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Hub-and-spoke cartels: Theory and evidence from the grocery industry

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Hub-and-spoke cartels: Theory and evidence from the grocery industry*

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Abstract

Numerous recently uncovered cartels operated along the supply chain, with firms at one end facilitating collusion at the other – hub-and-spoke arrangements. These cartels are hard to rationalize because they induce double marginalization and higher costs. We examine Canada's alleged bread cartel and provide the first comprehensive analysis of hub-and-spoke collusion. We make three contributions: i) Using court documents and pricing data we provide evidence that collusion existed at both ends of the supply chain, ii) we show that collusion was effective, increasing inflation by about 40% and iii) we provide a model explaining why this form of collusion arose.

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1 Introduction

The substantial literature on collusion has focused almost exclusively on agreements between manufacturers or between retailers: *horizontal collusion*. However, a large number of recently uncovered and prosecuted cartels operated along the supply chain with firms at one end facilitating collusion at the other – so called *hub-and-spoke* cartels. The first US hub-and-spoke case, Interstate Circuit v. United States, dates back to 1939 and involved an operator of first-run movies acting as the hub, coordinating the behavior of motion picture distributors in an effort to limit competition from subsequent-run movie theaters. More recently, the Department of Justice successfully prosecuted a hub-and-spoke case against Apple and five major book publishers (United States v. Apple, 791 F.3d 290 (2d Cir. 2015)) for raising ebook prices and exclusionary conduct (as a result of a most favored nation clause and since rival ebook distributor Amazon would be compelled to adopt an agency pricing model). Garrod, Harrington, and Olczak (2020) provide further examples.

Despite the prevalence of hub-and-spoke cartels, the existence of collusion along the supply chain is difficult to identify empirically, and hard to rationalize theoretically. From a theoretical point of view, manufacturers have incentive to limit market power in the retail sector, and vice versa, in order to avoid problems of double marginalization and of higher costs. As such, it is not clear what impact this sort of arrangement has on prices and why this form of cartel arises rather than say supplier-only or retailer-only collusion. From an empirical point of view, the challenge of antitrust authorities is to evaluate the involvement of firms at different levels of the supply chain in maintaining supra-competitive markups.

In this paper we answer these questions and provide the first comprehensive analysis of an actual hub-and-spoke collusive arrangement. Our focus is on the cartel uncovered in Canada's bread market. On January 31st 2018 documents were released containing allegations by the Competition Bureau of Canada that grocery retailers *and* suppliers had conspired to fix the wholesale and retail prices of fresh commercial bread.[1] The Bureau became aware of the alleged price fixing in March 2015 when a grocery retailer informed it of a collusive arrangement in the industry through the Bureau's immunity program. The allegations suggest that collusion began in late 2001 and continued for about a decade and a half. The Bureau documents describe a collusive arrangement in which suppliers helped to coordinate retail prices **and** retailers helped to coordinate supplier prices (a two-sided hub-and-spoke arrangement), and they provide evidence of fifteen price increases proposed by suppliers between 2001 and 2016.

We make three main contributions. Using (i) conversations with industry insiders about how

[1] Legal disclaimer: This paper analyses the alleged cartel case strictly from an economic point of view. The investigation into, and prosecution of, firms involved in the alleged conspiracy is ongoing. The allegations have not been proven in a court of justice. However, for the purpose of this paper, we take these facts as established. The analysis is preliminary and incomplete, and the findings are still subject to change. We base our understanding of the facts mostly on documents prepared by the Competition Bureau. The appendix provides a description of their content.

this market functioned before the cartel became operational, (ii) documents submitted by the Bureau to the courts that describe the collusive arrangement, and (iii) data on prices and market structure from Statistics Canada and Infogroup Canada, we first show that hub-and-spoke collusion was effective. We then provide evidence that both suppliers and retailers were involved in the cartel. Finally, to examine why coordination arose at both ends of the supply chain, we develop a theoretical model that explains the emergence of a two-sided hub-and-spoke collusion agreement, applicable in a broad class of consumer goods markets.

To confirm that the hub-and-spoke arrangement was successful and to quantify the impact of the cartel we use consumer price index data from Statistics Canada and a difference-in-differences approach in which we compare inflation rates of bread and control products around the start and end of the cartel. This approach has been used to study the impact of alleged price fixing in other markets (see for instance Clark and Houde (2014), Miller and Weinberg (2017), and Clark, Coviello, Gauthier, and Shneyerov (2018)). Our results suggest that bread prices grew at a faster rate than all other food categories over the entire period. At the end of the collusive period, we estimate that bread prices were roughly 40% higher because of the cartel's actions.

The objective of the second part of our empirical analysis is to test the hypothesis that both ends of the supply chain were implicated in the collusive arrangement. The court documents and subsequent commentary offer compelling evidence that the suppliers were colluding, but the allegation that retailers were involved has not been proven in court. We use store-level data from Statistics Canada and market structure information from Infogroup Canada to analyze the dispersion of prices within and across cities, both during the coordination period (prior to 2016), and during the months following the collapse of the agreement (2016-208).

We find that the pass-through of wholesale price increases during the cartel period, and the subsequent collapse in prices following the investigation were not uniform across markets and retailers. Looking first *across markets*, we document that price increases were more pronounced the greater the extent of concentration, and in markets with fewer discount chains. The end result was a higher pass-through rate in less competitive markets, consistent with the hypothesis that price coordination is easier in these markets. Similarly, looking *within markets*, we find that the collapse of the agreement was triggered by low-price (discount) retailers, that reduced bread prices by a greater amount and at a faster rate than rival high-price stations. This led to an increase in within-market price dispersion following the public announcement of the investigation. Together these results provide evidence supporting the claim that a group of retailers coordinated on supra-competitive margins. Given that the market does not exhibit wholesale price discrimination, had collusion been taking place solely upstream, pass-through should have been greater in more competitive markets

What remains to be explained is why they settled on the particular arrangement observed. More specifically, we are interested in understanding the incentives to collude and why collusion arose at both ends of the supply chain, rather than retailer-only or supplier-only collusion. Economists have only recently begun studying cartels linking both ends of the vertical supply chain. Existing explanations include those provided by Sahuguet and Walckiers (2017), Van Cayseele and Miegielsen (2013), Giardino-Karlinger (2014), and Gilo and Yehezkel (2020). In Sahuguet and Walckiers, if retailers are left to their own devices, their interactions generate inefficiencies for the entire market. In their setup, demand is assumed to be volatile (à la Rotemberg and Saloner (1986)) and the monopoly supplier does not know the state. In this case, information exchange between the supplier and retailers can increase profits of the vertical chain. In Van Cayseele and Miegielsen, Giardino-Karlinger, and in Gilo and Yehezkel, rewards or the threat of exclusion imposed by the supplier provide incentives to maintain the hub-and-spoke arrangement. In Van Cayseele and Miegielsen, and in Gilo and Yehyzkel the wholesale price is determined through a bilateral bargaining procedure and the supplier can charge higher price under retail collusion. In Giardino-Karlinger, the supplier earns zero along the collusive path, but absorbs all profits under punishment by exercising an exclusive dealing option.[2]

These explanation mostly involve settings featuring a monopoly wholesaler, or markets in which suppliers successfully exclude their rivals. These papers also focus on cases where one end of the vertical chain is a single entity acting as the hub helping to coordinate the behavior of the multiple spokes at the other end. These features do not accurately characterize the settings of many of the hub-and-spoke cases that have been uncovered by antitrust authorities. Two of the most famous are Toys R Us v. FTC and Argos & Littlewoods v OFT. In the former, Toys R Us, acting as the hub, organized and enforced a horizontal agreement among its various suppliers (for example Hasbro, Mattel, Fisher Price). In the latter, a manufacturer, Hasbro coordinated pricing by retailers Argos and Littlewoods. Clearly, there is competition at both ends of the supply chain. In other cases, it is evident that there are multiple entities performing the role of hub. Garrod, Harrington, and Olczak (2020) describe the hub-and-spoke cartel in the UK dairy market and note that there was "a degree of direct co-ordination and contact between the processors themselves with the aim of implementing a market wide cheese retail price increase" (see page 75). Moreover, we do not always observe exclusion. Rather, many business-to-business settings feature multi-sourcing, with the downstream firm sourcing from multiple upstream suppliers. Lastly, as in our setting, suppliers are the hub coordinating retailer behavior, but retailers in turn act as hubs to coordinate supplier pricing. In other words, the hub-and-spoke structure that we observe is two-sided. Our model addresses the shortcomings of the existing proposed explanations by allowing for (i) competition at both ends of the supply chain, (ii) multi-sourcing, and (iii) two-sided hub-and-spoke collusion.

Our model relies on two institutional features of the bread market that are present more generally in most consumer good markets. First, in addition to providing their product, in many markets suppliers are expected to provide important services to retailers; including shelving, removal of unsold products, etc. These services are costly to provide but have a public good aspect, so that a

[2] See also Sahuguet and Walckiers (2014), Van Cayseele and Miegielsen (2014), and Garrod, Harrington, and Olczak (2020) for discussion.

single supplier's services benefit a retailer carrying the products of multiple providers. As a result, retailers have an incentive to select a "category captain" (or main supplier). Moreover, since shelf space is scarce and the service costly, the shelf-space allocation is typically decided at the chain level, and the captain is awarded a better shelf space across all outlets of a given retailers. One or more "secondary" suppliers obtain the remaining shelf space share. This creates an endogenous asymmetry between otherwise symmetric suppliers, which reduces the ability of firms to collude upstream.

A second important factor is that wholesale prices are the outcome of negotiations between the suppliers and retailers, with suppliers competing to be the main supplier. The service relationship that is formed between retailer and main supplier is such that the former views it as costly to switch away from the latter towards rival suppliers. The resulting switching cost determines the relative leverage that the main supplier has in the wholesale price negotiations.

With retailers competing for consumer purchases and wholesalers competing to be a retailer's main supplier, it is not surprising that retailers would like to collude on retail prices and wholesalers collude on wholesale prices. One might even imagine that the wholesalers would prefer the retailers to collude in order to increase available surplus in the wholesale price negotiations (e.g. if aggregate demand is inelastic). There would appear to be no reason, however, for retailers to support wholesaler collusion: Doing so raises the retailers' costs and so shifts collusive profits from the retailers to the wholesalers. This argument is correct as long as there is no price discount that a wholesaler can profitably offer a retailer that induces the retailer to break the retail cartel. When the retail cartel is sustainable in this sense, then the incentive for retailers is to make wholesaler collusion as difficult as possible leading in the limit to a retailer-only collusion equilibrium.

When the retail cartel is not sustainable – i.e., when a wholesaler can break the cartel by offering a price discount that induces a retailer to price cut – competition between wholesalers limit the ability of retailers to collude. The existence of this negative externality is the main driver behind the existence of a hub-and-spoke collusive agreement: retailers want to facilitate wholesaler collusion in order to facilitate their own collusion. The retailers accomplish this by transferring some collusive profits to the wholesalers in the form of both higher wholesale prices and larger shelf share for the secondary supplier (i.e. reducing firm asymmetries). In this way, retailers act as a hub to facilitate wholesaler collusion in order to support their own collusion.

Hub-and-spoke collusion also has a secondary effect on the ability of the industry to sustain high margins. With wholesalers in the collusive arrangement, retailers are able to make supplier deviations common knowledge and so full cartel punishments – dissolution of both the retail and wholesale cartels – can be implemented even if the retailers do not deviate. The ability to implement these more stringent punishments means that the wholesalers actively facilitate retailer collusion. In this sense, wholesalers act as a hub to facilitate retailer collusion.

Related literature

In addition to the articles on hub-and-spoke cartels mentioned above, our paper is also related to a number of other literatures. First, we are related to the empirical literature on the organization of cartels. Some of these papers have focused on describing the inner workings of cartels, for instance Pesendorfer (2000), Genesove and Mullin (2001), Roller and Steen (2006), Asker (2010), Clark and Houde (2013), and Igami and Sugaya (2021). Other papers have focused on distinguishing collusion from competition, for instance Porter and Zona (1999), Bajari and Ye (2003), Conley and Decarolis (2016), Aryal and Gabrielli (2013), Schurter (2017), and Kawai and Nakabayashi (2018). Block, Nold, and Sidak (1981) examine collusion in the US bread market in the 1960s and 1970s. Finally, Ross (2004) reviews cartels in Canada.

We are also related to an extensive literature on facilitating practices. The notion that an outside (or third) party can help to organize the cartel has been considered. The literature has mostly focused on the role of trade associations. Early models studying the role of trade associations for collusion were developed by Vives (1984) and Kirby (1988). More recently Alé-Chilet and Atal (2019) empirically examine the role of a trade association for facilitating collusion amongst physicians in Chile. See Marshall and Marx (2012) for a number of other examples. Greif, Milgrom, and Weingast (1994) characterize a repeated interaction between a city and merchants and describe how the city might help the merchants organize themselves into a guild. There is a long literature on the ability of vertical relations (i.e. resale price maintenance, integration, advertising restrictions) for facilitating collusion. See for instance Nocke and White (2007), Normann (2009), Rey and Vergé (2010), Jullien and Rey (2007), Matthewson and Winter (1998), Slade (2020) and Asker and Bar-Isaac (2020). Piccolo and Miklos-Thal (2012) show that firms can collude more easily in the output market if they also collude on their input supply contracts. In a recent paper Asker and Hemphill (2020) study conduct in the Canadian sugar industry and describe a setting that featured both horizontal and vertical coalitions and highlight the interplay between exclusion and collusion along the supply chain. In a new paper, Chaves and Duarte (2021) study a hub-and-spoke arrangement in which gasoline distributors helped to coordinate a collusive arrangement amongst retailer stations.

A number of papers have pointed out the anticompetive effects of slotting allowance (see Shaffer (1991); Sudhir and Rao (2006); Marx and Shaffer (2010)). Lastly, there is a small but growing literature on so-called *category captains*. This term is given to suppliers who provide extensive advice to retailers. Some papers have alluded to the possibility that this could facilitate collusion (see for instance Gabrielson, Johansen, and Shaffer (2018) and Kurtulus and Toktay (2011)).

Finally, we are related to a number of papers studying on the grocery sector. This includes the literature on slotting contracts (for a discussion, see Wright (2007) or Wright and Klein (2007)),[3]

[3]See also Shaffer (1991), Sudhir and Rao (2006), Marx and Shaffer (2010), FTC (2001), and www.ftc.gov/os/2001/02/slottingallowancesreportfinal.pdf

and the literature on competition in the grocery sector (see for instance Smith (2004), Ellickson (2007), and Ellickson and Misra (2008)). It also includes literatures on the grocery supply chain (see Sudhir (2001), Villas-Boas (2007), Bonnet and Dubois (2010), Draganska, Klapper, and Villas-Boas (2010), Noton and Elberg (2018), and Ellickson, Kong, and Lovett (2018)).

Outline

The rest of the paper proceeds as follows. In the next section we describe the market, including the vertical arrangements that characterize it. In Sections 3 and 4 we present the data, the evidence that hub-and-spoke collusion took place, and the empirical analysis of the impact of the cartel on prices. Section 5 contains the model which explains why two-sided hub-and-spoke arose. Finally, Section 6 concludes.

2 Institutional Details and Market Structure

Retail sector

In 2016, food and beverage sales in Canada accounted for 17% of the retail landscape, with sales valued at US$86 billion (C$115 billion). Approximately 58% of food sales were through grocery stores, which are currently dominated by three big players: Loblaws, Sobeys, and Metro. According to the court documents these three retailers accounted for 33.5%, 18.9% and 15.5% of the grocery market respectively. Other important players are Walmart with 8.8%, Giant Tiger with 1.4%, and Overwaitea, which is geographically focused on Western Canada, at 2.2%. There are also thousands of smaller outlets that range from tiny independent convenience stores all the way to high-end specialty food providers. The Big three each have a number of discount banners. Loblaws and its supermarket banners had 1501 stores in 2009. Sobeys had 1351 and Metro had 1483.

Wholesale sector

The commercial bread industry in Canada had $US2.2 billion in sales in 2017. Commercial bread is baked and shipped daily by suppliers. Two main suppliers, George Weston Ltd. and Canada Bread Co., dominate the market with 21.5% and 16.7% market share respectively in 2016 (EU (2017)). These are the only suppliers active in markets all across the country, with the remaining 2,386 bread producers operating at a more regional level. According to the court documents (paragraph 4.121, Competition Bureau ITO November 1st 2017) Weston and Canada Bread issue prices for their products on a national basis.[4,5]

[4] Unless otherwise noted all paragraph references are to the Information to Obtain search warrants filed on Nov 1st 2017 by the Competition Bureau.

[5] Similar pricing has been documented for a number of grocery products in the US by Gentzkow and DellaVigna (2019).

Horizontal mergers

Interestingly, in the years leading up to the start of the cartel there were a number of major acquisitions that increased concentration at both ends of the supply chain. In 1998, Sobeys acquired the Oshawa Group, which owned the IGA franchise. It also acquired a number of regional chains in Ontario, and various food service and wholesale companies. In so doing it became the second-largest grocery chain in Canada. In November 1998 Loblaws acquired Agora Foods and its 80 outlets. Then one month later, it acquired Provigo Inc., the leading grocery chain in Quebec, pushing its market share to close to 40%. This acquisition led Metro to acquire Loeb in June 1999, which had been owned by Provigo who was forced to sell it for competitive reasons. On the supplier-side, Canada Bread made a major purchase in 2001, acquiring Quebec-based Multi-Marques, including its main brand POM. While we do not provide any causal analysis of the impact of these acquisitions, the fact that the cartel started so quickly after them, suggests that they may have had coordinated effects (see for instance Miller and Weinberg (2017), Igami and Sugaya (2021), Vasconcelos (2005) and Loertscher and Marx (2020)).

The retail market also experienced a number of acquisitions throughout the cartel period. Metro acquired The Great Atlantic & Pacific Tea Company, Inc in July 2005. Sobeys acquired Safeway in June 2013. Loblaws acquired Shoppers Drug Mart in July 2013.

Vertical arrangements

Our understanding of the functioning of the commercial bread industry is based in part on conversations with a former high-level executive in the industry. Importantly, to explain the incentives firms had to begin colluding, the insider provided us with a description of operation of this industry in the period leading up to the start of the cartel.

The most common type of vertical arrangement is characterized by asymmetric long-term contracts between each downstream chain and the two bread suppliers. In the marketing literature, this type of vertical arrangement is often referred to as a *category captain* contract.

According to the industry insider, six key features explain the incentives of firms at both ends of the supply chain to collude and why the particular structure of the cartel was chosen. First, retailers compete in prices for heterogeneous consumers. Second, retailers sell products of both suppliers (ie. multi-sourcing). Third, retailers require important, uncompensated services (shelving and display consulting, actual shelving of bread, removal of "stale" bread from stores, timely delivery of new product). Fourth, the nature of theses services and scarce shelf space imply retailers want one producer to be their *main supplier*, or *category*. Fifth, there is an asymmetry in shelf space allocation, with more allocated to *main* than to the *secondary* supplier. Finally, wholesale prices are negotiated intermittently at the national level between suppliers and retailer, with suppliers competing to be main supplier.

Although the details of the arrangements between grocery chains and manufacturers are kept

Table 1: Brand shares by retailer (%)

	Canada Bread	**Weston**	**Private Label**	**Others**
		Loblaws		
City				
Trois-Rivières	4.3	36.9	26.1	32.6
Sherbrooke	1	31	27.3	40.7
London	4.5	43.3	17.1	35
Kingston	7.2	38.7	18.5	35.4
		Metro		
City				
Trois-Rivières	37.5	7.3	4.2	51
Sherbrooke	36.7	7.1	4.1	52
London	47.1	11.7	2.9	38.2
Kingston	51.4	7.3	2.9	38.2
		Sobey's (IGA)		
City				
Trois-Rivières	62.6	0	7.6	29.7
Sherbrooke	49.6	0	7.9	42.4

secret, data on product assortments confirm that shelf spaces are allocated unequally across brands. Table 1 illustrates this point using data on the number of products of each brand offered online by the three main retailers. We focus our attention on the shopping platforms available for these retailers at mid-size cities in Ontario and Quebec.[6] We count the number of different bread products offered by all suppliers (including private label) and then determine the share of total offering represented by each of the two big suppliers (Canada Bread and Weston), by private labels, and by other producers. Weston is dominant at Loblaws, while Canada Bread is dominant at both Metro and Sobeys. In each case there are at least five times as many products available belonging to the dominant supplier than the secondary supplier.[7] It should be pointed out that Weston and Loblaws are vertically integrated, which explains why Weston is the main supplier for Loblaws. As discussed below, together they were the immunity applicants.

This sort of asymmetric arrangement in which retailers multi-source, but have one main supplier, is common in many retail environments and also in many business-to-business settings. In the US bread industry there are also two dominant suppliers: Grupo Bimbo and Flowers Foods. In 2017 Bimbo had 26.8% market share, while Flowers had 20.8%.[8] Moreover, there is evidence that they

[6] Sobeys itself does not have an online shopping platform. We look instead at IGA, the Sobeys banner in Quebec, which does have an online shopping platform.

[7] From Table 1 we cann see that Sobeys does not offer any Weston products through its IGA online shopping platform, but in its Ontario stores it stocks both Canada Bread and Weston products, although the former are much more prominent.

[8] See https://www.bakeryandsnacks.com/Article/2017/07/21/The-top-10-US-bread-suppliers-Rising-sales-for-

provided services to retailers at which they were dominant. In Appendix B we provide descriptions from a trade magazine of the types of services that each of these suppliers provided at certain retail chains.

Wholesale prices are set once every nine to twelve months, and are essentially fixed for the period. Wholesale prices are negotiated at the national/overall chain level and the process essentially involves the grocery chain taking wholesale price proposals/bids from the two bread makers. Because of the asymmetry retailers view it as costly to switch from one bread maker to the other. However, according to our contact, if the main supplier comes in with a higher wholesale price quote than the competitor supplier, the retailer typically goes back to the main supplier to ask the supplier to match the lower bid. Matching often happens, in our contact's experience.

3 Data

To study the effect of the cartel on prices at both ends of the supply chain we make use of the following four data sources.

First, we use information from the court documents to learn about wholesale price changes that occurred during the cartel period. As we explain in the next section, the court documents summarize information from the pricing letters that the bread producers sent to retailers in order to coordinate price increases.

Second, we collected national pricing data from Statistics Canada. We gathered information on the average retail price of a loaf (675gr) of bread across the country.[9] We use these data to verify the information on wholesale price coordination contained in the court documents, and to get a first sense of the impact on retail prices. Since prices at the loaf level are not comparable to prices of other products, we also collected data from the Monthly Consumer Price Index of Statistics Canada.[10] Specifically, we collected price-index information for the *Bread, rolls, and buns* category from 1995 to 2018 (September). This sample period covers five years prior to the start of the alleged collusion, as well as roughly two years following the public announcement of the investigation. We label the period between 2001 and 2015 the "coordination period," and the period between 2016 and 2018 the "collapse period."

In addition to the price index for bread, rolls and buns, we collected information on the general "food" price index, as well as the price index from two other categories: "cereal" and "other bakery products." We also collected information on the price index for "hard spring wheat flour," which is the main input into bread production (i.e. proxy for average variable cost),[11] and we have gathered similar price-index information for US bread prices from the U.S. Bureau of Labor

Aryzta-Bimbo-Flowers?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright.

[9]These data are compiled from Statistics Canada Table: 18-10-0002-01 (formerly CANSIM 326-0012).

[10](Table: 18-10-0004-03 (formerly CANSIM 326-0020).

[11]The wheat flour data were gathered from the Monthly Industrial Product Price Index (Table: 182121)

Statistics (BLS).[12] Note that the BLS reports prices for white bread alone, as opposed to the amalgam of bread, rolls, and buns that we see with Statistics Canada.[13] All price indices are normalized to 100 in the year 2002.

Third, from Statistics Canada, we have also been granted access to their CDER-CPI Research store-level data set. This data set includes prices for a sample of commodities of unchanged or equivalent quantity and quality used in the construction of the Canadian Consumer Price Index. We have access to this for the period 2009-2018, which allows us to study the last seven years of the coordination period and also the impact of the collapse of the cartel. These prices are available at 225 stores in 38 markets throughout Canada. A market is defined as a census metropolitan area (CMA). Note that the store identity is anonymized, preventing us from analyzing differences across chains.

We use these data in conjunction with our fourth data set, from Infogroup Canada, to study heterogeneity in the cartel impact across different market structures. Using the Infogroup data set we characterize the downstream concentration of each city (in terms of store presence), as well as the relative importance of discount chains. This data set provides information on the addresses, industry classifications and number of employees for businesses across the country for all grocery store establishments. The panel dimension of the data is not reliable, and so we use the 2014 data-set to construct our variables. Table 2 provides summary statistics from the Infogroup data set for the 42 markets for which we can match it with the CDER-CPI data set. From this we can see that the mean market size is almost 167 grocery and convenience stores, of which Statistics Canada surveys on average 7.05 when constructing its price index. The top-3 retail chains (Loblaw, Sobeys and Metro) are present in most markets, and control 58% of establishments with more than 20 employees. The presence of convenience stores and pharmacies selling bakery products reduces substantially concentration in the market. Finally, each major chain offers a brand of discount grocery stores, competing with independent discount chains like Giant Tiger. Importantly, a discount grocery chain is present in every city, and 62% of cities include a single discounter chain.

4 The Cartel: Arrangement and Impact

On March 3rd 2015, Weston and Loblaws informed the Bureau of a collusive arrangement in the commercial bread market through the Bureau's immunity program. Under this program, the first party to disclose an offense not yet detected, or to provide evidence leading to a case referral to the Public Prosecution Service of Canada, may receive immunity from prosecution. On January 4th 2016 allegations of collusion were leveled by the *Canadian Federation of Independent Grocers*

[12]US Bread prices: Series Id - APU0000702111, Series Title - Bread, white, pan, per lb. (453.6 gm) in U.S. city average, average price, not seasonally adjusted.

[13]This price index is also not adjusted for exchange rate differences.

Table 2: Market structure summary statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
HHI (all)	0.05	0.03	0	0.18
HHI (20 employees)	0.32	0.12	0.08	0.56
Top 3 share of stores	0.22	0.07	0.05	0.48
Top 3 share of stores (20+ empl.)	0.58	0.1	0.28	0.8
Single discounter	0.62	0.49	0	1
Total number of stores	167.21	219.46	11	1136
Total number of stores (20+ empl.)	45.33	48.21	4	192
Number of stores surveyed (avg.)	7.05	5.51	2	25
N		42		

(CFIG). On August 11th 2017 the Competition Commissioner commenced an inquiry (extended in October). In 2018 Canada Bread acknowledged the investigation and released a statement that it was looking into the wrong doings, which, it pointed out, allegedly took place under previous ownership.[14] In contrast, with the exception of Loblaws, the retailers alleged to have participated have denied the allegations, and so it is our understanding that the biggest point of contention is the participation of retailers in the collusive arrangement.[15]

In this section we use the court documents along with the data on prices and market structure described above to evaluate the claim that firms at both ends of the supply chain successfully colluded using a hub-and-spoke arrangement. We first characterize the impact of the cartel, focusing on the magnitude and patterns of price increases during the coordination period (2001-2015). We make use of court documents to describe the coordinated price increases initiated by upstream suppliers, and price-index data for bread, for other food segments and for the U.S. bread industry, to evaluate the extent to which the industry successfully maintained supra-competitive margins. We then use store-level data covering the last six years of the "coordination period" and the collapse period to analyze the role of retailers. The court documents describe how coordinated price increases were initiated by upstream suppliers. However, there is much less evidence that retailers participated, making the arrangement a two-sided hub-and-spoke cartel. To confirm the role of retailers, we analyze the relationship between retail concentration and the pass-through of wholesale price increases, as well as the speed of the cartel collapse.

[14] https://www.canadabread.com/media-statement-%E2%80%93-update-canada-bread-response-release-ito-related-industry-wide-competition-bureau

[15] See for instance https://www.thestar.com/business/2018/06/29/who-started-canadas-alleged-bread-cartel.html or https://business.financialpost.com/news/retail-marketing/why-the-hell-are-they-at-1-88-inside-the-damning-allegations-of-collusion-between-grocers-producers-to-fix-bread-prices.

4.1 Evidence of cartel impact

According to the allegations contained in the court documents, the collusive arrangement started towards the end of 2001 following conversations between participants at an industry event attended by retailers and suppliers (see paragraph 4.24, reproduced in the appendix along with the other paragraphs referenced in this section). The court documents allege that during these conversations, annual price increases in other industries were pointed to as a model for the bakery industry (paragraphs 4.25 and 4.26). Bread prices were underperforming and persons from the suppliers described a plan to achieve *buy-in* for price increases and an objective of *orchestrating alignment through the retail community* (paragraph 4.27).

The allegations suggest that top executives at the suppliers were aware of the price increases that occurred. The documents describe an active network of salespeople working for suppliers who communicated with retailers. Their job was to ensure alignment of prices across retailers by communicating one retailer's acceptance of a price increase to the others and by coordinating the timing of price changes (paragraphs 4.90 and 4.91).

Retailers acted as information conduits between suppliers during the *socialization* process of a price increase (paragraph 4.94). Information on proposed price increases (dates/magnitude) was passed through retailers from one supplier to another (paragraphs 4.95 and 4.96). The fact that all retail chains stock products from both suppliers facilitated this information transmission between suppliers. This is similar to the network centrality role played by a particular convenience store chain in a recent gasoline price-fixing case studied in Clark and Houde (2013). This chain had long-term vertical contracts with all distributors, thereby allowing "legal" communications with its rival chains' suppliers.

The court documents allege a **7/10** convention whereby the two leading wholesalers increased price periodically (around once per year) by 7 cents per unit (loaf of bread) and these increases were followed by retail price increases of 10 cents (paragraph 4.34). The documents describe fifteen occasions during which price increases were coordinated. These are summarized in Table 3. In each case the suppliers issue a *price-increase letter* in which they announce that they will be increasing price at a specific point in time (the *effective date*). According to the court documents, a price-increase chart was included announcing product names, universal product codes, the original price, and the posted-price increase per unit (paragraph 4.35). From the table we can see that sometimes the price increase was listed as 8 cents or 4%, but according to the court documents they were always 7 cents (paragraph 4.53). On one occasion, the price increase is listed as being 16 cents, but this was, in fact, a double increase (paragraph 4.48). Also, on one occasion, the price-increase attempt seems to have failed. During the attempted increase in the winter of 2012, Weston did not announce a price increase on certain types of bread. As a result, Canada Bread rescinded its price increase and Weston responded by doing the same (paragraph 4.62).

In Figure 1a we plot these alleged increases against data from Statistics Canada on the average

Table 3: Court documents: Price increases

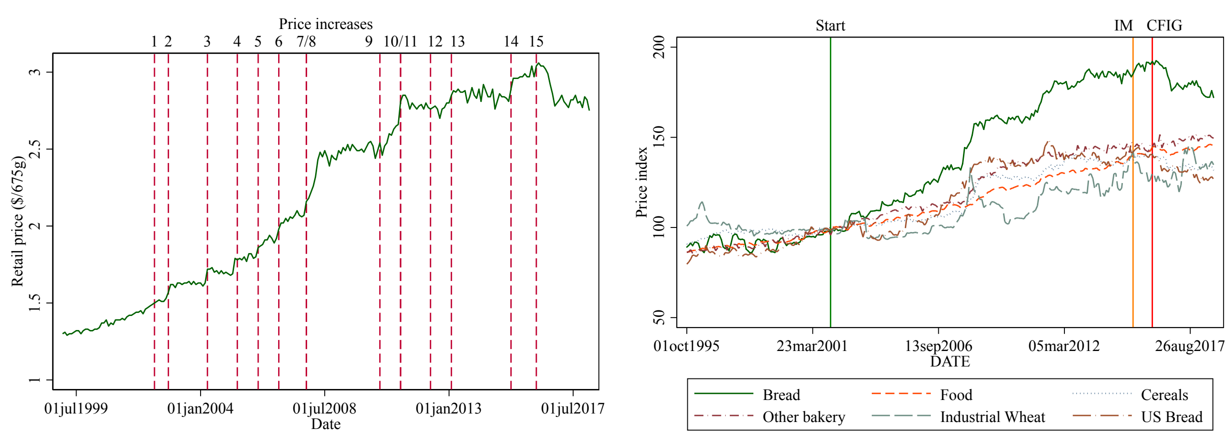
	Supplier 1			Supplier 2		
Price increase	Date of letter	Effective date	Amount of increase ($)	Date of letter	Effective date	Amount of increase ($)
1	Feb-02	Apr-02	0.07	20-Feb-02	29-Apr-02	0.07
2	Unknown	03-Nov-02	0.07	13-Sep-02	03-Nov-02	Unknown
3	Unknown	Unknown	Unkown	14-Jan-04	21-Mar-04	$\sim$ .08
4	Unknown	Unknown	Unknown	03-Feb-05	17-Apr-05	Unknown
5	Unknown	Unknown	Unknown	08-Nov-05	05-Feb-06	Unknown
6	27-Jul-06	15-Oct-06	.07 (branded)/ .06 (private label)	08-Aug-06	22-Oct-06	Unknown
7	Unknown	Unknown	Unknown	Unknown	21-Oct-07	0.08
8	Unknown	Unknown	Unknown	10-Sep-07	21-Oct-07	0.16
9	23-Mar-10	13-Jun-10	0.07	09-Apr-10	20-Jun-10	$\sim$ 4%
10	Dec-10	01-Feb-11	4%	10-Jan-11	27-Mar-11	$\sim$ 4%
11	Unknown	Unknown	Unknown	03-Feb-11	27-Mar-11	$\sim$ 8%
12	Feb-12	29-Apr-12	0.07*	01-Mar-12	06-May-12	Unknown*
13	24-Oct-12	27-Jan-13	$\sim$ .07	16-Oct-12	27-Jan-13	$\sim$ .07
14	15-Jan-15	19-Apr-15	$\sim$ .07	21-Jan-15	12-Apr-15	$\sim$ .07
15	02-Dec-15	28-Feb-16	0.07	30-Nov-15	06-Mar-16	0.07

* Indicates failed attempt.

Figure 1: National prices during the coordination period

(a) The 7/10 convention

(b) Bread vs other products



Vertical lines: Green = April 2002 (first coordinated price increase), Orange = March 2015 (immunity agreement), Red = January 2016 (independent grocers complaint)

retail price of a loaf (675gr) of bread across the country. The alleged coordinated price increases appear to line up very closely, in terms of both timing and magnitude, with price increases observed in the data on a national level. This suggests that the wholesale price increases listed in the court documents translated into retail price increases.

Figure 1b combines data from consumer price indices for 1995 to 2018 (with 2002=100) for bread, cereal, other bakery, and the aggregate food category. The figure also depicts the price index for hard spring wheat flour and for US bread prices. The red vertical lines indicate the alleged start date of the cartel (Start), the date of the immunity marker (IM), and the date of the allegations by the Canadian Federation of Independent Grocers (CFIG).

The price index for bread grows rapidly starting in 2002, around the time the cartel was alleged to have started.[16] It can also be seen that the price index falls sharply in 2016 around the time that allegations were made by the GFIG. This pattern can be compared to the pattern for wheat flour. Between 1995 and the end of 2001 wheat flour prices are similar to, if not greater than, those of bread, rolls, and buns. Wheat flour then experienced a much less pronounced inflation during the coordination period, suggesting that inflation in the bread category between 2002 and 2015 was mostly caused by an increase in the combined profit margin (i.e. retail+wholesale). Note that there were two sharp increases in the price of wheat flour during the coordination period. The first occurred in 2007-2008. This sudden and transitory shock was related to poor harvests, low stocks, rising oil prices, and financial speculation.[17] A second, more permanent price increase occurred in 2011. In both cases, the prices of bread, rolls, and buns increased sharply, but then did not fall back down.

Prices for other food categories also experience similar evolution to bread, rolls and buns prior to the start of the cartel, and less pronounced inflation during the coordination period, and do not break sharply at the end of the cartel period. The same is true of US bread prices, although from this series we can also see an increase in 2007-2008 at the time of the cost shock.

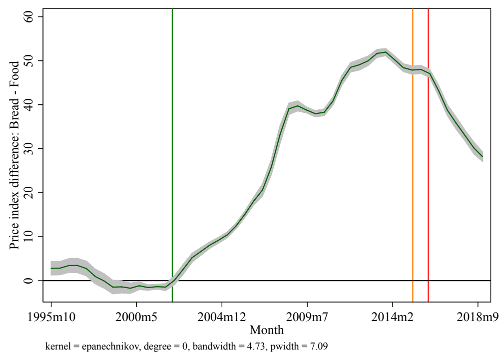
Figure 2 plots the difference between the price index of bread and each of the other categories.[18] Each line corresponds to a local polynomial regression of price differences on a time trend (confidence intervals in gray). As hinted by the evolution of the CPI levels, the price differences are not significantly different from zero (or slightly negative) prior to the start of the cartel, but grow almost linearly afterwards. Overall, the differences in annual inflation rates are significant and economically meaningful. Compared to food, bread grows at a 4.28% higher annual rate. The magnitude of these differences in trends is similar across all categories that we consider.[19]

The evolution of the price indices across segments and countries clearly displays a pattern of "progressive" coordinated price increases. This is similar to the behavior of other known cartels, although the period of increase would appear to be much longer in this case. For instance, Igami

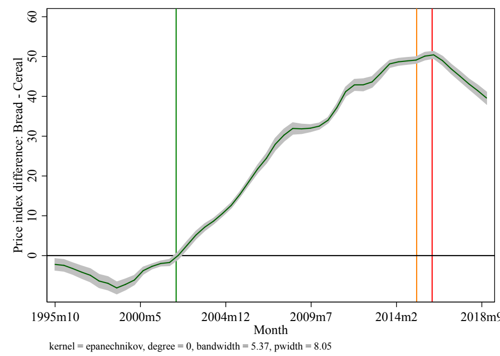
[16] Grier (2018) shows a similar pattern during the coordination period.
[17] See for instance https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6103.pdf.
[18] The regression coefficients are available in Tables ?? and ?? in the Appendix.
[19] See Table 5 in the appendix.

Figure 2: Relative price differences: Bread vs other products

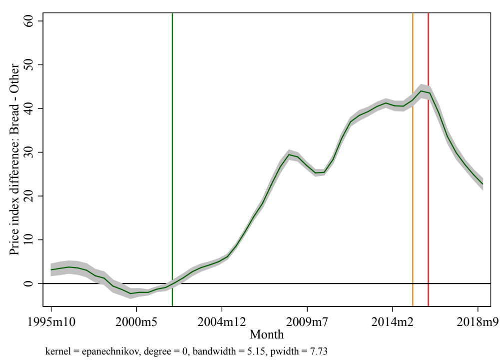
(a) Bread - Food



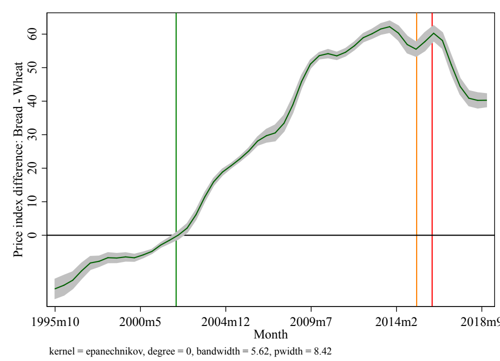
(b) Bread - Cereal



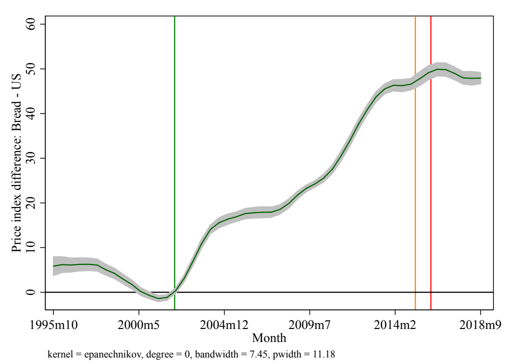
(c) Bread - Other bakery



(d) Bread - Wheat



(e) Bread - US vs CA



Note: CPI Index 2002 = 100. **Vertical lines:** Green = April 2002 (first coordinated price increase), Orange = March 2015 (immunity agreement), Red = January 2016 (independent grocers complaint).

and Sugaya (2021) document that vitamin C margins reached their stable levels roughly three years after the beginning of the collusive arrangement. See also Byrne and deRoos (2019) and Alé-Chilet (2018). Together with the description of price communications in the court documents, these findings suggest that the industry successfully sustained supra-competitive prices for an extended period of time.

Next, we test the hypothesis that the allegations of collusion triggered the collapse of the cartel and, with it, a national price decline. The first signs of instability for the cartel arose in March 2015 when Loblaws requested immunity from the Competition Bureau. Later that year, the Canadian Federation of Independent Grocers (CFIG) filed a formal complaint with the Bureau, alleging price fixing in the industry. We test this hypothesis formally using structural break tests to identify the best candidate date for the end of the cartel. Specifically, we calculate the Quandt Likelihood Ratio statistic, which is a modified Chow test that tests for breaks at all possible dates in some range. The hypothesis of a break at date t is tested for each t in the range using an F-statistic. The Quandt Likelihood Ratio statistic selects the largest of the resulting F-statistics to determine the best candidate break.[20] Results are presented in the appendix and show that the best candidate break occurred in the fall of 2016. As we will discuss below, this somewhat delayed response masks important heterogeneity within and across markets. Although this is a bit later than the CFIG complaint, we believe that it confirms that the cartel began to collapse prior to the inquiry launched by the Bureau in August 2017. We therefore use the CFIG complaint as the start date for the collapse period.[21]

We find that the impact of the cartel's collapse on annual bread price inflation was very pronounced. The price cuts were also spread-out over time, so that by the end of 2018, bread prices are still significantly higher than other categories. This could be because there has been less time for prices to adjust.[22] There is also some heterogeneity across control categories. The CFIG allegations led to a 7.33% annual decline in bread price relative to the food price index. This differential trend ranges from -9.96% (against wheat) to -2.5% (against U.S. bread prices). See Table 5 in the appendix.

4.2 Evidence of collusion at both ends of the supply chain

As mentioned in the introduction to this section, with the exception of the immunity applicant, the retailers have denied the allegations. Therefore, in order to confirm that a two-sided hub-and-spoke arrangement was in place it is necessary to provide confirmation that retailers were colluding. For this, we take advantage of our outlet-level panel to analyze price changes within and across markets during the 2009-2018 period, which includes both the last seven years of the coordination phase

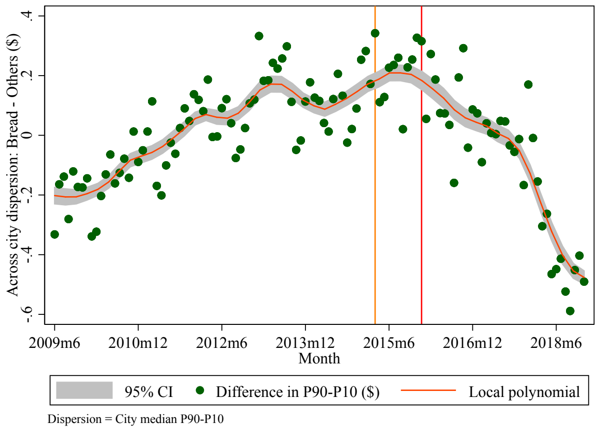
[20] The test was developed by Quandt (1960) and distributional properties were established by Andrews (1993). This test has been suggested and used in previous work involving collusive behaviour (see for instance Harrington (2008), Clark and Houde (2014), Boswijk, Bun, and Schinkel (2018), Crede (2019)).

[21] We have redone our difference-in-differences analysis below using this alternative break timing and our results are comparable, although the average price decline is slightly larger.

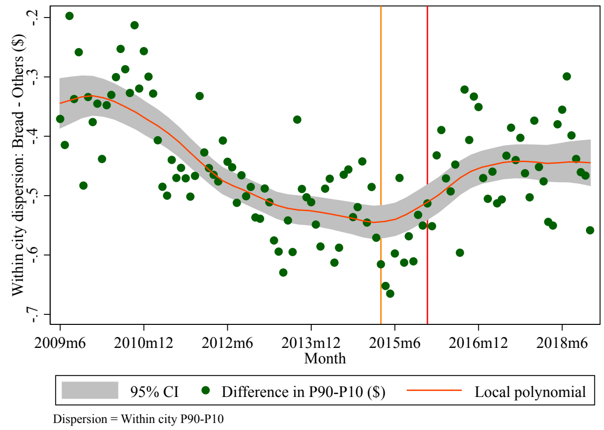
[22] Alternatively it could be because cartel participants strategically price above the competitive price following the collapse of the cartel knowing that antitrust authorities us post-collapse prices to calculate damages. See Harrington (2004).

Figure 3: Evolution of price dispersion for bread relative to other categories

(a) Across cities



(b) Within cities



Vertical lines: Orange = March 2015 (immunity agreement), Red = January 2016 (independent grocers complaint).

and the collapse phase. In particular we test two standard predictions of collusion models. First, we test the null hypothesis that price changes during the coordination and collapse periods were uniform across markets. Under the null hypothesis that retailers were not colluding, the effect of the allegations should not be a function of retail-market structure – price changes should be uniform across markets. Second, we analyze the relationship between collusion and the dispersion of prices within markets. A common flag for collusion is that prices are set uniformly across retailers. We therefore investigate how within-market price dispersion evolved over time as the industry transitioned from collusive to non-collusive. Rather than presenting results separately for different control products, we present results that compare the evolution of bread prices relative to all other products in our control group (between 18 and 21 products total).

Figure 3a illustrates how the distribution of prices across cities changed between 2009 and 2018 for bread compared to other products.[23] We first calculate the median price for each city/item/month combination. Each dot measures the average difference between the 90th and 10th percentile of the median price for the bread category, relative to other items. The average is calculated across products.

The figure shows an inverted-U pattern over time. At the peak, in June 2015, the difference between 90th percentile city and 10th percentile city was on average 20 cents higher for bread, compared to other categories. This was up from -20 cents in 2009 prior to the last wave of price increases documented in the court documents. In contrast, starting in the first quarter of 2016 (after the CFIG complain), prices became more uniform across cities. This drop in dispersion

[23]The CDER-CPI data set contains information on four different items in the bread, rolls, and buns category.

was particularly pronounced after the public announcement of the Bureau investigation in 2018. Importantly, this decline in price dispersion was caused by a drop in bread prices among "high-price" cities. Cities at the bottom of the price distribution were not impacted by the collapse of the cartel. This pattern implies that the pass-through of price increases proposed by manufacturers was not uniform across markets, suggesting that the ability to coordinate retail prices was easier in some markets than others. During the collapse period, retail profit margins declined among high-price cities, but stayed more or less constant in more competitive markets.

To understand better the source of these differences in markups across markets we analyze the relationship between local market concentration and annual price changes between 2009 and 2018. We estimate the following regression at the item (i), outlet (j) and month (t) level:

$$p_{i,j,t} = \beta_0 \times \text{Trend}_t \times 1(\text{Bread})_i + \beta_1 \times \text{Trend}_t \times 1(\text{Bread})_i \times X_m + \mu_{i,m} + \tau_t + e_{i,j,t}, \quad (1)$$

where Trend_t is a linear trend (divided by 12 to facilitate interpretation), $\mu_{i,m}$ is a market/item fixed-effect, and τ_t is a month/year fixed-effect. The coefficient β_0 measures the difference in the annualized change in prices for bread relative to other categories, while β_1 expresses the difference in trends as a function of market structure variable X_m. We use three measures of concentration: (i) the HHI index across all establishments, (ii) the share of establishments controlled by the top 3 chains, and (iii) an indicator variable equal to one for markets with a single discount chain.

Tables 4a and 4b present the estimates separately for the coordination and collapse periods. Looking first at the 2009-2015 period, we can see from column 1 that bread prices increased by 2.5 cents more per year than for other categories. Columns 2 to 4 break this result down by retail market structure and suggest that the pass-through of wholesale price increases was greater in more concentrated retail markets. A one standard-deviation increase in the HHI index increases the annual growth rate by 3 cents (or 18 cents over the period). Similarly, prices increased at a rate of 5.3 cents/year in markets with a single discounter, compared to zero in markets with multiple discount chains. The results from Table 4b reveal the reverse patterns during the collapse period. Bread prices fell 8.5 cents more per year than did prices in other categories, and the price decline was more pronounced in markets featuring a single discount chain and more establishment concentration.

These findings highlight how local concentration and symmetry between retailers facilitated coordination and increased the pass-through of wholesale price increases. After the announcement of the beginning of the investigation, concentrated markets cut prices by the largest amount, consistent with the idea that markets with more competition from regional chains and discounters failed to coordinate on the collusive markups prior to the collapse.

To investigate the role of discount and low-price chains further, we return to Figure 3 and focus our attention on Figure 3b, which presents the evolution of the within-market price distribution of bread compared to other products. As collusion becomes more and more successful between 2009

Table 4: Changes in outlet-level bread prices relative to other categories

(a) Coordination period: June 2009 to March 2015

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Trend/12 x Bread	0.0253**	-0.00956	-0.0219	-0.0106
	(0.0100)	(0.0112)	(0.0169)	(0.00630)
Trend/12 x Bread x HHI (all)		1.014***		
		(0.173)		
Trend/12 x Bread x Top 3 share (all)			0.239***	
			(0.0833)	
Trend/12 x Bread x Single discount chain				0.0637***
				(0.0141)
Constant	3.170***	3.170***	3.170***	3.171***
	(0.0241)	(0.0225)	(0.0230)	(0.0243)
Observations	384,932	384,932	384,932	384,932
R-squared	0.718	0.718	0.718	0.718

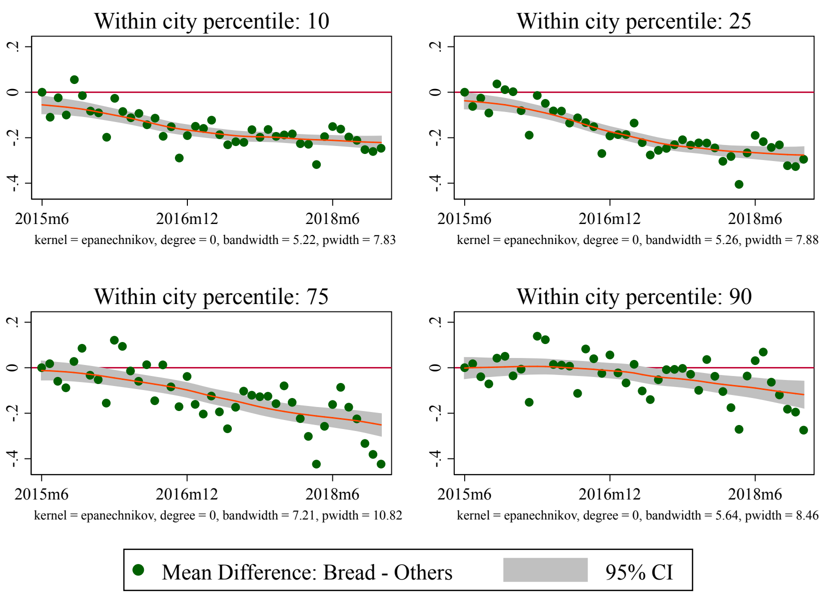
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Clustered std-errors: City. Additional controls: Month FE, City/Item FE.

(b) Cartel collapse period: March 2015 to December 2018

VARIABLES	(1) Price	(2) Price	(3) Price	(4) Price
Trend/12 x Bread	-0.0815***	-0.0453*	-0.0481	-0.0168
	(0.0156)	(0.0266)	(0.0551)	(0.0260)
Trend/12 x Bread x HHI (all)		-1.033**		
		(0.444)		
Trend/12 x Bread x Top 3 share (all)			-0.169	
			(0.250)	
Trend/12 x Bread x Single discount chain				-0.123***
				(0.0317)
Constant	3.678***	3.678***	3.678***	3.679***
	(0.0100)	(0.00977)	(0.00982)	(0.00884)
Observations	187,461	187,461	187,461	187,461
R-squared	0.673	0.673	0.673	0.673

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Clustered std-errors: City. Additional controls: Month FE, City/Item FE

Figure 4: Changes in the within-city distribution of prices during the collapse period



and 2015, within city price dispersion falls. When the cartel collapses, it increases sharply. In other words, bread prices were set more uniformly during the coordination period.

To understand why, we turn our attention to Figure 4, which plots the changes in the within-city distribution of prices during the collapse period relative to other products. We present results for the 10th, 25th, 75th, and 90th percentile. We observe that the lowest-price outlets (e.g. discount stores) quickly and significantly lowered prices following the collapse. Stores with prices in the 25th percentile adjust slightly later and those in the 75th later still. In contrast, the highest-price outlets cut prices only after the public announcement of the investigation.

This staggered pattern of price cuts within markets illustrates the role of asymmetry between retailers, and explains the increase in within-market price dispersion post-2016. The collapse of the collusive agreement was led by low-price chains, consistent with the theory that stores facing more elastic demand and/or lower costs are more likely to deviate from a collusive agreement (e.g. Jacquemin and Slade (1989)).

In summary, our analysis of the court documents and data provides evidence of successful collusion at both ends of the vertical chain. From the court documents it is clear that the suppliers coordinated their pricing strategies, but it is less obvious that retailers did. We analyze the role of retailers by measuring the effect of concentration and asymmetries on the ability of retailers to sustain supra-competitive margins. We find that the effect of the allegations of collusion was not uniform across markets, and instead was a function of retail market structure. In more concentrated grocery markets, we document a steeper decline in prices following the beginning of the

Bureau investigation, and more pronounced price increases during the coordination period. This is consistent with retailers coordinating on higher markups in more concentrated markets prior to the announcement, leading to a *higher* pass-through of wholesale prices (relative to more competitive markets). Also, consistent with the fact that successful collusion is often associated lower price dispersion, we find that prices were set more uniformly within markets during the coordination period, and that price dispersion increased significantly after Loblaw/Weston filed an immunity request with the Competitive Bureau.

Both pieces of evidence suggest that retailers were involved in the collusive agreement, and successfully maintained supra-competitive markups in markets in which price coordination was easier. What remains to be shown is why the arrangement that they settled on was one of two-sided hub-and-spoke. Put differently, why did the participants at either end of the vertical supply chain not form their own cartel that operated separately from the other end of the chain? To answer these questions, we turn to theory and develop a model that illustrates why a two-sided hub-and-spoke arrangement facilitated collusion.

5 A Model of Two-Sided Hub-and-Spoke Collusion

In this section we propose a model of the bread supply chain. Our objective is to provide insight into (i) the incentives for firms at both ends of the supply chain to collude, and (ii) the reasons a two-sided hub-and-spoke arrangement arose. The model also serves to address some of the elements lacking in the previous models of hub-and-spoke collusion. Specifically, our model allows for competition at both ends of the vertical chain, does not involve exclusion (ie. it features multi-sourcing) and explains why collusion should involve competitors at both ends of the chain (ie. is two-sided in nature).

A basic element of the model is that upstream firms – the wholesalers – provide important services to retailers. These services are costly for the wholesaler to provide but have a public good aspect, so that a single wholesaler's services benefit a retailer carrying the products of multiple wholesalers. The consequence is that each retailer wants a single wholesaler to be its "main" supplier. Because shelf space is scarce and the service costly, the retailer allocates a larger share of the scarce shelf space to its main supplier. One or more "secondary" suppliers obtain the remaining shelf space share. This main supplier-secondary supplier dichotomy creates an asymmetry between wholesalers and forms a crucial element of our analysis. A second fundamental element is that wholesale prices are the outcome of negotiations between wholesalers and retailers, with wholesalers competing to be the main supplier. We assume that switching main suppliers is costly for the retailer as it must work out service details with a new main supplier. The size of the switching cost determines the relative leverage that the main supplier has in the wholesale price negotiations.

On the retail side, we assume that consumers incur costs if they move across retailers to make purchases. The more consumers who are shoppers and the more sensitive these consumers are to differences in bread prices across retailers, the greater the competition in the retail market for bread. We model these features of the retail bread market by assuming that retailers are separately located in space and compete in price for those consumers willing to shop across locations. A greater fraction of price sensitive consumers induces lower retail margins and so profits.

The combination of an asymmetric supply relationship and endogenous wholesale price setting means that, in some cases, two-sided hub-and-spoke collusion is desirable, even to retailers, relative either to supplier-only or retailer-only collusion. Supplier-only collusion is difficult to sustain because the secondary supplier has an incentive to undercut the arrangement and become the main supplier: the *asymmetry problem*. Retailer-only collusion is hard to sustain because of the incentive that a wholesaler has to offer the retailer a lower wholesale price –the *endogeneity problem* – to induce retail price cutting. Doing so shifts customers from rival retailers at which the wholesaler is not the main supplier to the one at which it is, thereby increasing the wholesaler's profits. Among other things, joint collusion allows retailers and wholesalers i) to coordinate shelf share allocations between main and secondary suppliers and ii) to coordinate wholesale price offers in ways that resolve both the asymmetry and endogeneity problems. Joint collusion also allows joint punishments for deviation to be implemented, which also facilitates collusion.

5.1 Model details

We consider a setting in which time is discrete and there is a countable infinity of time periods labeled $t = 1, 2, ...$ In every period there are two producers of bread, designated $i = 1, 2$, that produce potentially differentiated varieties. Bread maker 1's variety is labeled B_1 and bread maker 2's variety B_2. Each bread maker produces its variety at a constant unit cost of $c \geq 0$, with the value of c identical across bread makers and time invariant. Bread makers' products are sold via retail grocery stores. For simplicity, we assume that there are two grocery retailers, labeled $j = a, b$, operating in locales L_a and L_b respectively. We assume that there are N_a consumers residing in locale L_a and N_b consumers residing in locale L_b.[24] We assume in what follows that $N_a = N_b = 1$. Each period, consumers demand at most one unit of one of the two varieties of bread. A consumer in a given locale can be one of three possible types, 1, 2, or 3. A type 1 consumer has a valuation of $\overline{v}$ for variety B_1 and a valuation $\underline{v}$ for variety B_2. Type 2 consumers have the opposite preferences, valuing B_1 at $\underline{v}$ and B_2 at $\overline{v}$. The fraction of type 1 consumers in each locale is the same, as is the fraction of type 2 consumers. These fractions are given by ϕ_1 and ϕ_2 respectively. For simplicity, we assume that $\phi_1 = \phi_2 = \phi$. The remaining fraction of consumers in each locale are type 3 consumers. These consumers view the two varieties of bread as identical, having a common valuation of v. The three types of consumers' valuations are such that $\overline{v} > v > c > \underline{v}$.

[24] This specification is meant to capture the idea that grocery retailers are spatially separated and that consumers tend to frequent a grocery store near them. We imagine that at least some of the customers of any given retailer are shoppers in the sense that a sufficiently large price difference across retailers would induce these consumers to switch retail locations.

For simplicity, we assume that the type 1 and type 2 consumers in any locale always purchase from the retailer in that locale, if at all. The type 3 consumers in each locale are the potential shoppers. The fraction that may shop in any given period is given by a shopping-propensity parameter, $\tau \in [0,1]$. The value of τ can be thought of as a retailer density measure, capturing the fraction of shoppers that find it "cheap" to move across locations. Whether or not these type 3 consumers shop at time t depends on the retail bread price difference between locales at t, $p_a^{\min t} - p_b^{\min t}$, where $p_j^{\min t}$ gives the minimum retail price of bread in locale j at t. A type 3 consumer who shops will purchase at the lower-priced locale if $\mid p_a^{\min t} - p_b^{\min t} \mid > \Psi > 0$. The parameter Ψ reflects their degree of loyalty to their retailer. We assume that shopping consumers are heterogeneous in Ψ. For simplicity, we assume that Ψ is identically and uniformly distributed over time on the interval $[0, \bar{\Psi}]$, with density $1/\bar{\Psi} = d$.

The state of retail competition is determined by the pair $[\tau, \bar{\Psi}]$, with greater competition as τ increases and $\bar{\Psi}$ decreases. That is, if either $\tau = 0$ or $\bar{\Psi}$ large enough, then the two retailers have local monopolies in the sense that, either there are no shoppers or the duopoly price exceeds consumers' willingness-to-pay. By contrast, when $\bar{\Psi}$ is small and $\tau = 1$, duopoly competition for the type 3 consumers results in low retail prices.

Given our focus only on bread, and not the full range of products that large grocery stores sell, we assume for the model that the only cost of selling a particular variety of bread for the retailer is the wholesale price, w_i, paid to bread maker i. Retail bread prices are assumed to be set sequentially after wholesale bread prices. This assumption is consistent with industry practice in which wholesale prices are negotiated intermittently at the chain-wide level. When determining its retail price(s), each retailer is assumed to observe the selection of varieties that its competitor carries and which wholesaler is the main supplier. A retailer is assumed not to observe the actual wholesale prices that its competitor negotiated with its wholesale suppliers.[25] Given knowledge of their own wholesale prices and the anticipated equilibrium wholesale prices for their competitor, each retailer simultaneously sets retail bread prices at time t to maximize profits.

The wholesale price negotiation process involves each grocery retailer taking wholesale price proposals / bids from each of the two bread makers at each date t. This wholesale bidding process occurs sequentially prior to the retail price determination process and is the point at which the value of s is determined.[26] The "winning" bidder becomes the main supplier and is paid its wholesale price bid for each unit supplied. As the main supplier, the wholesaler obtains a share of shelf space – a shelf share – $s > .5$. In exchange for the greater shelf share, the main supplier provides "free-of-charge" services to the retailer. These services result in a fixed cost of, F_I for the wholesaler. The other wholesaler – the "losing" bidder – becomes the secondary supplier and is paid its price

[25] This assumption is in keeping with the assumption in much of the contractig literature. It also provides a direct information role for joint retailer - wholesaler collusion.

[26] This timing of wholesale and retail price determination is not completely in keeping with the facts of the bread market where wholesale prices are committed to for a period of up to 1 year.

bid. The secondary supplier obtains a shelf share of $1 - s$ and incurs some lower fixed cost of supplying the retailer denoted by $F_S < F_I$. The shelf shares are set so that the larger share at least compensates for the higher fixed cost.

In keeping with observed features of the industry, at the beginning of the wholesale price negotiation process in any period, one of the two suppliers is the incumbent main supplier. Switching main suppliers is assumed costly for the retailer as new arrangements must be put in place for the retail services provided. We model this switching cost as a fixed cost, Δ, incurred by the retailer should it switch main suppliers. The value of Δ is not known to suppliers prior to submitting their wholesale price bids. Rather, suppliers view Δ as a random variable which, for simplicity, we assume has a uniform distribution on the interval $[0, \bar{\Delta}]$. The existence of this switching cost gives the incumbent supplier an advantage in the wholesale price negotiations in that it can offer a wholesale price above that of the secondary supplier and still maintain its incumbent status with non-trivial probability. As will be seen subsequently, the size of $\bar{\Delta}$ is a measure of the leverage that the incumbent supplier has in the wholesale price negotiation game, with incumbent profits increasing in Δ. In what follows, we assume that the distribution of Δ is time invariant and that draws of Δ are independent over time.

The wholesale pricing game involves each of the two wholesalers simultaneously making wholesale price bids to each of the two retailers at each date t. The wholesalers make these bids knowing who is the incumbent supplier to each retailer. Each wholesaler chooses bids to maximize the expected value of its profits, anticipating how its bids affect the retail pricing equilibrium. Profits for both the retailers and wholesalers are defined as the expected present value of profits, with both retailers and wholesalers sharing a common discount factor β with $0 \leq \beta \leq 1$. In the non-cooperative game, we restrict players to using stationary Markov strategies and define equilibrium outcomes by the symmetric, Markov perfect equilibrium.

We start our analysis by first determining the equilibrium for the static (one-shot) pricing game. This is the equilibrium for the case of $\beta = 0$. We do so by solving the game backwards, looking first at the retailer pricing game and then studying how the wholesalers price. Subsequently, we analyze both the non-cooperative equilibrium to the wholesale and retail pricing game when $\beta > 0$ and the cooperative /collusive outcomes for this case. The latter analysis will allow us to understand the situations in which two-sided hub-and-spoke collusion can be expected to arise and why it is of value to both parties.

5.2 Static setting: $\beta = 0$

5.2.1 Retail pricing

Since Ψ is uniformly distributed on the interval $[0, \bar{\Psi}]$, with density $1/\bar{\Psi} = d$, if retail prices are p_a, $p_b \leq v$, then demand for retailer a is given by:[27]

$$Q_a^R = [1 + \tau d(1 - 2\phi)(p_b - p_a)]. \tag{2}$$

Its profits are

$$\pi_a^R = (p_a - \overline{W_a})[1 + \tau d(1 - 2\phi)(p_b - p_a)], \tag{3}$$

where $\overline{W_a} = sw_I + (1 - s)w_S$ is the shelf share weighted average of the wholesale prices, (w_I, w_S) paid by retailer a to its incumbent main supplier and secondary supplier respectively. Retailer a's profit maximizing price, given some price, p_b, for retailer b is given by

$$[1 + \tau d(1 - 2\phi)(p_b - p_a)] - [\tau d(1 - 2\phi)](p_a - \overline{W_a}) = 0, \tag{4}$$

or

$$p_a = \frac{1}{2}(p_b + \overline{W_a}) + \frac{1}{2}\frac{1}{\tau d(1 - 2\phi)}. \tag{5}$$

The Nash equilibrium retail prices for retailers a and b, given average wholesale prices $(\overline{W_a}, \overline{W_b})$ are then:

$$p_a^*(\overline{W_a}, \overline{W_b}) = \frac{1}{\tau d(1 - 2\phi)} + \frac{2}{3}\overline{W_a} + \frac{1}{3}\overline{W_b}, \tag{6}$$

$$p_b^*(\overline{W_a}, \overline{W_b}) = \frac{1}{\tau d(1 - 2\phi)} + \frac{2}{3}\overline{W_b} + \frac{1}{3}\overline{W_a}. \tag{7}$$

Note that as either ϕ shrinks or t increases, there are more shoppers and p_j^* falls. When d increases, p_j^* falls also. In this case, d increasing implies that $\bar{\Psi}$ shrinks, so there are also more shoppers (less local-retailer loyalty).

In a symmetric equilibrium (i.e. one in which $\overline{W_a} = \overline{W_b}$), the quantity sold by each retailer is 1 and profits are

$$\pi_j^{R*} = (\overline{W} + \frac{1}{\tau d(1 - 2\phi)} - \overline{W}) = \frac{1}{\tau d(1 - 2\phi)}. \tag{8}$$

[27] We assume here and in what follows that parameters are such that it is more profitable for a retailer to serve all types at a common price than to serve only types 1 and 2. This assumption is a restriction on the numbers of type 1 and 2 consumers and the values of F_I and F_S.

In general, profits for retailer a are

$$\pi_a^{R*} = \frac{1}{\tau\ d(1-2\phi)} + \frac{2}{3}(\overline{W_b} - \overline{W_a}) + \frac{\tau d(1-2\phi)}{9}(\overline{W_b} - \overline{W_a})^2. \tag{9}$$

Note that, for $\overline{W_a} \neq \overline{W_b}$, retailer a's profits are declining in $\overline{W_a}$. In the symmetric case, retailer profits are declining in both t and d and increasing in ϕ. This will be true in the asymmetric case as well as long as the difference between $\overline{W_a}$ and $\overline{W_b}$ is not too large.

Finally, a local monopoly must ensue if the minimum of $p_a^*, p_b^* < v$. This will occur if τ is small, and/or d is small (i.e. $\bar{\Psi}$ is big).

5.2.2 Wholesale pricing

To establish some initial results on wholesale pricing, we begin with the case in which retailers are local monopolies. We then extend to the case of competing duopoly retailers and, finally, to a multiperiod competition setting.

Local retail monopoly

Suppose that wholesaler 1 is the incumbent main supplier to retailer a and wholesaler 2 the incumbent main supplier to retailer b. In a local monopoly setting, given any wholesale price bids to retailer a by 1 and 2 of (w_1^a, w_2^a) respectively, wholesaler 1 remains the main supplier if the unit cost for the retailer associated with keeping 1 as the main supplier, $sw_1^a + (1-s)w_2^a$, is less than the unit cost to the retailer of switching, $sw_2^a + (1-s)w_1^a - \Delta$. The critical value of Δ for which the retailer is just indifferent between switching and not is $\Delta^*_{mon} = (2s-1)(w_1^a - w_2^a)$. Given the assumption that Δ is uniformly distributed, this means that retailer a switches main suppliers with probability $\frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}$. The same would apply for wholesaler 2 as the incumbent to retailer b.

Given that retailer switching rule, we have that, for any bid pair (w_1^a, w_2^a) to retailer a, the expected profit for wholesaler 1, as the incumbent supplier to retailer a is:

$$\begin{aligned}\pi_1^w(w_1^a; w_2^a) = \quad & (w_1^a - c)\left[s\left(1 - \frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}\right) + (1-s)\left(\frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}\right)\right] \\ & -F_I + (F_I - F_S)\frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}.\end{aligned}$$

For the same bid pair, the expected profit for wholesaler 2 as the secondary supplier to retailer a is:

$$\begin{aligned}\pi_2^w(w_1^a; w_2^a) = \quad & (w_2^a - c)\left[(1-s)\left(1 - \frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}\right) + s\left(\frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}\right)\right] \\ & -F_S - (F_I - F_S)\frac{(2s-1)(w_1^a - w_2^a)}{\bar{\Delta}}.\end{aligned}$$

For bids to retailer b, the retailer for which wholesaler 2 is the incumbent, the opposite holds in terms of expected profits.[28]

Given the retailers are local monopolists, we can examine the wholesale price bidding to each retailer separately. In this case, the profit maximizing values of w_1^a and w_2^a offered to retailer a by wholesalers 1 and 2 respectively, given main supplier shelf share $s > .5$, are given by

$$\frac{d\pi_1^w}{dw_1^a} = 0 \quad \Leftrightarrow \quad s - \frac{w_1^a - w_2^a}{\bar{\Delta}}(2s-1)^2 - (w_1^a - c)\frac{(2s-1)^2}{\bar{\Delta}} + \frac{(2S-1)(F_I - F_S)}{\bar{\Delta}} = 0,$$
$$\frac{d\pi_2^w}{dw_2^a} = 0 \quad \Leftrightarrow \quad 1 - s + \frac{w_1^a - w_2^a}{\bar{\Delta}}(2s-1)^2 - (w_2^a - c)\frac{(2s-1)^2}{\bar{\Delta}} + \frac{(2S-1)(F_I - F_S)}{\bar{\Delta}} = 0.$$

Solving theses two equations, we obtain the equilibrium bids, (w_1^{a*}, w_2^{a*}):

$$w_1^{a*} = c + \frac{\bar{\Delta}(s+1)}{3(2s-1)^2} + \frac{F_I - F_S}{(2s-1)}, \qquad w_2^{a*} = c + \frac{\bar{\Delta}(2-s)}{3(2s-1)^2} + \frac{F_I - F_S}{(2s-1)}.$$

Since $s > .5$, we have that $w_1^{a*} > w_2^{a*} > c$. Indeed, it is straightforward to show that $w_1^{a*} - w_2^{a*} = \bar{\Delta}/3(2s-1)$, implying that, under the equilibrium bidding strategies, wholesaler 1 remains the main supplier with probability 2/3, while wholesaler 2 becomes the main supplier with probability 1/3. Therefore, in the local monopoly equilibrium, a retailer's expected unit costs are:

$$E\overline{W}(s) = c + \frac{F_I - F_S}{(2s-1)} + \frac{\bar{\Delta}}{9}\frac{4.5}{(2s-1)^2} - \frac{\bar{\Delta}}{18}. \tag{10}$$

Note that this expression is a decreasing function of s, meaning that it must be profit maximizing for retailers to set s as large as possible consistent with wholesaler 2 participating when it is the secondary supplier. That is, the value of s is defined so that $(w_2^{a*} - c)(1-s) = F_s$. This yields the local monopoly equilibrium shelf share, s^* as:

$$\frac{\bar{\Delta}(2-s)(1-s)}{3(2s-1)^2} + \frac{(F_I - F_S)(1-s)}{(2s-1)^2} = F_S.$$

Remark 1: This wholesale pricing game will prove important in the analysis of collusive outcomes. In particular, when $\beta > 0$, the Markov prefect equilibrium analogue of this problem (section 5.3) defines the non-cooperative outcome to the wholesale pricing game in cases in which the retailers are successfully colluding independently of the wholesalers.

Retail duopoly

With duopoly retailers, when a wholesaler chooses its price bids, it must anticipate the duopoly retail pricing outcomes that may arise and the ensuing quantities each retailer sells. Wholesale price

[28] Because the markets are symmetric, we will examine the equilibrium bids to retailer a in what follows.

competition is no longer just about competition for the larger shelf share, but also about shifting the duopoly retail equilibrium in a way that is expected to favor a given wholesaler. In many cases, competition in the wholesale market can spill over into greater competition in the retail market. As we will show subsequently, this spillover effect can impact the ability of retailers to raise prices.

How a given wholesaler values additional sales for retailer a relative to b depends on whether the wholesaler turns out to be the main supplier to a, b or both. Because of switching costs, a wholesaler is more likely to be the main supplier to a given retailer if it was that retailer's incumbent main supplier. Consequently, the way that a wholesaler assesses the value of any given bidding strategy depends on its state – incumbent or secondary supplier – prior to negotiations. In what follows, we distinguish two payoff relevant states: IS and II. In state IS, retailer a has a different incumbent main supplier than b. In state II, a and b have the same incumbent main supplier. The other wholesaler is the secondary supplier to both. As will be seen, the competition spillover effect is particularly acute in the IS state.

Another consideration under duopoly is that by affecting its average unit wholesale cost the retailer's choice of main/secondary supplier affects its competitive position vis-a-vis the other retailer. As a result, a retailer's decision to switch from the incumbent main supplier to its competitor (previously the secondary supplier) turns on how significantly switching impacts expected duopoly profits relative to the cost of switching. We show in the Mathematical Appendix that the decision rule for switching continues to be a cut-off rule whereby the retailer switches main suppliers if the realized value of Δ is below the cutoff and maintains the incumbent as the main supplier otherwise. Letting $\mathbf{w} = (w_1^a, w_1^b, w_2^a, w_2^b)$, we denote the cutoff values of Δ for retailers a and b, given the vector of wholesale prices $\mathbf{w}$, as $\Delta_a(\mathbf{w})$ and $\Delta_b(\mathbf{w})$, respectively.

Given these retailer switching rules and supposing that, initially, wholesaler 1 is the incumbent supplier to retailer a and the secondary supplier to retailer b, wholesaler 1's expected profits, given bids, $(w_1^a, w_1^b, w_2^a, w_2^b)$, are:

$$
\begin{aligned}
\pi_1^{IS}(\mathbf{w}) = \quad & (1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})[(w_1^a - c)sQ_a^1(\mathbf{w}) + (w_1^b - c)(1-s)Q_b^1(\mathbf{w}) - F_I - F_S] \\
& +(\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})[(w_1^a - c)(1-s)Q_a^2(\mathbf{w}) + (w_1^b - c)sQ_b^2(\mathbf{w}) - F_I - F_S] \\
& +(1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})[(w_1^a - c)sQ_a^3(\mathbf{w}) + (w_1^b - c)sQ_b^3(\mathbf{w}) - 2F_I] \\
& +(\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})[(w_1^a - c)(1-s)Q_a^4(\mathbf{w}) + (w_1^b - c)(1-s)Q_b^4(\mathbf{w}) - 2F_S].
\end{aligned}
$$

The first term in the expected profit expression gives the profit if 1 remains the main supplier to retailer a and the secondary supplier to b. This outcome occurs with probability $(1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}}$. The values of $Q_a^1(\mathbf{w})$ and $Q_b^1(\mathbf{w})$ give the quantities sold by retailers a and b respectively. The other terms give the outcomes, respectively, in which (i) wholesalers 1 and 2 switch the retailer for which they are the main supplier (outcome 2), (ii) wholesaler 1 is the main supplier to both retailers (outcome 3), and (iii) wholesaler 1 is the secondary supplier to both (outcome 4). Wholesaler's 2's expected profits in this situation are defined analogously.[29]

Wholesaler 1's equilibrium bids when it is the incumbent main supplier to retailer a and the secondary supplier to retailer b will be values of w_1^a, w_1^b that maximize its expected profits. In equilibrium, these bids will satisfy the following two first-order conditions:

$$
\begin{aligned}
&\left(1-\frac{\Delta^*}{\Delta}\right)^2\{sQ_a^1+[(w_1^a-c)s-(w_1^b-c)(1-s)]\frac{dQ_a^1}{dw_1^a}\}-\left(1-\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^a}{dw_1^a}[\Pi_1^1]+\\
&\left(\frac{\Delta^*}{\Delta}\right)^2\{(1-s)Q_a^2+[(w_1^a-c)(1-s)-(w_1^b-c)s]\frac{dQ_a^2}{dw_1^a}\}+\left(\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^a}{dw_1^a}[\Pi_1^2]+\\
&\left(1-\frac{\Delta^*}{\Delta}\right)\left(\frac{\Delta^*}{\Delta}\right)\{sQ_a^3+[(w_1^a-c)s-(w_1^b-c)s]\frac{dQ_a^3}{dw_1^a}\}-\left(\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^a}{dw_1^a}[\Pi_1^3]+\\
&\left(1-\frac{\Delta^*}{\Delta}\right)\left(\frac{\Delta^*}{\Delta}\right)\{(1-s)Q_a^4+[(w_1^a-c)(1-s)-(w_1^b-c)(1-s)]\frac{dQ_a^4}{dw_1^a}\}+\left(1-\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^a}{dw_1^a}[\Pi_1^4]\\
&=0,
\end{aligned}
$$

and

$$
\begin{aligned}
&\left(1-\frac{\Delta^*}{\Delta}\right)^2\{(1-s)Q_b^1-[(w_1^a-c)s-(w_1^b-c)(1-s)]\frac{dQ_b^1}{dw_1^b}\}-\left(1-\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^b}{dw_1^b}[\Pi_1^1]+\\
&\left(\frac{\Delta^*}{\Delta}\right)^2\{sQ_b^2-[(w_1^a-c)(1-s)-(w_1^b-c)s]\frac{dQ_b^2}{dw_1^b}\}+\left(\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^b}{dw_1^b}[\Pi_1^2]+\\
&\left(1-\frac{\Delta^*}{\Delta}\right)\left(\frac{\Delta^*}{\Delta}\right)\{sQ_b^3-[(w_1^a-c)s-(w_1^b-c)s]\frac{dQ_b^3}{dw_1^b}\}+\left(\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^b}{dw_1^b}[\Pi_1^3]+\\
&\left(1-\frac{\Delta^*}{\Delta}\right)\left(\frac{\Delta^*}{\Delta}\right)\{(1-s)Q_b^4-[(w_1^a-c)(1-s)-(w_1^b-c)(1-s)]\frac{dQ_b^4}{dw_1^b}\}-\left(1-\frac{\Delta^*}{\Delta}\right)\frac{1}{\Delta}\frac{d\Delta^b}{dw_1^b}[\Pi_1^4]\\
&=0.
\end{aligned}
$$

In the above expressions, the variable Q_j^1 refers to the quantity sold by retailer j in the case in which neither retailer switches main suppliers. The value Π_1^1 gives wholesaler 1's profits when neither retailer switches main suppliers. The values of Q_j^2, Π_1^2 give the quantity sold by retailer j and profit for wholesaler 1 when both retailers switch main suppliers and so on. An analogous set of first-order conditions define wholesaler 2's equilibrium bids. In the symmetric equilibrium,

[29] Expected profits for wholesalers 1 and 2 when 1 is the incumbent main supplier to both retailers (with 2 the incumbent secondary supplier to both) are defined analogously and are provided in the appendix.

$Q_j^1 = Q_j^2 = 1$, while $Q_a^3 = Q_b^4 < 1 < Q_a^4 = Q_b^3$. The first-order conditions defining the symmetric equilibrium bids are given in the appendix.

Remark 2: As mentioned earlier, wholesale price competition consists of two components: the direct competition for shelf share and the cross-retailer quantity shifting effect. The latter is specific to the duopoly setting and is captured in the above two equations by the bracketed expressions multiplied by a quantity derivative. It is this latter competitive effect that is crucial to understanding the value of two-sided hub-and-spoke collusion. To see why, consider the case in which neither retailer switches (the first line of the above two equations), so that wholesaler 1 remains the main supplier for retailer a and the secondary supplier for b. Both because wholesaler 1's shelf share is lower for b than for a and because $w_1^{a*} > w_1^{b*}$, per unit profits from a are larger than those from b. This means that wholesaler 1 gains by shifting retail customers from b to a. Wholesaler 2 wants to do the opposite and drive customers from retailer a to retailer b.[30] This spillover of competition from the wholesale market to the retail market is ultimately what drives retailers and wholesalers to collude jointly.

5.3 Multiperiod setting: $\beta > 0$

At the point of making the retail price decision, retailers have no payoff relevant state variables that condition their pricing strategies. As a result, the equilibrium retail price strategy is the same as in the static game.[31] Such is not the case for the wholesalers. Because of the switching cost, Δ, the incumbent main supplier can set a higher wholesale price than its competitor and yet still maintain a significant chance of continuing as the main supplier. As a result, in equilibrium, the incumbent sets a higher wholesale price than the secondary supplier and obtains a higher expected profit. When $\beta > 0$, the profit differential enjoyed by the incumbent main supplier becomes an additional (i.e., beyond the larger shelf share and quantity shifting effects) source of wholesale price competition. The non-cooperative equilibrium must account for this added source of competition. The non-cooperative equilibrium is now given by the symmetric, stationary, Markov perfect equilibrium that solves the following problem:

$$\begin{aligned} V_{IS}^*(w_1^a, w_2^{a*}, w_2^{b*}, w_1^b) &= \max_{w_1^a, w_1^b} \pi_1^{IS}(\mathbf{w}) + \beta([(1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}}) + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{IS}^* \\ &+ (1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{II}^* + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{SS}^*), \end{aligned}$$

[30] Essentially wholesaler 1 wants to adjust its bids to the two retailers so as to lower retailer a's price relative to that of retailer b. Wholesaler 2 wants to do the opposite. Compared to the wholesale price bids if only the direct competition effect were present, this tends to lower the main supplier boid relative to the secondary supplier bid.

[31] In what follows, we assume that the retailers follow the static switching rule in making their choice of main and secondary suppliers. This restriction makes the model significantly more tractable. In addition, as will be seen, this switching rule is the Markov switching rule in the collusive equilibrium, so that the restriction only affects the payoffs in the punishment state. As a result, the mechanism that makes joint collusion desirable would still apply if a Markov switching rule were used in the non-cooperative equilibrium.

$$V_{II}^*(w_1^a, w_2^{a*}, w_2^{b*}, w_1^b) \quad = \quad \max_{w_1^a, w_1^b} \pi_1^{II}(\mathbf{w}) + \beta((1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{II}^* + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{SS}^*$$
$$+ \quad [(1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}}) + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{IS}^*),$$

$$V_{SS}^*(w_1^a, w_2^{a*}, w_2^{b*}, w_1^b) \quad = \quad \max_{w_1^a, w_1^b} \pi_1^{SS}(\mathbf{w}) + \beta((1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{SS}^* + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{II}^*$$
$$+ \quad [(1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}}) + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{IS}^*),$$

where the expressions for $\pi_1^{SS}(\mathbf{w})$ and $\pi_1^{II}(\mathbf{w})$ are provided in the appendix, as are all of the relevant first-order conditions.

Remark 3: The important property of this equilibrium is that the incentive for both the incumbent and secondary suppliers is to set lower wholesale prices than in the static duopoly situation. Doing so increases the odds of remaining / becoming the incumbent supplier and capturing the rents from that state.

5.4 Collusive rings along the supply chain

We know from the duopoly pricing results that, when t and d are high, retail margins, and so profits are low for any given value of $\overline{W}$. As a result, retailers find price collusion extremely profitable in these settings. From the wholesale pricing section, we have that low switching costs and large values of t and d induce significant wholesale price competition. As a result, wholesalers also have a significant incentive to collude on wholesale prices. What is less obvious is what incentives the wholesalers and retailers have to create a joint collusive ring rather than each group just colluding separately. In particular, if the retailers can already successfully collude, why would they ever want to encourage wholesale price raising by encouraging wholesaler collusion?

Ultimately, what proves to be the downfall of independent collusion is the asymmetry in the wholesale market – the main supplier-secondary supplier arrangement – that it induces. This asymmetry has two effects. First, as is usual, it makes independent collusion by the wholesalers difficult: the secondary supplier has significant incentives to deviate. In addition, as was demonstrated above, a wholesaler can benefit from inducing competition in the retail market to the extent that such competition shifts customers away from the retailer for which it is a secondary supplier and toward the retailer for which it is the main supplier. This spillover of wholesale competition into the retail market can undermine retailer collusion. The solution is for the group to form a collusive ring – bring the wholesalers into the collusion – and to do so in a way that reduces asymmetries in the wholesale market.

In the analysis to follow we demonstrate these claims. In particular, we provide two settings, one in which the retailers' incentives are to make wholesaler collusion as difficult as possible and one in which the retailers' incentives are to facilitate wholesaler collusion by forming a joint collusive ring. We demonstrate what drives the incentives in each setting, how joint collusion works and what each side gains from forming a two-sided hub-and-spoke arrangement.

5.4.1 Independent versus joint collusion

To address the question of joint versus independent collusive behavior, we need some notion of how to distinguish one from the other. To do this, we first note that, if the retailers are capable of sustaining price collusion when wholesalers are acting non-cooperatively, then the retailers have no incentive to promote wholesaler collusion. Doing so can only raise wholesale prices and so lower the retailers collusive profits. Indeed, in this case, retailers have every incentive to make wholesaler collusion as difficult as possible. This insight provides a natural way to characterise independent collusion. In particular, independent collusion imposes two constraint on any collusive outcome. First, the collusive wholesale prices must mimic the non-cooperative solution in the sense of having the difference between the incumbent and secondary supplier prices the same as those in the non-cooperative outcome with retailer collusion. The essence of this assumption is that, in the case of independent collusion, the wholesalers choose prices so as not to reveal their collusive behavior to the (non-cooperating) retailers. The second constraint is that retailers continue to set shelf share allocations so that profits of the secondary supplier are zero. This makes wholesaler collusion as difficult as possible, the preferred outcome for successfully colluding retailers. For retailers, independent retailer collusion involves separate and independent wholesale price negotiations and shelf share allocations but cooperation on retail prices. In terms of strategies, this means that retailers can condition their strategies at time t on all past retail price outcomes; wholesalers can condition their strategies at t on all past wholesale price bids to the two retailers. Finally, with independent collusion, deviation results in reversion to the non-cooperative equilibrium only in the markets – wholesale or retail – in which the deviation occurred.

For joint collusion, the wholesalers and retailers can jointly decide on wholesale and retail prices and shelf-share allocation. The only constraint is that the collusive outcomes satisfy the relevant repeated game incentive constraints. In this case, strategies for all players at time t can be conditioned on all past price realizations, both wholesale and retail. Further, with joint collusion, any deviation by any party results in reversion to the non-cooperative equilibrium for all parties. In both the case of independent and joint collusive outcomes, we restrict attention to symmetric, stationary perfect equilibrium strategies. We further restrict attention to collusive agreements that are state independent; that is, agreements of the form (p, w_I, w_S, s).

As noted above, joint wholesaler-retailer collusion is not a preferred outcome for "successfully colluding" retailers. This means that, if joint collusion occurs, it is because retailers cannot successfully collude unless they promote wholesaler collusion. The most straightforward way to understand the benefit of joint collusion, is to consider the problem of the retailers colluding independently of the wholesalers. If, in this case, they set some common retail price, $p^{co} > p^*$, then, for some average wholesale price of $\overline{W}$, they obtain collusive profits of:

$$\pi_j^{co} = \frac{1}{1-\beta}(p^{co} - \overline{W}^*). \tag{11}$$

Assuming Nash reversion occurs after any deviation, then the incentive constraint for retailer-only collusion is:

$$\frac{1}{1-\beta}(p^{co} - \overline{W}) \geq (\tilde{p} - \overline{W})Q(\tilde{p}, p^{co}) + \frac{\beta}{1-\beta}(p^* - \overline{W}), \tag{12}$$

where $\tilde{p}$ is the best one-shot deviation price, given the other retailer is setting a price of p^{co} and $Q(\tilde{p}, p^{co})$ is the associated quantity sold.

Of course, in contrast to the typical retailer collusive incentive constraint, the above constraint is different because the value of $\overline{W}$ is not a parameter. Rather, its value is determined by the wholesale market equilibrium and the state of competition there. If the wholesalers do not collude, the value of $\overline{W}$ that would occur depends on how successfully the retailers are colluding. If there is no profitable price deviation that a wholesaler can make that induces retailers to lower price below p^{co}, as would be the case if β were close to 1, then the one-shot equilibrium in the wholesale market is the local monopoly wholesale price equilibrium. In this case, the retailers have no incentive to support further wholesale price increases by supporting wholesaler collusion.

Consider, however, what happens as the value of β declines. As β becomes low, the non-cooperating wholesalers can induce a retail price cut by altering wholesale prices, as in the duopoly equilibrium, and so destroy the collusive arrangement. In this case, the retailers' failure to promote wholesaler collusion has led to a failure in retailer collusion. A joint collusive outcome becomes a way of restoring retailer collusion and benefitting both retailers and wholesalers. Below, we illustrate the mechanisms involved both in retailers wanting to bring wholesalers into the collusive agreement and in creating successful joint collusion.

5.4.2 An Illustration

Given that joint collusion imposes fewer constraints on collusive allocations and has (weakly) stronger punishments, it is unsurprising, and of no especial interest, to note that joint collusion can sustain allocations not achievable under independent collusion. More relevant is to understand the mechanism that makes independent collusion unsustainable and the mechanism by which joint collusion restores sustainability. It is these issues we explore here. We do so by considering an extended example for the wholesale and retail pricing / collusion problem. The details of the example are provided in the appendix. The appendix also provides formal statements of the incentive constraints for collusive equilibria.

In our example, we consider a symmetric collusive retailer agreement in which the retailers set a collusive price, p^{co}, independent of the supplier state. Obviously, for values of β close enough to 1, this collusive outcome is supportable independent of the activities of the suppliers. In this case, the non-cooperative outcome for the wholesale market is the multiperiod, local monopoly outcome. Among these, the most profitable for the retailers, subject to supplier participation each period, is the one in which the collusive shelf share, s^{co}, is set such that the per-period profit for the secondary supplier is just zero. We assume in what follows that this value is chosen by the retailers in the event of no collusion at the wholesale level. This means that any independent collusion by the suppliers must generate expected profits at least as large as those achievable in the local monopoly case. As any increase in profits for the suppliers comes at the expense of the retailers in the collusive case, the retailers have no incentive to support supplier collusion as long as the value of β is large enough. Indeed, the retailers' incentives are to make supplier collusion as difficult as possible. This fact motivates our definition of independent collusion.

For the suppliers engaging in independent collusion, their price bids must mimic the non-cooperative outcome. Since, in the local monopoly case, the values of the incumbent main and secondary suppliers' price bids are independent of the wholesale state, it must be that i) the collusive bids are independent of the wholesale state and ii) the difference in the bids must be the same as in the local monopoly case. The collusive shelf share will continue to be the one that yields zero per-period profits for the secondary supplier. Even with these restrictions, again for values of β close enough to 1, independent supplier collusion will also be sustainable. The question is what happens as the value of β declines and collusion, particularly retailer collusion, becomes more difficult. Is there now a case for joint retailer-supplier collusion where there was not one before and what does this joint collusion accomplish? As the independent supplier collusion is a simple price level shift from the local monopoly case, the simplest way to answer these questions is to consider the case in which the retailers are colluding but the suppliers are simply operating at the multiperiod local monopoly outcome.

In our example, we consider the case in the value of β is 0.4. We consider a collusive retail price of $p^{co} = 4.9$. In this case, if retailer a, say, considers a deviation from the collusive retail agreement, the best price deviation for a, given b continues to set the collusive price, is given by (recall that deviation leads to reversion to the non-cooperative equilibrium):

$$\hat{p}_a = .5\frac{1}{\lambda} + .5p^{co} + .5\bar{W}_a, \tag{13}$$

where $\bar{W}_a$ is retailer a's average per-unit cost and $\lambda = \tau d(1 - 2\phi)$. The value of $\bar{W}_a$ depends on whether retailer a has switched main suppliers, with the value being lower if a has switched main suppliers than if it has not. The quantity sold by retailer a under its best deviation is $\hat{Q}_a = .5 + .5\lambda(p^{co} - \bar{W}_a)$ as long as $(p^{co} - \hat{p}_a)d < 1$. Otherwise, $\hat{Q}_a = 1 + \tau(1 - 2\phi)$. For the case in which $(p^{co} - \hat{p}_a)d < 1$, the one-shot deviation profits for retailer a are:

$$\hat{\pi}_R = .25[\frac{1}{\lambda} + 2(p^{co} - \bar{W}_a) + \lambda(p^{co} - \bar{W}_a)^2]. \tag{14}$$

As $\bar{W_a}$ is smaller when retailer a has switched main suppliers, deviation profits are larger in this case.

For the parameter configuration adopted in our example, the values of the incumbent main and secondary supplier price bids when $\beta = .4$ are $w_h^{lm} = 2.319$ and $w_l^{lm} = 1.476$ respectively. The collusive shelf share is $s^{co} = .797$. This gives an average unit cost to retailer a of $\bar{W_a} = 1.65$ in the case in which a switches main suppliers. Then, from above, retailer a's best deviation is $\hat{p}_a = 3.9$. The value of $\hat{Q}_a = 1.8$, which is just at the corner solution (we assume that $d = 1$ in the illustration). This gives one-shot deviation profits for a of $\hat{\pi}_R = 4.05$. After deviation, retailer a obtains its expected profits under the non-cooperative solution, where wholesale prices are set according to the the multiperiod duopoly problem. These profits are approximately 1.25 per period. If retailer a chooses not to deviate and maintain the collusive agreement, then its expected profits are:

$$p^{co} - \bar{W_a} + \frac{\beta}{1-\beta}[p^{co} - \bar{W_h}^{co} + \frac{\Delta^{co}}{\bar{\Delta}}(\bar{W_h}^{co} - \bar{W_l}^{co})], \tag{15}$$

where $\Delta^{co} = (2s^{co} - 1)(w_h^{lm} - w_l^{lm})$ and $\bar{W_h}^{co} - \bar{W_l}^{co}$ gives the difference between a's average unit price when it does not switch main suppliers versus when it does. The value of maintaining the collusive agreement in this case is 5.19. The return from the deviation by retailer a is 4.88 so that, at the local monopoly wholesale prices, retailer a does not find deviation profitable.

This is, however not the entire story. In this case, the difference between the return to maintaining the collusive agreement and the return to deviation is only .31. With such a small difference, it may prove profitable for a supplier to deviate to a lower wholesale price, one low enough to make retailer deviation profitable. In so doing, the supplier destroys the retail collusive agreement. Our illustration shows that this is, in fact, what happens. In particular, if supplier 1, for instance, is the incumbent secondary supplier and deviates to an offer that results in retailer a having an average unit cost of 1.27 when it switches main suppliers (i.e., switches from supplier 2 being the main supplier to supplier 1), then retailer a can be induced to deviate from the collusive arrangement when it switches main suppliers. The wholesale price bid that accomplishes this is a bid of 1. The question, of course, is whether it is profitable for supplier 1 to lower its bid to 1. Doing so may gain it current expected profits but will shift the future wholesale equilibrium from the local monopoly one to the duopoly outcome as the retail cartel collapses. What we show in the appendix is that, in spite of this fact, the deviation for wholesaler 1 is profitable when it is the incumbent secondary supplier to both retailers.

Remark 4: Two things are crucial to this result. First, because independent collusion causes significant asymmetries in terms of both wholesale prices and shelf share between the main and secondary suppliers, a wholesaler that finds itself the secondary supplier to both retailers obtains little benefit from the collusive arrangement. Second, wholesale price is endogenous here and so, by deviating to a lower wholesale price bid – one low enough to induce retailer deviation – the wholesaler can increase the chances that it will i) become the main supplier to the retailer and ii) obtain a significant sales boost from the retailer price cutting. The former effect generates increased expected future profits for the wholesaler while the latter generates immediate short-term profits. This combination makes significant price cutting attractive for the wholesaler given the low expected returns when it is the secondary supplier to both retailers. As a result, when the value of β is low, the wholesaler has significant incentives to break any collusive arrangement when it is the secondary supplier to both retailers.

In these circumstances, the collusive outcome cannot be an equilibrium with independent collusion. The question is whether joint collusion can resolve the problem and, if so, how does it help. From the retailers' perspective, a low cost way of trying to support the cartel is to have the punishment implemented if either a retailer or a wholesaler deviates from the cartel agreement. Under independent collusion, the retail cartel only dissolves if a retailer deviates. This means that, if supplier 1 deviates to a wholesale price bid of 1.06 but retailer a's switching costs are so large that it doesn't switch and so doesn't deviate, the retail cartel remains: in essence, supplier 1's deviation is not punished. Under joint collusion, this deviation would be punished with reversion to the duopoly outcome. In some sense, this punishment outcome is the simplest way to bring the suppliers into the collusive arrangement. It turns out that, in the case of our example, even this punishment will not prevent the deviation.

Remark 5: As noted above, the fundamental problem is that wholesale prices and shelf shares are sufficiently asymmetric between the main and secondary suppliers that, when a supplier finds itself in the situation of being the (incumbent) secondary supplier to both retailers, its future under the cartel arrangement is just not very attractive. There is significant payoff in this case not just to grabbing some current sales from the deviation but also from improving its future prospects by increasing the likelihood that it will become the incumbent main supplier to at least one of the retailers. Joint collusion resolves this problem by altering either the shelf share allocation, wholesale prices or both so that the outcome for secondary and main suppliers is less asymmetric. Doing so reduces the incentive for wholesaler 1 to deviate when it finds itself the (incumbent) secondary supplier to both retailers. Of course, punishment of any deviation is also implemented.

In our example, both wholesale prices and shelf share are reallocated. In particular, wholesale prices for both the main and secondary suppliers increase by about 20 percent: $w_h^{co} = 2.719$ and $w_l^{co} = 1.794$. A wholesale price increase is consistent with what we observe in the data. In addition, the shelf share of the secondary supplier also increases by a little more than 10 percent as well, from $1 - s^{co} = .203$ to $1 - s^{co} = .22$. This both shifts some profits from the retail cartel to the suppliers but also makes the allocation of the supplier profits less asymmetrical. Because it is the secondary supplier that has an incentive to break the collusion, the key here is re-allocating shelf share and and payment to the secondary supplier so that it is not so unprofitable should a wholesa;er find itself in this state. The proposed allocation here does just that. As a resut, wholesaler 1 needs a larger profit in order to make deviation pay. As shown in the appendix, this re-allocation is such that it is now no longer pays for wholesaler 1 to deviate in the SS state.

6 Discussion

In this paper we provided the first comprehensive analysis of a hub-and-spoke cartel using as a case study the cartel that operated in the Canadian bread market. Over a period of about fifteen years suppliers helped to coordinate retail prices and retailers helped to coordinate supplier prices. Our empirical analysis showed that this joint coordination resulted in bread price inflation that was 40% higher than for various control products. We also provided evidence that the cartel operated at both ends of the vertical supply chain by that the collapse of the cartel led to heterogeneous changes in pricing across retail markets and that this heterogeneity depended on retail-market structure.

Our model provides an explanation for this sort of cartel utilizing the fact that there is price competition at both ends of the supply chain – retail and wholesale – and that the large retail stores stock both wholesalers' products using a main supplier / secondary supplier allocation of shelf space. The endogeneity of wholesale prices and asymmetries in payoffs induced by the main supplier / secondary supplier approach ultimately result in wholesalers undermining any independent collusion. This problem is resolved by joint collusion.

One might ask if there is not a simpler way to resolve this problem than jointly colluding. One possibility is that the bread makers divide the country up into exclusive regions such that one bread maker serves all retailers in one region while the other bread maker serves all retailers in the other. In terms of our model, one can think of two identical regions, 1 and 2, having retailers A and B in both. Wholesaler 1 would serve region 1 exclusively and wholesaler 2 would serve region 2 exclusively. In this case, standard hub-and-spoke collusion would resolve the problem for each region in the usual way. For the Canadian bread market, there are two problems with this solution. First, Weston (wholesaler) and Loblaws (retailer) are vertically integrated. Since Loblaws has retail chains across Canada this makes exclusive regions problematic. In addition, Canada's population distribution makes a reasonably equitable division of exclusive regions challenging. As a result, this simpler solution using exclusive regions seems unlikely to be implementable.

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A Court documents

For the purpose of this paper, we base our understanding of the facts with respect to the alleged bread cartel case mostly on documents prepared by the Competition Bureau related to the investigation into allegations that Canada Bread Company, Limited; Weston Foods, Incorporated; Loblaw Companies Limited; Wal-Mart Canada Corporation; Sobeys Incorporated; Metro Incorporated; Giant Tiger Stores Limited and others persons known and unknown have engaged in conduct contrary to paragraphs 45(1)(b) and (c) of the Competition Act9as it existed form 2001-2010) and paragraph 45(1)(a) of the Act, as amended in 2010.

The Competition Bureau filed a first application for (Information to Obtain - ITO) search warrants in this matter on October 24th 2017 with the Ontario Superior Court of Justice (East Region). With the initial ITO, the Bureau was seeking warrants to search eight premises. Of these, seven belonged to the targets of the investigation (list them), and one to a third party. On October 30th, the Bureau submitted a revised version of the ITO in which sought three additional search warrants for premises belonging to the Immunity Applicant. On October 31st 2017, Bureau officers began executing search warrants, at which point they discovered that additional warrants were required and so on the same day another ITO was filed for four additional search warrants. Finally, one additional site was identified and a companion ITO was filed on November 1st 2018.

The ITOs (henceforth to be referred to as the *Competition Bureau documents* or *court documents*) explain that on August 11th 2017, the Commissioner commenced an inquiry to investigate allegations of price fixing. The inquiry was expanded on the 23rd of October 2017 to cover the time period form November 2001 to the time of the ITOs. Loblaw Companies Limited (LCL), George Weston Limited and Weston Foods (Canada) are, collectively, the Immunity Applicant. The targets of the investigation were Canada Bread, Walmart, Sobeys, Metro and Giant Tiger.

Paragraph 1.12.1 of the November 1st 2017 ITO alleges that Canada Bread and Weston Bakeries agreed to increase their respective wholesale prices for the sale of fresh commercial bread via direct communications between senior officers in their organizations. According to paragraph 1.12.2, the suppliers then met individually with their retail customers to inform them of the price increase and obtain acceptance of the agreed-upon price. This was known as *socialization* of a price increase.

The ITOs explain that the investigation arose following (i) the application on March 3rd 2015 by LCL to the Bureau's immunity program (paragraph 4.1) and (ii) the reception of an email on January 4th 2016 from the Canadian Federation of Independent Grocers (CFIG) alleging collusion between Canada Bread and Weston Bakers with respect to a price increase for fresh commercial bread (paragraph 4.2).

This paper analyses the alleged cartel case strictly from an economic point of view. The investigation into, and prosecution of, firms involved in the alleged conspiracy is ongoing. The allegations have not been proven in a court of justice. However, for the purpose of this paper, we take these facts as established. The analysis is preliminary and incomplete, and the findings are still subject to change. We base our understanding of the facts mostly on documents prepared by the Competition Bureau.

B Evidence of asymmetry and services provided

The following passages describe the category management roles played by Bimbo and Flowers in the US bread market:[32]

- **Bimbo** *helped a Southeast regional grocer build same-store sales, using space-to-sales recommendations that yielded overall growth while the rest of the market held flat .... Developing the right assortment on a store-by-store basis allowed consumers to see more selection, while delivering the freshest product available and driving down waste. Identifying stores by different demographics enabled vendors to focus on the main items that are selling for each subcategory.*

- **Flowers Foods** *delivered impactful benchmarking, promotion analysis, assortment studies and outstanding in-store execution. Leveraging the latest technology, Flowers automated the process of generating consistent, store-specific planograms across thousands of stores, using a retailer rule-based approach that allows for accurate, on-the-fly adjustments and provides real value to retailers.*

[32] Source: https://progressivegrocer.com/winnng-game-plans.

C Paragraphs from court documents

C.1 The Bureau's case

4.109 The evidence collected by the Bureau to date indicates that the price of fresh commercial bread was increased via secretive agreements made by senior executives at the Suppliers. Further, the price increases were facilitated by key decision-makers at both Suppliers and Retailers which enabled the alleged cartel to raise wholesale and retail prices. These are both qualitative factors that speak to the unreasonableness of the methods employed to raise the price of fresh commercial bread.

C.2 Cartel origins

4.24 On 20-21 December 2016, I conducted an interview of [redacted] During the interview, [redacted] informed me that, at some point [redacted] was approached by Person X, an employee of Canada Bread [redacted] believes that the approach may have occurred during an industry event called the where all the retailers and manufacturers/suppliers got together.

(a) Industry event

4.25 [redacted] recalled that during [redacted] conversation, Person X stated: "You know, this industry is crazy. In the business, increase prices every year. There's no reason the bakery business shouldn't do the same."

(b) Looking at other industries

4.26 [redacted] recounted that Person X showed [redacted] a PowerPoint presentation that Person X had prepared. Person X allegedly informed [redacted] that " have a document that taking out to the retail community to show them the power of pricing in bakery". [redacted] stated that "the basis of this presentation was that the profitability of the fresh bakery shelf at retail was underperforming, and then the wholesale side, the manufacturers, were underperforming as well from a price realization standpoint, and Person X did comparisons for retailers. Per-

(c) Looking at other industries

4.27 [redacted] recounted that [redacted] was informed, by Person X, of a plan whereby Person X was going to the retailers to get their buy-in for a price increase with the goal of orchestrating alignment through the retail community. [redacted] stated that "clearly when it left the meeting, Person X had a feeling and a sense that I was anxious and willing on behalf of Weston Bakeries to comply with an increase."

(d) Buy-in

C.3 Cartel organization

4.34 [redacted] described how this first increase was the point in time during which 7 cents at wholesale and 10 cents at retail became the pattern for increases. This pattern became colloquially known as "the 7/10 Convention".

4.35 I have reviewed a product price increase chart issued by Canada Bread. The price increase chart identifies that Canada Bread had announced a price increase (the date of the announcement is not specified) with an effective date of 3 November 2002. The chart features numerous product names with their corresponding UPCs (universal product codes) along with the former price per unit and a post-price increase price per unit. The chart specifies an increase of 7 cents per unit.

4.48 [redacted] stated that given the deviation from the 7/10 Convention, namely, that this price increase was – in fact – a "double", likely meant that the suppliers had coordinated this deviation from the norm to make sure that the price increase letters reflected the "double" rather than the usual "single".

4.53 I reviewed a price increase letter from Weston Bakeries in which Weston Bakeries announced its own price increase of "approximately 4%" on 10 January 2011 with an effective date of 27 March 2011.

4.62 Notably, Weston Bakeries did not announce a price increase on plain white bread (including Weston's Wonder and Gadoua brands) or private label bread. [redacted] informed me that Canada Bread responded by rescinding its price increase which, in turn, led to Weston Bakeries not implementing its price increase.

C.3.1 Supplier activity

4.90 [redacted](R) stated that, during discussions with Suppliers, [redacted] would look for confirmation from the Suppliers regarding competing Retailers. For instance, [redacted](R) would inquire as to whether specific Retailers would continue to aggressively price a Supplier's product. Further, [redacted](R) would ask for the Supplier to go back to the Retailer who was pricing aggressively and explain to them that such prices were not in their best interest. [redacted](R) confirmed that the Suppliers would come back to [redacted] and tell [redacted] exactly what the competing Retailer had said.

4.91 [redacted](S) stated that the Retailers frequently complained to Weston Bakeries about prices, at their retail competitors, that they did not like. In reviewing an example of one such complaint memorialized in an email dated 24 April 2015, [redacted](S) explained that "[Ken Kunkel (Metro)] is essentially asking 'why the hell are they [Giant Tiger] at $1.88? The price increase just happened. Why would they go this cheap? You're upsetting the market. One crazy retail will cause other [Retailers] to [decrease their retail prices] and it'll get aggressive and therefore drive the overall retails down."

C.3.2 Retailer activity

4.94 According to [redacted] Canada Bread and Weston Bakeries each used the Retailers as conduits of information during the "socialization" process of a price increase.

4.95 [redacted] (R) recalled that during the first price increase in which [redacted] was involved, Weston Bakeries had approached [redacted] indicating that they wanted to take a price increase. [redacted] (R) then recalls being instructed by [redacted] to have pricing conversations with Canada Bread to determine whether Canada Bread was also interested in taking a price increase.

4.97 [redacted] (R) then recalls acting upon instructions from [redacted] and calling Rory Lesperance of Canada Bread [redacted]. As part of that conversation, [redacted] (R) stated that [redacted] would communicate Weston Bakeries' pricing intentions to Canada Bread along with the date of the proposed price increase.

D Additional tables and figures

Table 5: Differences in annual inflation rates: Bread CPI vs Other products

VARIABLES	(1) Food	(2) Cereal	(3) Other	(4) Wheat	(5) US
Annual change (coordination period)	4.284***	3.920***	3.593***	4.790***	3.413***
	(0.342)	(0.183)	(0.171)	(0.496)	(0.231)
Annual change (collapse period)	-7.332***	-4.672***	-8.467***	-9.963***	-2.485***
	(0.503)	(0.360)	(0.886)	(1.711)	(0.805)
Observations	204	204	204	204	201

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Period: January 2002 to March 2015.

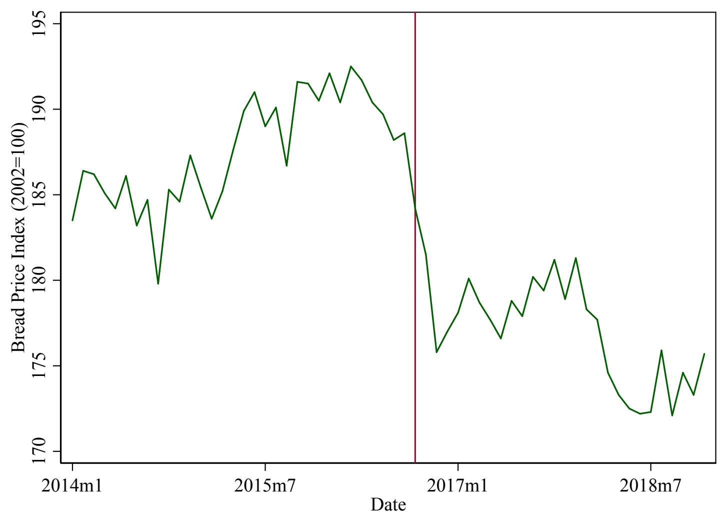

Figure 5: Test for structural break in the bread price index

- Quandt Likelihood Ratio statistic: modified Chow test, test for breaks at all possible dates in range
  - Hypothesis of break at date t tested using an F-statistic
  - QLR selects the largest of the resulting F-stats to determine the break
- Best candidate break: September 2016 (significant at 1%)

E Mathematical Appendix

E.1 One-Shot Games

E.1.1 States and outcomes

A state in this game is configuration of incumbent main and secondary suppliers to the two retailers prior to the wholesale negotiation game. These states are IS, in which one of the wholesalers is the incumbent main supplier to retailer a and the other wholesaler is the incumbent main supplier to retailer b; II, in which one of the wholesalers is the incumbent main supplier to both retailers a and b and implying that the other wholesaler is the incumbent secondary supplier to both retailers a and b and so is in the SS state.

For each of the states $k = IS, II, SS$, there are four possible retailer choice outcomes given a bid vector $W = \left(w_1^a, w_1^b, w_2^a, w_2^b\right)$. We define these outcomes as $\omega = 1, 2, 3, 4$ with $\omega = 1$ being the situation in which neither retailer switches main supplier (the incumbent main suppliers remain main suppliers), $\omega = 2$ being the situation in which both retailers switches main supplier (the incumbent secondary supplier to retailer a becomes the main supplier to a and the incumbent secondary supplier to b becomes the main supplier to b), $\omega = 3$ being the situation in which retailer a does not switch main supplier but retailer b does (the incumbent main supplier to retailer a remains the main supplier to a and the incumbent secondary supplier to b becomes the main supplier to b) and $\omega = 4$ being the situation in which retailer a switches main supplier but retailer b does not (the incumbent secondary supplier to retailer a becomes the main supplier to a and the incumbent main supplier to b remains the main supplier to b). The switching outcome is relevant because it determines relative unit costs for retailers under the bid vector W. In the duopoly situation, these relative unit costs effcet equilibrium prices and quantities.

E.1.2 Duopoly retailer equilibrium switching rule

Consider for any given state k, a symmetric equilibrium shelf share value of s_k^* and wholesale pricing vector (w_k^{h*}, w_k^{l*}), with w_k^{h*} giving the incumbent main supplier wholesale price bid in the symmetric equilibrium for state k and w_k^{l*} giving the incumbent secondary supplier wholesale price bid in the symmetric equilibrium for k. Faced with these bids, a retailer calculates the expected profits from not switching vs the expected profits from switching, net of the realized switching cost, Δ, and makes a switching decision based on which yields higher profits. Suppose that retailer a believes that retailer b switches if $\Delta < \Delta_k^*(w_k^{h*}, w_k^{l*})$ and does not switch if $\Delta \geq \Delta_k^*(w_k^{h*}, w_k^{l*})$. Then we have that if retailer a does not switch, with probability $1 - \frac{\Delta_k^*}{\bar{\Delta}}$ retailer b does not switch either. In this case, $p_a = p_b = \bar{w}_k^{h*} + \frac{1}{\tau d(1-2\phi)}$, where $\bar{w}_k^{h*} = s_k^* w_k^{h*} + (1 - s_k^*) w_k^{l*}$ and $Q_a = Q_b = 1$. This gives profits of $\frac{1}{\tau d(1-2\phi)}$. With probability $\frac{\Delta_k^*}{\bar{\Delta}}$, retailer b does switch. This is state $\omega = 3$ and results in an equilibrium price-cost margin for retailer a of $p_a - \bar{w}_a = \frac{1}{\tau d(1-2\phi)} - \frac{1}{3}(\bar{w}_k{}^{h*} - \bar{w}_k{}^{l*})$, where $\bar{w}_k^{l*} = s_k^* w_k^{l*} + (1-s_k^*)w_k^{h*}$. In this case, $Q_a = 1 - \tau d(1-2\phi)\frac{1}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*})$. Profits are $\frac{1}{\lambda} - \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*}) + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})^2$, where $\lambda = \tau d(1-2\phi)$. This gives expected profits from not switching of:

$$\frac{1}{\lambda} - \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}}. \tag{16}$$

Similarly, if retailer a switches, then it expects retailer b to switch with probability $\frac{\Delta_k^*}{\bar{\Delta}}$ and retailer a gets profits of $\frac{1}{\lambda}$. With probability $1 - \frac{\Delta_k^*}{\bar{\Delta}}$ retailer b does not switch and retailer a gets profits of $\frac{1}{\lambda} + \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*}) + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})$. This gives expected profits from switching of:

$$\frac{1}{\lambda} - \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*}))\frac{\Delta_k^*}{\bar{\Delta}} - \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} + \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*}) + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*}). \tag{17}$$

Switching comes at a cost of Δ. The equilibrium value Δ_k^* is such that retailer a is just indifferent between switching and not switching when the switching cost is Δ_k^*. It is defined by:

$$\begin{aligned}
&\frac{1}{\lambda} - \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} = \\
&\frac{1}{\lambda} - \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} - \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*})\frac{\Delta_k^*}{\bar{\Delta}} + \frac{2}{3}(\bar{w_k}^{h*} - \bar{w_k}^{l*}) + \frac{\lambda}{9}(\bar{w_k}^{h*} - \bar{w_k}^{l*}) - \Delta_k^*.
\end{aligned}$$

Substituting in for $\bar{w_k}^{h*}$ and $\bar{w_k}^{l*}$ gives:

$$\Delta_k^* \quad = \frac{\frac{2}{3}(2s_k^*-1)(w_k^{h*}-w_k^{l*}) + \frac{\lambda}{9}(2s_k^*-1)^2(w_k^{h*}-w_k^{l*})^2}{1+\frac{2\lambda}{9}(2s_k^*-1)^2(w_k^{h*}-w_k^{l*})^2\frac{1}{\bar{\Delta}}}. \tag{18}$$

E.1.3 Deviations and retailer beliefs

To determine the wholesaler bidding equilibrium for wholesaler 1, for instance, we consider a vector $\hat{W} = (w_1^a, w_1^b, w_2^{a^*}, w_2^{b^*})$. Given this vector, we need to determine what wholesaler 1 expects the price (and implied quantity) responses will be by the retailers under the deviation. Recall that neither retailer observes the wholesale prices the other receives. So when retailer b sets its retail price, it believes that retailer a faces wholesale prices $(w_1^{a^*}, w_2^{a^*})$. Retailer a believes that retailer b receives wholesale prices $(w_1^{b^*}, w_2^{b^*})$. So when retailer b sets its retail price using its first-order condition, retailer b believes that retailer a has received the equilibrium bids and that retailer a believes that reatiler b has received the equilibrium bids. So the p_a that retailer b uses in determining p_b is $p_a^* = \frac{1}{\lambda} + \frac{2}{3}\bar{w_a}^* + \frac{1}{3}\bar{w_b}^*$, where the values of $\bar{w_a}^*$ and $\bar{w_b}^*$ vary depending on the state ω. Retailer a will do the same.

Given the retailers' first-order conditions, we then have that, under the deviation, wholesaler 1 expects:

$$p_b = \frac{1}{\lambda} + \frac{\bar{w_b}}{2} + \frac{1}{3}\bar{w_a}^* + \frac{1}{6}\bar{w_b}^*,$$

$$p_a = \frac{1}{\lambda} + \frac{\bar{w_a}}{2} + \frac{1}{3}\bar{w_b}^* + \frac{1}{6}\bar{w_a}^*,$$

where, in each case, $\bar{w_a}$ ($\bar{w_b}$) is the actual unit cost under the deviation (retailer a knows its own unit costs and retailer b know its own unit costs). So we have that

$$p_b - p_a = \frac{\bar{w_b}}{2} - \frac{\bar{w_a}}{2} + \frac{1}{6}\bar{w_a}^* - \frac{1}{6}\bar{w_b}^*.$$

In all cases, the values of $\bar{w_a}$ ($\bar{w_b}$) depend on the the value of ω. These prices determine both the derivatives of quantity and Δ with respect to wholesale prices.

As to the latter, imagine a deviation by wholesaler 1 to some $w_1^a \neq w_1^{a*}$ (all other wholesale prices at their equilibrium values). As above, retailer a does not observe retailer b's bids and assumes that they are (w_1^{b*}, w_2^{b*}). Further, since retailer b does not observe retailer a's bids, retailer b assumes that retailer a has bids (w_1^{a*}, w_2^{a*}). This means that retailer b will use cut-off rule $\Delta^*(w^*)$ and will set price P_b^*, from retailer a's perspective. Using retailer a's first-order conditions, we have that retailer a will then set a price of

$$p_a = \frac{1}{\tau d(1-2\phi)} + \frac{1}{3}\bar{w_b}^* + \frac{1}{6}\bar{w_a}^* + \frac{1}{2}\bar{w_a}, \tag{19}$$

yielding a price-cost margin, quantity sold and profits for retailer a of:

$$\begin{aligned}
(p_a - \bar{w_a}) &= [\frac{1}{\lambda} + \frac{1}{3}\bar{w_b}^* + \frac{1}{6}\bar{w_a}^* - \frac{1}{2}\bar{w_a}] \\
Q_a &= 1 + \lambda[\frac{1}{3}\bar{w_b}^* + \frac{1}{6}\bar{w_a}^* - \frac{1}{2}\bar{w_a}] \\
\Pi_R^a &= \frac{1}{\lambda} + \frac{2}{3}\bar{w_b}^* + \frac{1}{3}\bar{w_a}^* - \bar{w_a} + \lambda[\frac{1}{3}\bar{w_b}^* + \frac{1}{6}\bar{w_a}^* - \frac{1}{2}\bar{w_a}]^2,
\end{aligned}$$

respectively and where the values of $\bar{w_b}^*, \bar{w_a}^*$ and $\bar{w_a}$ depend on the realization of ω.

This allows us to determine the cutoff value of Δ for retailer a, Δ^a much as before. In particular, if under the deviation, a decides not to switch, then a's belief is thatretailer b doesn't switch with probability $1 - \frac{\Delta^*}{\Delta}$. Further, in this case, $\bar{w_a}^* = \bar{w_b}^*$. This gives expected profits for a of

$$\frac{1}{\lambda} + \bar{w}^{h*} - \bar{w}_a^{ns} + \lambda[\frac{1}{2}\bar{w}^* - \frac{1}{2}\bar{w}_a^{ns}]^2,$$

with $\bar{w}_a^{ns} = sw_1^a + (1-s)w_2^{a*}$. If retailer b does switch, then letting $\bar{w}^{h*} = sw^{h*} + (1-s)w^{l*}$ and

$\bar{w}^{l*} = sw^{l*} + (1-s)w^{h*}$, the profits are:

$$\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{l*} + \frac{1}{3}\bar{w}^{h*} - \bar{w}_a^{ns} + \lambda[\frac{1}{3}\bar{w}^{l*} + \frac{1}{6}\bar{w}^{h*} - \frac{1}{2}\bar{w}_a^{ns}]^2.$$

This gives expected profits from not switching of

$$\Big(1 - \frac{\Delta^*}{\bar{\Delta}}\Big)\Big[\frac{1}{\lambda} + \bar{w}^{h*} - \bar{w}_a^{ns} + \lambda[\frac{1}{2}\bar{w}^* - \frac{1}{2}\bar{w}_a^{ns}]^2\Big] + \frac{\Delta^*}{\bar{\Delta}}\Big[\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{l*} + \frac{1}{3}\bar{w}^{h*} - \bar{w}_a^{ns} + \lambda[\frac{1}{3}\bar{w}^{l*} + \frac{1}{6}\bar{w}^{h*} - \frac{1}{2}\bar{w}_a^{ns}]^2\Big].$$

If retailer a does switch, then retailer b switches with probability $\frac{\Delta^*}{\bar{\Delta}}$. In this case, retailer a's expected profits are:

$$\frac{1}{\lambda} + \bar{w}^{l*} - \bar{w}_a^s + \lambda[\frac{1}{2}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a^s]^2,$$

with $\bar{w}_a^s = sw_2^{a*} + (1-s)w_1^a$. If retailer b doesn't switch, then retailer a's profits are:

$$\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{h*} + \frac{1}{3}\bar{w}^{l*} - \bar{w}_a^s + \lambda[\frac{1}{3}\bar{w}^{h*} + \frac{1}{6}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a^s]^2.$$

This yields expected profits from switching of:

$$\frac{\Delta^*}{\bar{\Delta}}\Big[\frac{1}{\lambda} + \bar{w}^{l*} - \bar{w}_a + \lambda[\frac{1}{2}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a^s]^2\Big] + \Big(1 - \frac{\Delta^*}{\bar{\Delta}}\Big)\Big[\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{h*} + \frac{1}{3}\bar{w}^{l*} - \bar{w}_a^s + \lambda[\frac{1}{3}\bar{w}^{h*} + \frac{1}{6}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a^s]^2\Big] - \Delta.$$

This gives a cutoff rule for retailer a, $\Delta^a(w_1^a, w_2^{a*})$ defined by the value Δ^a such that the expected profit from switching = the expected profits from not switching. There will be an analogous cutoff rule for retailer b, $\Delta^b(w_1^b, w_2^{b*})$.

Finally, from these cutoff rules, we can determine the value of $\frac{\partial \Delta^a}{\partial w_1^a}$ evaluated at the equilibrium wholesale price vector. This will be used in the first-order conditions defining the equilibrium wholesale prices. from above, we have that

$$\begin{aligned}
\Delta^a = &- \Big(1 - \frac{\Delta^*}{\bar{\Delta}}\Big)[\frac{1}{\lambda} + \bar{w}^{h*} - \bar{w}_a{}^{ns} + \lambda(\frac{1}{2}\bar{w}^{h*} - \frac{1}{2}\bar{w}_a{}^{ns})^2] \\
&- \Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{l*} + \frac{1}{3}\bar{w}^{h*} - \bar{w}_a{}^{Ns} + \lambda(\frac{1}{3}\bar{w}^{l*} + \frac{1}{6}\bar{w}^{h*} - \frac{1}{2}\bar{w}_a{}^{Ns})^2] \\
&+ \Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[\frac{1}{\lambda} + \bar{w}^{l*} - \bar{w}_a{}^{s} + \lambda(\frac{1}{2}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a{}^{s})^2] \\
&+ \Big(1 - \frac{\Delta^*}{\bar{\Delta}}\Big)[\frac{1}{\lambda} + \frac{2}{3}\bar{w}^{h*} + \frac{1}{3}\bar{w}^{l*} - \bar{w}_a{}^{s} + \lambda(\frac{1}{3}\bar{w}^{h*} + \frac{1}{6}\bar{w}^{l*} - \frac{1}{2}\bar{w}_a{}^{s})^2],
\end{aligned}$$

implying that:

$$\frac{\partial \Delta^a}{\partial w_1^a} = -\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)[-s-\lambda s(\frac{1}{2}\bar{w}^{h*}-\frac{1}{2}\bar{w_a}^{ns})] - \Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[-s-\lambda s(\frac{1}{3}\bar{w}^{l*}+\frac{1}{6}\bar{w}^{h*}-\frac{1}{2}\bar{w_a}^{ns})]$$

$$+\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[-(1-s)-\lambda(1-s)(\frac{1}{2}\bar{w}^{l*}-\frac{1}{2}\bar{w_a}^{s})]$$

$$+\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)[-(1-s)-\lambda(1-s)(\frac{1}{3}\bar{w}^{h*}+\frac{1}{6}\bar{w}^{l*}-\frac{1}{2}\bar{w_a}^{s})].$$

Evaluated at the equilibrium values w_1^{a*}, w_2^{a*} we have that $\bar{w}^{h*} = \bar{w_a}^{ns}, \quad \bar{w}^{l*} = \bar{w_a}^{s}$. So we have that:

$$\frac{\partial \Delta^a}{\partial w_1^a} = \Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)s + s\Big(\frac{\Delta^*}{\bar{\Delta}}\Big) - \frac{\lambda s}{3}\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)(\bar{w}^{h*}-\bar{w}^{l*}) -$$

$$\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)(1-s) - (1-s)\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big) - \frac{\lambda(1-s)}{3}\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)(\bar{w}^{h*}-\bar{w}^{l*}).$$

This gives:

$$\frac{\partial \Delta^a}{\partial w_1^a} = (2s-1) - \frac{\lambda}{3}(\bar{w}^{h*}-\bar{w}^{l*})\Big[s\Big(\frac{\Delta^*}{\bar{\Delta}}\Big) + (1-s)\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big].$$

We also have:

$$\frac{\partial \Delta^a}{\partial w_2^a} = -\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)[-(1-s)-\lambda(1-s)(\frac{1}{2}\bar{w}^{h*}-\bar{w_a}^{ns})]$$

$$-\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[-(1-s)-\lambda(1-s)(\frac{1}{3}\bar{w}^{l*}+\frac{1}{6}\bar{w}^{h*}-\frac{1}{2}\bar{w_a}^{ns})]$$

$$+\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)[-s-\lambda s(\frac{1}{2}\bar{w}^{l*}-\frac{1}{2}\bar{w_a}^{s})]$$

$$+\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)[-s-\lambda s(\frac{1}{3}\bar{w}^{h*}+\frac{1}{6}\bar{w}^{l*}-\frac{1}{2}\bar{w_a}^{s})].$$

Which yields:

$$\frac{\partial \Delta^a}{\partial w_2^a} = \Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)(1-s) + (1-s)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big) - \frac{\lambda(1-s)}{3}\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)(\bar{w}^{h*}-\bar{w}^{l*}) -$$

$$\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)s - s\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big) - \frac{\lambda s}{3}\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)(\bar{w}^{h*}-\bar{w}^{l*}),$$

or

$$\frac{\partial \Delta^a}{\partial w_2^a} = \quad -(2s-1) - \tfrac{\lambda}{3}(\bar{w}^{h*}-\bar{w}^{l*})\Big[(1-s)\Big(\tfrac{\Delta^*}{\bar{\Delta}}\Big) + s\Big(1-\tfrac{\Delta^*}{\bar{\Delta}}\Big)\Big] < 0. \tag{20}$$

In the symmetric equilibrium, the derivatives of Δ^b will be defined similarly.

E.1.4 Wholesale price equilibrium: IS state

For the IS state, the symmetric equilibrium wholesale price bids are given by the following two first-order conditions, with $w_1^a = w_2^b = w_h^*,\ w_2^a = w_1^b = w_l^*$ giving the symmetric equilibrium bids for the incumbent main and secondary suppliers respectively.

$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)^2\{sQ_a^1+[(w_1^a-c)s-(w_1^b-c)(1-s)]\frac{\partial Q_a^1}{\partial w_1^a}\}-\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^1]+$$
$$\Big(\frac{\Delta^*}{\bar\Delta}\Big)^2\{(1-s)Q_a^2+[(w_1^a-c)(1-s)-(w_1^b-c)s]\frac{\partial Q_a^2}{\partial w_1^a}\}+\Big(\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^2]+$$
$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\Big(\frac{\Delta^*}{\bar\Delta}\Big)\{sQ_a^3+[(w_1^a-c)s-(w_1^b-c)s]\frac{\partial Q_a^3}{\partial w_1^a}\}-\Big(\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^3]+$$
$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\Big(\frac{\Delta^*}{\bar\Delta}\Big)\{(1-s)Q_a^4+[(w_1^a-c)(1-s)-(w_1^b-c)(1-s)]\frac{\partial Q_a^4}{\partial w_1^a}\}+\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^4]$$
$$=0,$$

and

$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)^2\{(1-s)Q_a^1-[(w_2^b-c)s-(w_2^a-c)(1-s)]\frac{\partial Q_a^1}{\partial w_2^a}\}-\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^1]+$$
$$\Big(\frac{\Delta^*}{\bar\Delta}\Big)^2\{sQ_a^2-[(w_2^b-c)(1-s)-(w_2^a-c)s]\frac{\partial Q_a^2}{\partial w_2^a}\}+\Big(\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^2]+$$
$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\Big(\frac{\Delta^*}{\bar\Delta}\Big)\{(1-s)Q_a^3-[(w_2^b-c)(1-s)-(w_2^a-c)(1-s)]\frac{\partial Q_a^3}{\partial w_2^a}\}-\Big(\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^3]+$$
$$\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\Big(\frac{\Delta^*}{\bar\Delta}\Big)\{sQ_a^4-[(w_2^b-c)s-(w_2^a-c)s]\frac{\partial Q_a^4}{\partial w_2^a}\}+\Big(1-\frac{\Delta^*}{\bar\Delta}\Big)\frac{1}{\bar\Delta}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^4]$$
$$=0,$$

where the former defines the value of $w_1^a = w_2^b = w_h^*$ and the latter the value of $w_2^a = w_1^b = w_l^*$. Also, $\Pi_1^1 = (w_1^{a*}-c)sQ_a^1+(w_1^{b*}-c)(1-s)Q_b^1-F_I-F_s$, $\Pi_1^2 = (w_1^{a*}-c)(1-s)Q_a^2+(w_1^{b*}-c)sQ_b^2-F_I-F_s$, etc. The values of Π_2 are defined analogously.The values of the quantities sold are $Q_a^1 = Q_b^1 = 1 = Q_a^2 = Q_b^2$, $Q_a^3 = 1-\frac{\lambda}{3}(2s-1)(w_h^*-w_l^*) = Q_b^4$ and $Q_b^3 = 1+\frac{\lambda}{3}(2s-1)(w_h^*-w_l^*) = Q_a^4$. Finally, the values of $\frac{\partial Q_a^1}{\partial w_1^a}, \frac{\partial Q_a^1}{\partial w_2^a}$, and so on are defined using the values of p_a and p_b from the preceding section. Specifically, we have that $p_b-p_a = \frac{\bar{w_b}}{2}-\frac{\bar{w_a}}{2}+\frac{1}{6}\bar{w_a^*}-\frac{1}{6}\bar{w_b^*}$, where $\bar{w_a},\ \bar{w_b}$ are the unit prices under the deviation for different outcomes. This gives $\frac{\partial Q_a^1}{\partial w_1^a} = -\lambda \frac{s}{2}$, $\frac{\partial Q_a^1}{\partial w_2^a} = -\lambda \frac{(1-s)}{2}$. The remainder are derived in the same way. The equilibrium value of s is defined by the participation condition $(w_l^* - c)(1-s)Q_a^3 = F_S$.

E.1.5 Wholesale price equilibrium: II/SS state

For the II state in which wholesaler1 is the incumbent in both markets, 1's expected profits are:

$$\left(1 - \frac{\Delta^a}{\bar{\Delta}}\right)\left(1 - \frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)sQ_a^1 + (w_1^b - c)sQ_b^1 - 2F_I] +$$

$$\left(\frac{\Delta^a}{\bar{\Delta}}\right)\left(\frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)(1-s)Q_a^2 + (w_1^b - c)(1-s)Q_b^2 - 2F_s] +$$

$$\left(1 - \frac{\Delta^a}{\bar{\Delta}}\right)\left(\frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)sQ_a^3 + (w_1^b - c)(1-s)Q_b^3 - F_I - F_S] +$$

$$\left(\frac{\Delta^a}{\bar{\Delta}}\right)\left(1 - \frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)(1-s)Q_a^4 + (w_1^b - c)sQ_b^4 - F_I - F_s]$$

The symmetric equilibrium value of $w_1^a = w_1^b = w_h^*$ is defined by the condition:

$$\left(1 - \frac{\Delta^*}{\bar{\Delta}}\right)^2 \{sQ_a^1 + [(w_1^a - c)s - (w_1^b - c)s]\frac{\partial Q_a^1}{\partial w_1^a}\} - \left(1 - \frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial dw_1^a}[\Pi_1^1] +$$

$$\left(\frac{\Delta^*}{\bar{\Delta}}\right)^2 \{(1-s)Q_a^2 + [(w_1^a - c)(1-s) - (w_1^b - c)(1-s)]\frac{\partial Q_a^2}{\partial w_1^a}\} + \left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^2] +$$

$$\left(1 - \frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{sQ_a^3 + [(w_1^a - c)s - (w_1^b - c)(1-s)]\frac{\partial Q_a^3}{\partial w_1^a}\} - \left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^3] +$$

$$\left(1 - \frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{(1-s)Q_a^4 + [(w_1^a - c)(1-s) - (w_1^b - c)s]\frac{\partial Q_a^4}{\partial w_1^a}\} + \left(1 - \frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^4]$$

$$= 0$$

where all variables are defined as previously.

If wholesaler 1 is the incumbent main supplier in the II state, then wholesaler 2 is the incumbent secondary suplier in both markets. For wholesaler 2 we have that expected profit is:

$$\Big(1-\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)[(w_2^a-c)(1-s)Q_a^1+(w_2^b-c)(1-s)Q_b^1-2F_S]+$$

$$\Big(\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)[(w_2^a-c)sQ_a^2+(w_2^b-c)sQ_b^2-2F_I]+$$

$$\Big(1-\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)[(w_2^a-c)(1-s)Q_a^3+(w_2^b-c)sQ_b^3-F_I-F_S]+$$

$$\Big(\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)[(w_2^a-c)sQ_a^4+(w_2^b-c)(1-s)Q_b^4-F_I-F_s].$$

In equilibrium, $w_2^a=w_2^b=w_l^*$ and is defined by the condition:

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{(1-s)Q_a^1+[(w_2^a-c)(1-s)-(w_2^b-c)(1-s)]\frac{\partial Q_a^1}{\partial w_2^a}\}-\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^1]+$$

$$\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{sQ_a^2+[(w_2^a-c)s-(w_2^b-c)s]\frac{\partial Q_a^2}{\partial w_2^a}\}+\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^2]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{(1-s)Q_a^3+[(w_2^a-c)(1-s)-(w_2^b-c)s]\frac{\partial Q_a^3}{\partial w_2^a}\}-\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^3]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{sQ_a^4+[(w_2^a-c)s-(w_2^b-c)(1-s)]\frac{\partial Q_a^4}{\partial w_2^a}\}+\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^4]$$

$$=0,$$

where all variables are as defined previously.

E.2 Multiperiod Equilibrium

The non-cooperative equilibrium in the multiperiod setting is the symmetric, stationary, Markov perfect equilibrium. It is defined by four first-order conditions that solve for values of the wholesale prices. These four values are:$(w_{IS}^{h*}, w_{IS}^{l*}, w_{II}^{h*}, w_{II}^{l*})$. The four first order conditions are:

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)^2\{sQ_a^1+[(w_1^a-c)s-(w_1^b-c)(1-s)]\frac{\partial Q_a^1}{\partial w_1^a}\}-\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^1+\beta V_{IS}^*]+$$

$$\left(\frac{\Delta^*}{\bar{\Delta}}\right)^2\{(1-s)Q_a^2+[(w_1^a-c)(1-s)-(w_1^b-c)s]\frac{\partial Q_a^2}{\partial w_1^a}\}+\left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^2+\beta V_{IS}^*]+$$

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{sQ_a^3+[(w_1^a-c)s-(w_1^b-c)s]\frac{\partial Q_a^3}{\partial w_1^a}\}-\left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^3+\beta V_{II}^*]+$$

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{(1-s)Q_a^4+[(w_1^a-c)(1-s)-(w_1^b-c)(1-s)]\frac{\partial Q_a^4}{\partial w_1^a}\}+\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_1^a}[\Pi_1^4+\beta V_{SS}^*]$$

$$=0,$$

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)^2\{(1-s)Q_a^1-[(w_2^b-c)s-(w_2^a-c)(1-s)]\frac{\partial Q_a^1}{\partial w_2^a}\}-\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^1+\beta V_{IS}^*]+$$

$$\left(\frac{\Delta^*}{\bar{\Delta}}\right)^2\{sQ_a^2-[(w_2^b-c)(1-s)-(w_2^a-c)s]\frac{\partial Q_a^2}{\partial w_2^a}\}+\left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^2+\beta V_{IS}^*]+$$

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{(1-s)Q_a^3-[(w_2^b-c)(1-s)-(w_2^a-c)(1-s)]\frac{\partial Q_a^3}{\partial w_2^a}\}-\left(\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^3+\beta V_{SS}^*]+$$

$$\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\left(\frac{\Delta^*}{\bar{\Delta}}\right)\{sQ_a^4-[(w_2^b-c)s-(w_2^a-c)s]\frac{\partial Q_a^4}{\partial w_2^a}\}+\left(1-\frac{\Delta^*}{\bar{\Delta}}\right)\frac{1}{\bar{\Delta}}\frac{\partial \Delta^a}{\partial w_2^a}[\Pi_2^4+\beta V_{II}^*]$$

$$=0,$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{sQ_a^1+[(w_1^a-c)s-(w_1^b-c)s]\frac{\partial Q_a^1}{\partial w_1^a}\}-\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial dw_1^a}[\Pi_1^1+\beta V_{II}^*]+$$

$$\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{(1-s)Q_a^2+[(w_1^a-c)(1-s)-(w_1^b-c)(1-s)]\frac{\partial Q_a^2}{\partial w_1^a}\}+\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^2+\beta V_{SS}^*]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{sQ_a^3+[(w_1^a-c)s-(w_1^b-c)(1-s)]\frac{\partial Q_a^3}{\partial w_1^a}\}-\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^3+\beta V_{IS}^*]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{(1-s)Q_a^4+[(w_1^a-c)(1-s)-(w_1^b-c)s]\frac{\partial Q_a^4}{\partial w_1^a}\}+\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^4+\beta V_{IS}^*]$$

$$=0,$$

and

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{(1-s)Q_a^1+[(w_2^a-c)(1-s)-(w_2^b-c)(1-s)]\frac{\partial Q_a^1}{\partial w_2^a}\}-\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^1+\beta V_{SS}^*]+$$

$$\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)^2\{sQ_a^2+[(w_2^a-c)s-(w_2^b-c)s]\frac{\partial Q_a^2}{\partial w_2^a}\}+\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^2+\beta V_{II}^*]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{(1-s)Q_a^3+[(w_2^a-c)(1-s)-(w_2^b-c)s]\frac{\partial Q_a^3}{\partial w_2^a}\}-\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^3+\beta V_{IS}^*]+$$

$$\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\Big(\frac{\Delta^*}{\bar{\Delta}}\Big)\{sQ_a^4+[(w_2^a-c)s-(w_2^b-c)(1-s)]\frac{\partial Q_a^4}{\partial w_2^a}\}+\Big(1-\frac{\Delta^*}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_2^a}[\Pi_2^4+\beta V_{IS}^*]$$

$$=0.$$

In the first two equations, $w_1^a = w_{IS}^{h*}$ and $w_1^b = w_{IS}^{l*}$. In the third equation, $w_1^a = w_{II}^{h*}$ and in the fourth equation, $w_2^a = w_{SS}^{l*}$. The profit expressions, profit derivatives and derivatives of Δ are as defined in the one-shot game for the IS state and II states.

For the case of multiperiod local retail monopoly, the equilibrium wholesale prices can defined by either set of first-order conditions (either the ones for the IS case or the ones for the II/SS case) but with the value of $\tau = 0$ and the value of the cutoff Δ given by $\Delta = (2s-1)(w_h - w_l)$.

E.3 Collusion

We consider a collusive arrangement that involves a single retail price, p^{co}, state independent wholesale prices of (w_h^{co}, w_l^{co}) bid by the incumbent main supplier and the incumbent secondary supplier respectively and a collusive shelf share, s^{co}.

E.3.1 Retailer collusion

Expected collusive profits

Since $p_a = p_b = p^{co}$ each retailer sells quantity $Q_a = Q_b = 1$. This means that the decision to switch is driven purely by minimization of unit cost for the retailer. We know from the local monopoly case, that the critical value of Δ for switching occurs is $\Delta^{co} = (2s^{co} - 1)(w_h^{co} - w_l^{co})$. If we let $\bar{W_h}^{co} = s^{co}w_h^{co} + (1 - s^{co})w_l^{co}$ and $\bar{W_l}^{co} = s^{co}w_l^{co} + (1 - s^{co})w_h^{co}$, then retailer expected per-period profit under collusion is:

$$\pi_R^{co} = p^{co} - \bar{W_h}^{co} + \frac{\Delta^{co}}{\bar{\Delta}}(\bar{W_h}^{co} - \bar{W_l}^{co}). \tag{21}$$

The present value of expected collusive profits is then $\frac{\pi_R^{co}}{1-\beta}$.

Profits: price deviation

If retailer a deviates, the best one-shot deviation price is given by $\max[\hat{p}_a = .5\frac{1}{\lambda} + .5p^{co} + .5\bar{W}_a, p^{co} - \frac{1}{d}]$, where $\bar{W}_a$ is either $\bar{W_h}^{co}$ or $\bar{W_l}^{co}$. The quantity sold by retailer a is $\hat{Q}_a = \min[.5 + .5\lambda(p^{co} - \bar{W}_a), 1 + \tau d(1-2\phi)$. This gives deviation profits of $\hat{\pi}_R = .25[\frac{1}{\lambda} + 2(p^{co} - \bar{W}_a) + \lambda(p^{co} - \bar{W}_a)^2]$ if $p_a^d = .5\frac{1}{\lambda} + .5p^{co} + .5\bar{W}_a < p^{co} - \frac{1}{d}]$ and profits of $[p^{co} - \frac{1}{d} - \bar{W}_a][1 + \tau d(1 - 2\phi)]$. Obviously, deviation profits are greater when $\bar{W}_a = \bar{W_l}^{co}$.

Post-Deviation profits: joint collusion

From the one-shot duopoly pricing game, we know that, when either both retailers switch or neither switches main supplier, one-period profits are $1/\lambda$. If retailer a switches and retailer b does not, retailer a profits are

$$\frac{1}{\lambda} + \frac{2}{3}(\bar{W}_h - \bar{W}_l) + \frac{\lambda}{9}(\bar{W}_h - \bar{W}_l)^2. \tag{22}$$

If retailer a does not switch but retailer b does switch, then retailer a's profits are:

$$\frac{1}{\lambda} - \frac{2}{3}(\bar{W}_h - \bar{W}_l) + \frac{\lambda}{9}(\bar{W}_h - \bar{W}_l)^2. \tag{23}$$

The probability that neither retailer switches is $(1 - \frac{\Delta^*}{\bar{\Delta}})^2 + (\frac{\Delta^*}{\bar{\Delta}})^2$; the probability that b switches and a does not is $(1 - \frac{\Delta^*}{\bar{\Delta}})(\frac{\Delta^*}{\bar{\Delta}})$; the probability that a switches and b does not is the same. This gives expected one-period profits for retailer a post deviation of:

$$\pi_R^{nc} = \frac{1}{\lambda} + 2(1 - \frac{\Delta^*}{\bar{\Delta}})(\frac{\Delta^*}{\bar{\Delta}})(\frac{\lambda}{9}(\bar{W}_h - \bar{W}_l)^2. \tag{24}$$

The values of $\bar{W}_h$ and $\bar{W}_l$ are determined by whether the non-cooperative wholesale equilibrium is in the IS state or the II state at a given time t: $\psi_t^{IS}, 1 - \psi_t^{IS}$. At time $t-1$, the retailer can either deviate when a different wholesaler is the main supplier to each, putting the non-cooperative equilibrium at time t in the IS state or deviate when the same wholesaler is the main supplier to both, putting the non-coopeative game in the II state at time t. One can then calculate the PDV of expected retailer profits from the state transition matrix. In particular, we will have the following state transition matrix, Ω:

$$\begin{bmatrix} (\frac{\Delta^*_{IS}}{\Delta})^2 + (1 - \frac{\Delta^*_{IS}}{\Delta})^2 & 2(\frac{\Delta^*_{IS}}{\Delta})(1 - \frac{\Delta_{IS}}{\Delta}) \\ 2(\frac{\Delta^*_{II}}{\Delta})(1 - \frac{\Delta^*_{II}}{\Delta}) & (\frac{\Delta^*_{II}}{\Delta})^2 + (1 - \frac{\Delta^*_{II}}{\Delta})^2. \end{bmatrix} \tag{25}$$

If we let ψ_{t-1} be the row vector $[\psi^{IS}_{t-1} 1 - \psi^{IS}_{t-1}]$ and ψ_t be the column vector $[\psi^{IS}_t 1 - \psi^{IS}_t]$, then we have that $\psi_{t-1}\Omega = \psi_t$. This allows one to calculate the expected profits for a retailer post deviation.

Based on this can define the present value of expected profit from deviation, both for the case when the retailer deviates in the IS situation and in the II situation. If the retailer deviates at some time $\bar{t}$ such that the value of $\bar{W}^{co} = \bar{W}^{co}_l$ and a different wholesaler is the main supplier to the two retailers (the IS situation), then the present value of expected profits under the deviation is (assuming that $p^d_a = .5\frac{1}{\lambda} + .5p^{co} + .5\bar{W}_a < p^{co} - \frac{1}{d}]$) :

$$V^{IS}_R = E\Pi^d_R + \sum \beta^t [\frac{1}{\lambda} + \frac{2}{9}\lambda[Prob_{\bar{t}+t}(IS)(2s^{IS} - 1)^2 (w^{IS}_h - w^{IS}_l)^2 \frac{\Delta^*_{IS}}{\bar{\Delta}}(1 - \frac{\Delta^*_{IS}}{\bar{\Delta}})] + \tag{26}$$

$$\frac{2}{9}\lambda[Prob_{\bar{t}+t}(II)(2s^{II} - 1)^2 (w^{II}_h - w^{II}_l)^2 \frac{\Delta^*_{II}}{\bar{\Delta}}(1 - \frac{\Delta^*_{II}}{\bar{\Delta}})], \tag{27}$$

with $Prob_{\bar{t}+1}(IS) = 1$. If the retailer deviates in the II situation, get value V^{II}_R defined similarly except that $Prob_{\bar{t}+1}(IS) = 0$.

Retailer IC constraint: joint collusion

The retailer IC constraint for joint collusion is:

$$\frac{\Pi^{co}_R}{1 - \beta} \geq \max[V^{IS}_R, V^{II}_R]. \tag{28}$$

E.3.2 Wholesaler collusion

Collusive expected profits

Given $Q^{co}_a = Q^{co}_b = 1$, wholesaler profits just depend on whether it is the main supplier to a retailer, earning revenues of $s^{co}(w^{co}_h - c)$ or the secondary supplier, earning revenues of $(1 - s^{co})(w^{co}_l - c)$. If collusion initially starts in the IS state, then the wholesaler earns profits of $(w^{co}_h - c)s^{co} + (w^{co}_l - c)(1 - s^{co}) - F_I - F_S$ if the wholesaler remains in the IS state. This occurs with probability $(1 - \frac{\Delta^*}{\Delta})^2 + (\frac{\Delta^*}{\Delta})^2$. If wholesaler 1 becomes the main supplier to both retailers, then it earns profits of $2(w^{co}_h - c)s^{co} - 2F_I$. This outcome occurs with probability $(1 - \frac{\Delta^*}{\Delta})(\frac{\Delta^*}{\Delta})$. If wholesaler 1 becomes the secondary supplier to both retailers, which occurs with probability $(1 - \frac{\Delta^*}{\Delta})(\frac{\Delta^*}{\Delta})$, the 1 earns profits of $2(w^{co}_l - c)(1 - s^{co}) - 2F_S$. This gives expected profits if the wholesaler initially is in the IS state of

$$[(w_l^{co}-c)+s^{co}(w_h^{co}-w_l^{co})-F_I-F_S][(1-\frac{\Delta^*}{\bar{\Delta}})^2+(\frac{\Delta^*}{\bar{\Delta}})^2]$$
$$+2(1-\frac{\Delta^*}{\bar{\Delta}})(\frac{\Delta^*}{\bar{\Delta}})[(w_l^{co}-c)+s^{co}(w_h^{co}-w_l^{co})-F_I-F_S], \tag{29}$$

which is clearly equal to $[(w_l^{co}-c)+s^{co}(w_h^{co}-w_l^{co})-F_I-F_S]$. One can do the same for the II/SS state and obtain the same expected profits. Thus, we have that the wholesaler ex ante one-period expected profit under collusion is:

$$\pi_i^{co}=(w_l^{co}-c)+s^{co}(w_h^{co}-w_l^{co})-F_I-F_S, \tag{30}$$

and the present value of ex ante collusive profit is $\pi_i^{co}/(1-\beta)$.

For any given state, the expected present value of profits will depend on the state. If the wholesalers are in IS state at time t, then the expected PDV of collusion from time t onwards is V_{IS}^{co}. Similarly if a wholesaler is in either state II or SS, then the expected PDV of collusion from t on is V_{II}^{co}, V_{SS}^{co} respectively. These are defined as:

$$\begin{aligned}
V_{IS}^{co} &= (w_l^{co}-c)+s^{co}(w_h^{co}-w_l^{co})-F_I-F_S \\
&\quad +[(1-\frac{\Delta^{co}}{\bar{\Delta}})^2+(\frac{\Delta^{co}}{\bar{\Delta}})^2]\beta V_{IS}^{co}+(1-\frac{\Delta^{co}}{\bar{\Delta}})\frac{\Delta^{co}}{\bar{\Delta}}\beta(V_{II}^{co}+V_{SS}^{co}), \\
V_{II}^{co} &= 2(1-\frac{\Delta^{co}}{\bar{\Delta}})[(w_h^{co}-c)s^{co}-F_I]+2(\frac{\Delta^{co}}{\bar{\Delta}})[(w_h^{co}-c)(1-s^{co})-F_S] \\
&\quad +(1-\frac{\Delta^{co}}{\bar{\Delta}})^2\beta V_{II}^{co}+(\frac{\Delta^{co}}{\bar{\Delta}})^2\beta V_{SS}^{co}+2(1-\frac{\Delta^{co}}{\bar{\Delta}})\frac{\Delta^{co}}{\bar{\Delta}}\beta V_{IS}^{co}, \\
V_{SS}^{co} &= 2(1-\frac{\Delta^{co}}{\bar{\Delta}})[(w_h^{co}-c)(1-s^{co})-F_S]+2(\frac{\Delta^{co}}{\bar{\Delta}})[(w_h^{co}-c)s^{co}-F_I] \\
&\quad +(1-\frac{\Delta^{co}}{\bar{\Delta}})^2\beta V_{SS}^{co}+(\frac{\Delta^{co}}{\bar{\Delta}})^2\beta V_{II}^{co}+2(1-\frac{\Delta^{co}}{\bar{\Delta}})\frac{\Delta^{co}}{\bar{\Delta}}\beta V_{IS}^{co}.
\end{aligned}$$

Expected profits under deviation: independent collusion, no retail price effects

If wholesaler 1 deviates from the collusive arrangement, there are two possible outcomes. One is that the retail collusion is sufficiently robust that the wholesaler deviation has no price effects (retailers cotinue to collude at p^{co}). In this case, the deviation is purely about shelf-share competition and wholesaler 1 is deviating to try to get a more profitable supplier and shelf outcome. The expected profits and best deviation in this case are derived from the multiperiod, local retail monopoly equations. It is state dependent. If wholesaler 1 deviates in the IS state, then the best deviation and future expected value is defined by the V_{IS} value function for the local retail monopoly with the values of (w_2^a, w_2^b) at the time of deviation given by w_l^{co}, w_h^{co} respectively. In particular, the optimal deviation, $(\hat{w}_1^a, \hat{w}_1^b)$ for wholesaler 1 in the IS state is given by:

$$
\begin{aligned}
&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)(s)-\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{da}}{\partial w_1^a}[\Pi_1^1+\beta V_{IS}^*]+\\
&\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)(1-s)+\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{da}}{\partial w_1^a}[\Pi_1^2+\beta V_{IS}^*]+\\
&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)(s)-\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{da}}{\partial w_1^a}[\Pi_1^3+\beta V_{II}^*]+\\
&\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)(1-s)+\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{da}}{\partial w_1^a}[\Pi_1^4+\beta V_{SS}^*]\\
&=0,
\end{aligned}
$$

and

$$
\begin{aligned}
&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)(1-s)-\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{db}}{\partial w_1^b}[\Pi_1^1+\beta V_{IS}^*]+\\
&\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)(s)+\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{db}}{\partial w_1^b}[\Pi_1^2+\beta V_{IS}^*]+\\
&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)(s)+\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{db}}{\partial w_1^b}[\Pi_1^3+\beta V_{II}^*]+\\
&\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)(1-s)-\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^{db}}{\partial w_1^b}[\Pi_1^4+\beta V_{SS}^*]\\
&=0,
\end{aligned}
$$

where $\Delta^{da}=(2s^{co}-1)(\hat{w}_1^a-w_l^{co})$ and $\Delta^{db}=(2s^{co}-1)(w_h^{co}-\hat{w}_1^b)$. Also, $\Pi_1^1=\hat{w}_1^a(s)+\hat{w}_1^b(1-s)-F_I-F_S$, $\Pi_1^2=\hat{w}_1^a(1-s)+\hat{w}_1^b(s)-F_I-F_S$, etc.

The expected value of the deviation and continuation is given by V_{IS}^d defined as:

$$
\begin{aligned}
V_{IS}^d=&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)[\Pi_1^1+\beta V_{IS}^*]+\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)[\Pi_1^2+\beta V_{IS}^*]+\\
&\Big(1-\frac{\Delta^{da}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{db}}{\bar{\Delta}}\Big)[\Pi_1^3+\beta V_{II}^*]+\Big(1-\frac{\Delta^{db}}{\bar{\Delta}}\Big)\Big(\frac{\Delta^{da}}{\bar{\Delta}}\Big)[\Pi_1^4+\beta V_{SS}^*],
\end{aligned}
$$

and the incentive constraint for this case is $V_{IS}^{co} \geq V_{IS}^{d}$. Deviations for the II and SS states are defined similarly.

Expected profits under deviation: independent collusion, retail price effects

If the deviation induces the retailer to deviate from the collusive arrangement, at least for some outcomes, then the conditions are akin to those for the multiperiod duopoly problem. Suppose that at time t both wholesalers and retailers are colluding independently and that, at the beginning of time t, wholesaler 1 is in the SS state (the incumbent secondary supplier to both retailers). Suppose that there are feasible wholesale price deviations (wholesale price greater than zero) that induce a retailer to deviate from the collusive agreement when it switches main suppliers. Suppose that wholesaler 1 makes such a wholesale price offer to retailer a. Then, in outcomes $\omega = 2$ and $\omega = 4$, retailer a deviates from the collusive agreement while in outcomes $\omega = 1$ and $\omega = 3$ retailer a does not deviate from the collusive agreement. Under independent collusion, this mean that retail collusion is maintained under outcomes $\omega = 1$ and $\omega = 3$ but is destroyed under outcomes $\omega = 2$ and $\omega = 4$.

Given this, the expected value under the best deviation for wholesaler 1 is given by:

$$\begin{aligned} V_{SS}^{dp}(w_1^a, w_2^{co}, w_2^m, w_1^{co}) &= \max_{w_1^a} \pi_{SS}^{dp}(\mathbf{w}) + \beta((1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{SS}^{dp} + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})]V_{II}^* \\ &+ (1 - \frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(\frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{SS}^{dp} + (\frac{\Delta_a(\mathbf{w})}{\bar{\Delta}})(1 - \frac{\Delta_b(\mathbf{w})}{\bar{\Delta}})V_{IS}^*, \end{aligned}$$

where $w_1^a = \hat{w}_l^{SS}$, $\Delta_a = \Delta_b = (2s^{co} - 1)(w_h^{co} - w_1^a)$, V_{II}^* is the multiperiod duopoly equilibrium value of the II state, V_{IS}^* is the multiperiod duopoly equilibrium value of the IS state, and π_{SS}^{dp} is:

$$\begin{aligned} &\left(1 - \frac{\Delta^a}{\bar{\Delta}}\right)\left(1 - \frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)(1-s)Q_a^1 + (w_1^{co} - c)(1-s)Q_b^1 - 2F_S]+ \\ &\left(\frac{\Delta^a}{\bar{\Delta}}\right)\left(\frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)sQ_a^2 + (w_1^{co} - c)sQ_b^2 - 2F_I]+ \\ &\left(1 - \frac{\Delta^a}{\bar{\Delta}}\right)\left(\frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)(1-s)Q_a^3 + (w_1^{co} - c)sQ_b^3 - F_I - F_S]+ \\ &\left(\frac{\Delta^a}{\bar{\Delta}}\right)\left(1 - \frac{\Delta^b}{\bar{\Delta}}\right)[(w_1^a - c)sQ_a^4 + (w_1^{co} - c)(1-s)Q_b^4 - F_I - F_s]. \end{aligned}$$

Given the assumption on how the deviation affects the retailer collusion, it must be that $Q_a^1 = Q_b^1 = Q_b^3 = Q_a^3 = 1$. If the price deviation by retailer a is such that $\hat{p}_a < p^{co} - \frac{1}{d}$, then the value of $Q_a^2 = Q_a^4 = \hat{Q}_a = .5 + .5\lambda(p^{co} - \bar{W}_a)$ and $Q_b^2 = Q_b^4 = 2 - Q_a^2$. The value of $\bar{w}$ in each case is $s^{co}\hat{w}_l^{SS} + (1 - s^{co})w_h^m$.

The value of $\hat{w}_l^{SS}$ is given by the following derivative condition:

$$\Big(1-\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)(1-s)-\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^1+\beta V_{SS}^{dp}]+$$

$$\Big(\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)\{sQ_a^2+[(w_1^a-c)s-(w_1^{co}-c)(1-s)]\frac{\partial Q_a^2}{\partial w_1^a}\}+\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^2+\beta V_{II}^*]+$$

$$\Big(1-\frac{\Delta^a}{\bar{\Delta}}\Big)\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)(1-s)-\Big(\frac{\Delta^b}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^3+\beta V_{SS}^{dp}]+$$

$$\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)\Big(\frac{\Delta^a}{\bar{\Delta}}\Big)\{sQ_a^4+[(w_1^a-c)s-(w_1^{co}-c)(1-s)]\frac{\partial Q_a^4}{\partial w_1^a}\}+\Big(1-\frac{\Delta^b}{\bar{\Delta}}\Big)\frac{1}{\bar{\Delta}}\frac{\partial\Delta^a}{\partial w_1^a}[\Pi_1^4+\beta V_{IS}^*]$$

$$=0,$$

where $\frac{d\Delta^a}{dw_1^a}=-(2s^{co}-1)$, $\frac{dQ_a^4}{dw_1^a}=-.5s^{co}\lambda$ and $\pi_1^1=2[(w_1^a-c)(1-s)-F_S]$, $\pi_1^2=2[(w_1^a-c)s-F_I]$, etc. The incentive constraint for an equilibrium in this case is that $V_{SS}^{co}\geq V_{SS}^{dp}$. Similar incentive constraints apply for deviation in the IS and II cases. The only difference for joint collusion is that, even in outcomes $\omega=1$ and $\omega=3$ the retail collusion dissolves. This means that, in the above equations, the value V_{SS}^{dp} is replaced by the multiperiod duopoly values V_{SS}^* and V_{IS}^* respectively.

E.3.3 Example

The example in the text assumes values for the model parameters of: $c=0,\bar{\Delta}=1.5,F_I=0.5,F_S=0.3,\tau=1,d=1,\phi=0.1$. For a value of $\beta=0.4$, the equilibrium wholesale price bids, w_h^m,w_l^m and the equilibrium shelf share for the main supplier,s^m are defined by the multiperiod local retail monopoly equilibrium from above: $w_h^m=2.319,w_l^m=1.476,s^m=.797$. These give the non-cooperative wholesale equilibrium should the retailers collude successfully on price. We use this wholesale equilibrium outcome as the basis for our example. With these prices, we have that $\bar{W}_h=s^mw_h^m+(1-s^m)w_l^m=2.15$ and $\bar{W}_l=s^mw_l^m+(1-s^m)w_h^m=1.65$. The collusive retail price, $p^{co}=4.9$.

If retailer a deviates when its per unit costs is $\bar{W}_l$, it's best deviation gives a price of 3.9 and so sales of $1+\tau d(1-2\phi)=1.8$ (the corner solution). From above, retailer a's expected profits under the deviation are $V_R^{II}=(3.9-1.65)1.8+\frac{\beta}{1-\beta}\frac{1}{\lambda}+\sigma$, where σ represents the value of the summation in the expression for V_R^{II} and is approximately .01. This gives an expected deviation value of approximately 4.89. This is insufficient to induce retailer a to deviate. To induce retailer a to deviate, the value of $\bar{W}_l$ must be such that $4.9-\bar{W}_l+1.94=(3.9-\bar{W}_l)1.8+.843$. This means that a value of $\bar{W}_l=1.27$ will induce retailer$a$ to deviate. The value of $\hat{w}_l$ that accomplishes solves the equation $.797\hat{w}_l+.(203)(2.319)=1.27$, giving $\hat{w}_l=1$.

The question is whether or not this deviation is profitable for wholesaler 1. with no deviation, wholesaler 1's expected value from not deviating is $V_S S^m = 1.126$. The value of the deviation can be calculated from the expression for V_{SS}^{dp} above for joint collusion. In that expression, the multiperiod duopoly values are $V_{IS}^* = 1.789, V_{II}^* = 3.335, V_{SS}^* = 1.159$. This gives a value of $V_{SS}^{dp} = 1.177$ and so the deviation pays even if there is joint collusion in the sense of any deviation by the wholesaler causes the retail and wholesale collusion to dissolve.

One can do the same calculations for the case in which $w_h^{co} = 2.719, w_l^{co} = 1.794$ and $s^{co} = .77$. In this case, the value of maintaining the collusive arrangement for wholesaler 1 in the SS state is 1.64. The value of $\bar{w}_a$ that induces retailer a to deviate is determined as before and is $\bar{w}_a = 1.579$. This requires a value of $\hat{w}_l = 1.24$. The best deviation for wholesaler 1 in this case is to offer $\hat{w}_l = 1.24$ to both retailers. The value of this deviation tio wholesaler 1, V_{SS}^{dp} can be calculated using the formula for V_{SS}^{dp} above but for the case in which both retailers are offered the deviation price. Doing so gives $V_{SS}^{dp} = 1.61$ and so the deviation does not pay and the collusive arrangement is maintained.