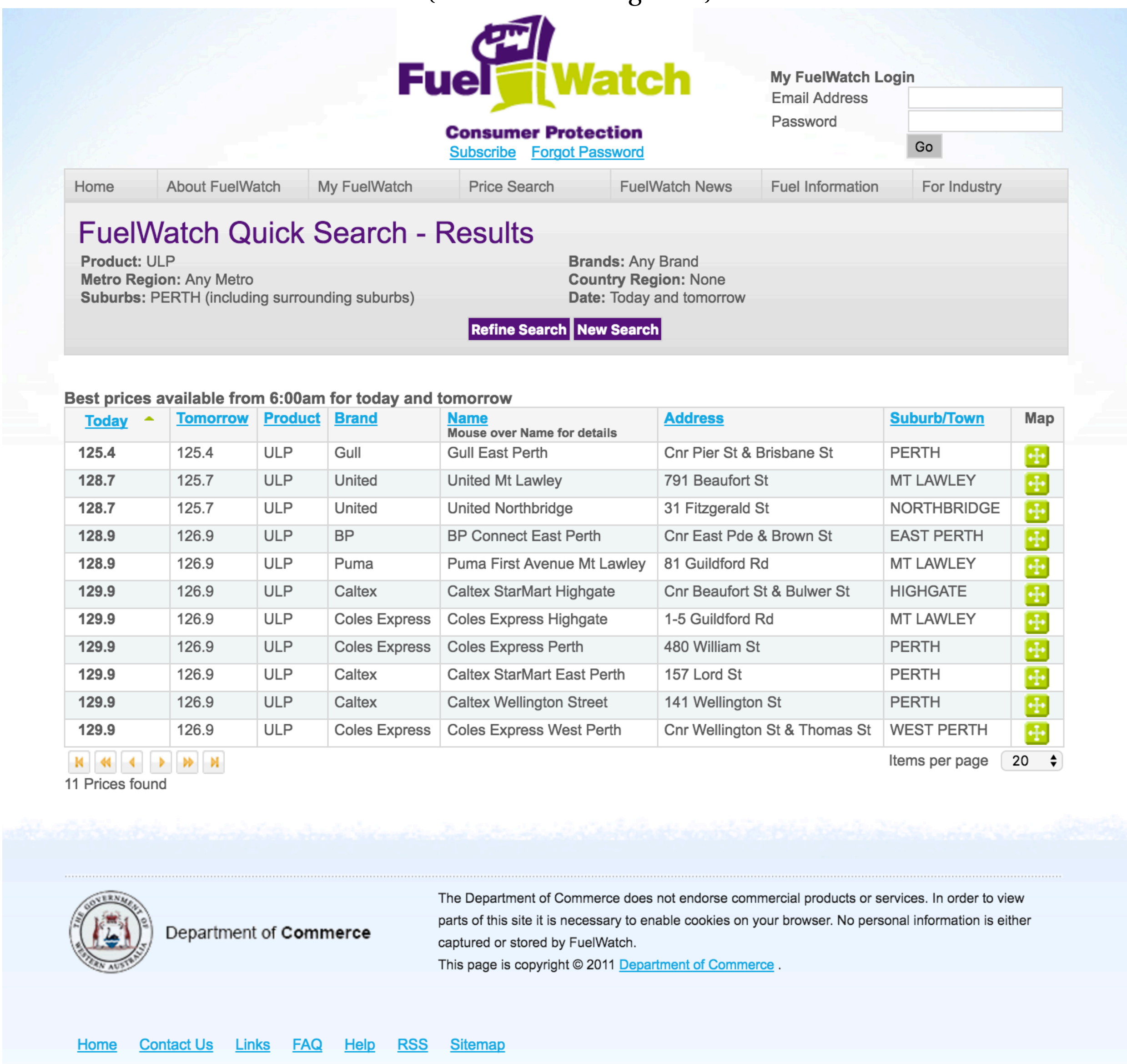
Appendix

A Supplemental figures

Figure A.1: Fuelwatch Price Comparison Website
(www.fuelwatch.gov.au)



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Consumer Protection
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Email Address
Password
Go

Home | About FuelWatch | My FuelWatch | Price Search | FuelWatch News | Fuel Information | For Industry

FuelWatch Quick Search - Results

Product: ULP
Metro Region: Any Metro
Suburbs: PERTH (including surrounding suburbs)
Brands: Any Brand
Country Region: None
Date: Today and tomorrow

Refine Search | New Search

Best prices available from 6:00am for today and tomorrow

Today	Tomorrow	Product	Brand	Name (Mouse over Name for details)	Address	Suburb/Town	Map
125.4	125.4	ULP	Gull	Gull East Perth	Cnr Pier St & Brisbane St	PERTH	
128.7	125.7	ULP	United	United Mt Lawley	791 Beaufort St	MT LAWLEY	
128.7	125.7	ULP	United	United Northbridge	31 Fitzgerald St	NORTHBRIDGE	
128.9	126.9	ULP	BP	BP Connect East Perth	Cnr East Pde & Brown St	EAST PERTH	
128.9	126.9	ULP	Puma	Puma First Avenue Mt Lawley	81 Guildford Rd	MT LAWLEY	
129.9	126.9	ULP	Caltex	Caltex StarMart Highgate	Cnr Beaufort St & Bulwer St	HIGHGATE	
129.9	126.9	ULP	Coles Express	Coles Express Highgate	1-5 Guildford Rd	MT LAWLEY	
129.9	126.9	ULP	Coles Express	Coles Express Perth	480 William St	PERTH	
129.9	126.9	ULP	Caltex	Caltex StarMart East Perth	157 Lord St	PERTH	
129.9	126.9	ULP	Caltex	Caltex Wellington Street	141 Wellington St	PERTH	
129.9	126.9	ULP	Coles Express	Coles Express West Perth	Cnr Wellington St & Thomas St	WEST PERTH	

Items per page 20
11 Prices found

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B Difference-in-difference analysis of Perth's retail margin

This appendix provides supporting documentation for the **3.65 cpl** difference-in-difference estimate of the differential growth in retail margins in Perth relative to other Australian markets after January 2010. Recall that we quoted this figure on page ## in documenting the growth in margins in Perth during this period where we simultaneously find a substantial increase in tacit price coordination among firms.

To examine city-specific trends in margins, we collect auxiliary data on monthly retail prices and terminal gate prices (TGP) for 125 local markets in Australia for the period of June 2009 to January 2014 from the Australian Institute of Petroleum (AIP). Average retail prices for each market and month are freely available from the AIP at `http://www.aip.com.au/pricing/retail.htm`. The average TGP across the gasoline terminals within each major Australian city is available from `http://www.aip.com.au/pricing/tgp.htm`. We match each market in the sample to its geographically closest terminal gate to construct a TGP and retail margin measure in every markets. The markets in the sample include the state capitals of Adelaide, Brisbane, Canberra, Melbourne, Perth and Sydney, as well as a range of intermediate-sized cities and small towns. We focus on the 2009-14 period because this represents a period without any aggregate crude oil price shocks, and hence where price cycles are stable in Perth and other cycling markets such as the state capitals (except for Canberra).

We begin with some graphical evidence. Figure B.1 plots the average monthly retail margin for Perth, Adelaide, Melbourne and Sydney, as well as the 12-month moving average of the retail margin. The figure shows that retail margins to not exhibit a differential trend from June 2009 to December 2009 in any of the markets. Starting in 2010, however, we observed a break in the trend in retail margins in Perth that is not observed in the other markets.

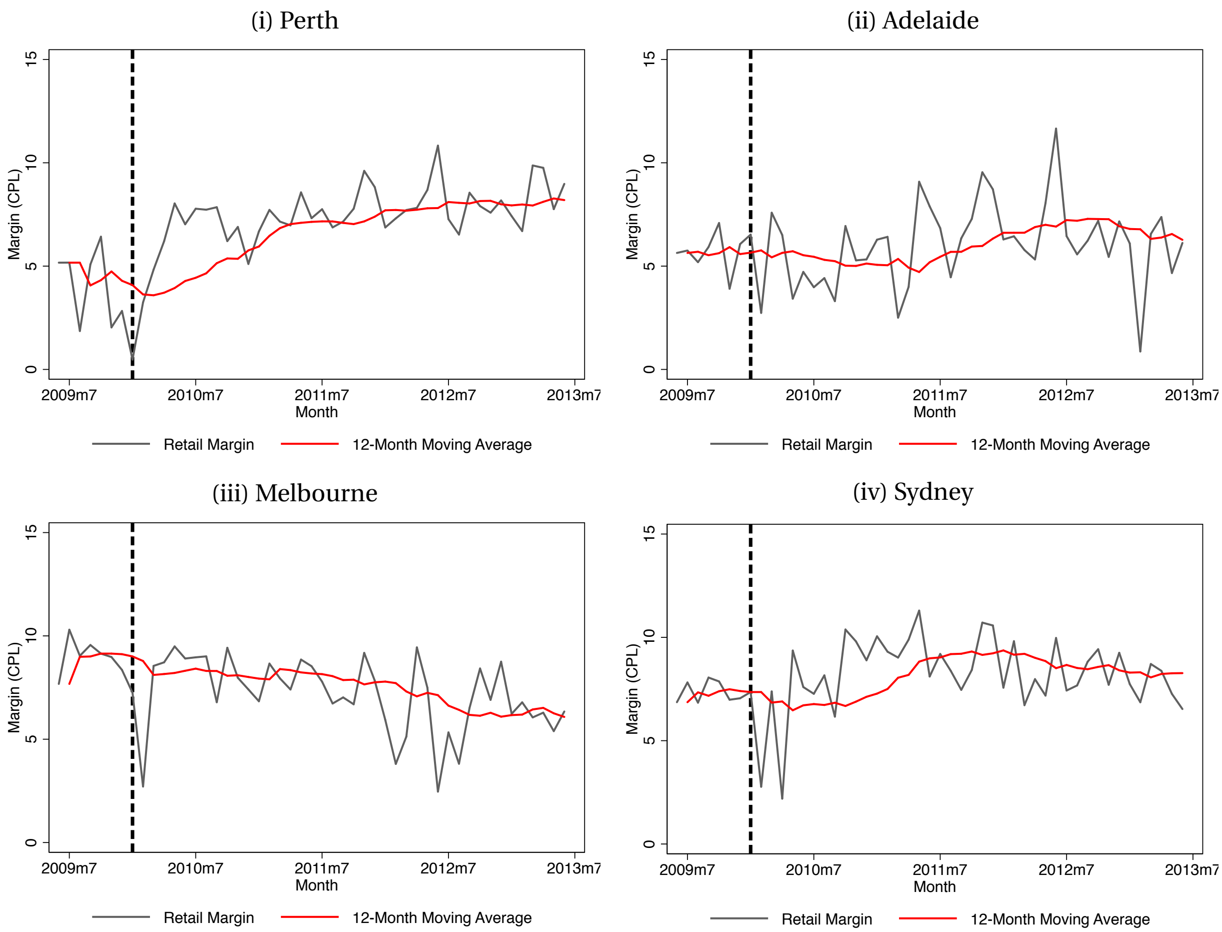
To estimate the local change in Perth's retail margin relative to other markets in January 2010, we use the following difference-in-difference empirical specification:

$$m_{it} = \beta_0 + \beta_1 1\{Post\ T\}_t + \beta_2 1\{Post\ T\}_t \times 1\{Perth\}_i + \nu_i + \tau_t + \epsilon_{it} \tag{1}$$

where $m_{it} = p_{it} - c_{it}$ is the retail margin in month i in year t, $1\{Post\ T\}_t$ is a dummy variable that equals one for all dates after date T (which is January 2010 in our preferred specification), $1\{Perth\}_i\}$ is a dummy variable that equals one for observations from Perth, ν_i and τ_t correspond to market i and date t fixed effects, and ϵ_{it} is the error term. The difference-in-difference estimate of the growth in Perth's margin after date T is the estimate of β_2.

Table B.1 presents estimation results for our preferred specification based on the June 2009-December 2014 period, including the capital cities with price cycles (Adelaide, Brisbane, Melbourne, Perth, Sydney), and where the break date in margins is set to T=Jan2010. The difference-

Figure B.1: Retail Margins Across Cities



in-difference estimate implies a local 3.65 increase Perth's profit margin relative to other cycling capital cities after January 2010.

Table B.2 presents a series of robustness checks on the difference-in-difference results. Here we vary the break date in margins by two months before and after January 2010, allowing for T =Nov2009, ..., Mar2010. We also vary the cities included in the sample, thereby varying the "control" group with which we compare the change in local retail margins in Perth before and after T. We consider five different control groups:

- Cycling capital cities - Adelaide, Brisbane, Melbourne, Perth, Sydney
- Adelaide only
- All markets in Australia
- All markets in Western Australia (WA) and South Australia (SA)
- All markets in Western Australia

Table B.1: Difference-in-Difference Estimation Results

$1\{Post\ T\}_t \times 1\{Perth\}_i$	3.44***
	(0.70)
$1\{Post\ T\}_t$	-0.66
	(0.78)
Brisbane	4.05***
	(0.27)
Melbourne	1.29***
	(0.36)
Perth	-2.06***
	(0.68)
Sydney	2.14***
	(0.29)
Constant	6.64***
	(0.54)
Date Fixed Effects	Y
R-Squared	0.58
Observations	230

Notes: Outcome variable is average monthly retail gasoline margin in cents per litre. The break date for the change in margins is set to T=Jan2010. Robust standard errors reported in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Adelaide is the geographically nearest cycling city to Perth that is also similar in size, and hence likely represents the "closest" comparison market to Perth. The latter two sets of control groups similarly focus on more local control markets in WA (Perth's state) and the neighbouring state of SA.

Table B.2, which presents the robustness checks results, shows that regardless of where the break date is set, or how the comparison group is defined, we almost always find a statistically significant difference-in-difference estimate. The estimates imply that Perth's local retail gasoline margin grew by 2 cpl to 4 cpl relative to other markets around the start of 2010, depending on the comparison group. We even find a statistically significant and similar magnitude estimate if we focus on WA markets only (bottom panel of the table), all of which recall are under the Fuelwatch price transparency program. The rise in margins we find is truely local to Perth in the state.

Table B.2: Difference-in-Difference Estimation Results

	Comparison Group: Cycling Capital Cities				
Margin Break Date (T):	Nov2009	Dec2009	Jan2010	Feb2010	Mar2010
$1\{Post\ T\}_t \times 1\{Perth\}_i$	2.01***	2.97***	3.44***	4.23***	3.50***
	(0.60)	(0.82)	(0.70)	(0.77)	(0.89)
R-Squared	0.55	0.57	0.58	0.61	0.60
Observations	230	230	230	230	230
	Comparison Group: Adelaide				
Margin Break Date (T):	Nov2009	Dec2009	Jan2010	Feb2010	Mar2010
$1\{Post\ T\}_t \times 1\{Perth\}_i$	1.91***	2.36***	2.99***	4.05***	3.57***
	(0.34)	(0.46)	(0.62)	(0.95)	(0.94)
R-Squared	0.41	0.43	0.48	0.59	0.58
Observations	92	92	92	92	92
	Comparison Group: All Markets in Australia				
Margin Break Date (T):	Nov2009	Dec2009	Jan2010	Feb2010	Mar2010
$1\{Post\ T\}_t \times 1\{Perth\}_i$	1.53***	2.20***	2.34***	2.90***	2.70***
	(0.38)	(0.62)	(0.53)	(0.62)	(0.59)
R-Squared	0.85	0.86	0.86	0.86	0.86
Observations	5609	5609	5609	5609	5609
	Comparison Group: All Markets in WA and SA				
Margin Break Date (T):	Nov2009	Dec2009	Jan2010	Feb2010	Mar2010
$1\{Post\ T\}_t \times 1\{Perth\}_i$	1.58**	2.16***	2.19***	2.57***	2.28***
	(0.69)	(0.71)	(0.61)	(0.59)	(0.61)
R-Squared	0.90	0.90	0.90	0.90	0.90
Observations	828	828	828	828	828
	Comparison Group: All Markets in WA				
Margin Break Date (T):	Nov2009	Dec2009	Jan2010	Feb2010	Mar2010
$1\{Post\ T\}_t \times 1\{Perth\}_i$	1.36	1.71	1.66	1.73*	1.48*
	(1.51)	(1.23)	(1.05)	(0.91)	(0.85)
R-Squared	0.90	0.90	0.90	0.90	0.90
Observations	322	322	322	322	322

Notes: Outcome variable is average monthly retail gasoline margin in cents per litre. All specifications include a dummy variable that equals one for all dates after the break date T, as well as market i and date t fixed effects. Robust standard errors reported in parentheses. $^{***}\ p < 0.01$, $^{**}\ p < 0.05$, $^{*}\ p < 0.1$.