Hump-shaped cross-price effects and the extensive margin in cross-border shopping

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DISCUSSION PAPER

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Hump-shaped cross-price effects and the extensive margin in cross-border shopping*

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Abstract

This paper examines the effect of cross-border shopping on grocery demand in Norway using monthly store×category sales data from Norway's largest grocery chain 2011-2016. The sensitivity of demand to foreign price is hump-shaped and greatest 30-60 minutes' driving distance from the closest foreign store. Combining continuous demand, fixed costs of cross-border shopping and linear transport costs à la Hotelling we show how this hump-shape can arise through a combination of intensive and extensive margins of cross-border shopping. Our conclusions are further supported by novel survey evidence and cross-border traffic data.

Keywords: Cross-border shopping, competition in grocery markets, product differentiation.

JEL: F15; H73; L66; R20.

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1 Introduction

Large and persistent price differences between jurisdictions may lead to cross-border shopping by consumers and imply that retail activity in border areas responds to exchange rate swings (see e.g. Campbell and Lapham (2004), Manuszak and Moul (2009)). The motivation for the current paper is to understand how the sensitivity of local demand with respect to foreign prices varies with distance to foreign stores. A common view is that consumers and stores closest to the border are those most affected by changes in relative prices across borders. As we discuss below, the previous literature could be interpreted as supporting such a view.

In this paper we empirically examine a case where, even though consumers closer to the border are those most likely to shop abroad, the cross-price effect of relative price changes is *not* the greatest at the border, but rather some distance away from the closest foreign store. We show how such an outcome, which may seem surprising at first glance, arises intuitively when cross-border shopping is determined by both the intensive (how much to shop abroad) and the extensive margin (should you travel abroad to shop at all). If price is lower abroad, which is what incentivizes cross-border shopping in the first place, a simple Hotelling competition model (Hotelling, 1929) predicts that consumers closest to the border always shop abroad, and as relative prices change, the location of the marginal consumer changes. In such a model, with only an extensive margin, the result that responsiveness is strongest some distance away from the border is intuitive. Combining a Hotelling-like model of geographic differentiation with a standard representative consumer linear demand function (see e.g. Bowley, 1924; Singh, 1984) and heterogeneous fixed cost of travel we show how a hump-shaped pattern of cross-price effects can emerge. We also use the model to stress that the responsiveness to changes should not be confused with level effects. The *level* of cross-border shopping is predicted to be the greatest closest to the border even if the response to *changes* in the attractiveness of cross-border shopping is greatest some distance inland (because that is where the extensive margin bites).

Our empirical analysis uses monthly sales data at the store and category level from the largest Norwegian grocery chain for the period 2011-2016 to examine cross-border shopping into neighboring Sweden for four product groups subject to cross-border shopping (meat, cheese, soda and candy). We find that cross-border shopping is responsive to relative prices and effects linger substantially inland. We confirm a hump-shaped pattern with respect to how sales respond to relative (Norwegian/Swedish) price changes: For the three most bought product groups, the price sensitivity 30-60 minutes' driving distance from the closest Swedish store is between 6 and 19 percent stronger than the price sensitivity 0-30 minutes' from the closest Swedish store. In most cases we find that these differences are statistically significant.

To support our finding that relative prices between Norway and Sweden affect local sales in Norway through cross-border trade, we analyze how the border crossings between Norway and Sweden are affected by changes in the exchange rate over the period 2001 to 2017. In line with Chandra et al. (2014) and Baggs et al. (2018) we find that, after controlling for trends and seasonality, the number of cars crossing the border are significantly and positively correlated with the exchange rate. We find that a 10% depreciation of the Norwegian krone (NOK, which makes border shopping less attractive) decreases the border traffic to Sweden by 2.8%. With the aim to verify that this positive relationship is not driven by other factors and general economic development we undertake the same analysis for larger vehicles (typically commercial traffic) and find no such relationship.

Let us now relate our findings to the previous literature. Much of the literature on cross-border shopping has focused on goods for which excise taxes make up a substantial portion of the price (e.g. alcoholic beverages, cigarettes, gambling and gasoline) and a number of theoretical contributions have examined the links between tax competition and cross-border shopping (see Kanbur and Keen (1993) for a seminal contribution). Most of the empirical studies compare sales in border regions to sales in more inland regions and thus establish that cross-border shopping exerts an influence on local shopping behavior, but do not allow for a study of how effects die off with distance (see Leal et al. (2010) for a survey).

A handful of previous articles have examined how the cross-price elasticity with respect to foreign prices decreases with distance to the border. Results indicate that the closer a location is to the border, the more sensitive is local demand to foreign prices, but also that effects of cross-border shopping can stretch far inland. Asplund et al. (2007), for instance, examine Swedish sales of alcoholic beverages and find that the cross-price elasticity for spirits is statistically indistinguishable from zero only some 700 kilometers from the border. Similarly, using Canadian data on several retail sectors, Baggs et al. (2016) find effects that stretch far inland even though the most marked effect is up to 50 kilometers from the border. Building from a search-theoretic model with heterogeneous consumers Baggs et al. (2018) estimate that an appreciation of the Canadian dollar substantially decreases sales of Canadian retailers and that this effect decreases with distance from the closest US stores (see also Chen et al. (2017)). Chandra et al. (2014) also build a model with heterogenous consumers to examine travel across the Canada-

U.S. border and show that border crossings respond strongly to exchange rate changes and that distance exerts a major influence on the propensity to cross the border.[1]

To our knowledge, the finding of non-monotonic cross-price effects are new to the literature on cross-border shopping and should be of interest also to the broader literature on product differentiation, which has typically paid little attention to combined effects of extensive and intensive margins. The theoretical studies of differentiated product demand in oligopoly can be categorized into two main classes. One relies on consumers located in geographic space facing travel costs and having unit demand (Hotelling, 1929; Salop, 1979) and the other relies on representative consumers with continuous demand, with linear-quadratic utility as a popular form as it gives rise to linear demand functions (see e.g. Bowley, 1924; Singh, 1984; Amir et al., 2017). Both strands of models are the subject of thriving theoretical literatures but relatively few analyses combine the two types of models. An early important exception is Stahl (1982) who combines linear-quadratic utility with linear transport costs. We are not aware of any previous empirical work that documents a hump-shaped relation between demand responses to price changes and distance, nor any work that links such a predicted pattern to the interaction of extensive and intensive margins.[2]

By examining consumption of grocery products we also contribute to the literature on competition in grocery retail markets. It is typically found that competition in grocery retail markets is very localized and that consumers rarely travel long distances to buy grocery products (see e.g. Ellickson and Grieco (2013), Agarwal et al. (2017), Allain et al. (2017), Marshall and Pires (2018)). However, the evidence in our paper suggest that such a finding is partly an artifact of low price differences across stores within a country (DellaVigna and Gentzkow (2017)). With large discrete price differences across the border consumers may travel long distances to take advantage of the lower prices

[1]The above papers examine how cross-price effects vary with distance. Another set of closely related articles examine how levels of sales or local taxes vary with distance. For instance, Lovenheim (2008) uses data from the current population survey in the U.S. to examine how cigarette demand depends on a linear measure of distance to lower priced locations. Merriman (2010) uses sales-origin information from littered cigarette packs in Chicago to estimate how the level of cross-border shopping depends on a linear measure of distance. Agrawal (2015) documents strong effects of distance on tax competition (as measured by local sales taxes in the U.S.) and includes a flexible polynomial form of distance in regressions.

[2]Perhaps closest to ours is a recent article which examines how cross-price elasticities relate to spatial differentiation in a Hotelling duopoly with asymmetric qualities, Kolay and Tyagi (2018). We relate to this article in greater detail in our concluding comments. Another recent strand of somewhat related work uses household-level data and examines competition across space when allowing for transport costs (see e.g. Thomassen et al. (2017)). Yet another strand examines loss-leading and consumer choice between stores (see e.g. Johnson (2017). Neither has studied the humpshape of cross-price effects however.

abroad (see e.g. Gopinath et al. (2011) for evidence on the discrete effect of a border on prices).

The next section lays the foundation for our more detailed study, presenting questionnaire responses on cross-border shopping and describing price differences between Norway and Sweden. Following several previous studies of cross-border shopping, we use the exchange rate as a source of exogenous variation in relative prices between countries. In the last part of the section, we use traffic data to establish that exchange rate changes significantly affect passenger car traffic across the border (but not commercial traffic). Section 3 presents the main data set and Section 4 presents regression results with the key takeaway that the elasticity of demand with respect to the relative price is greatest 30-60 minutes' driving distance from the nearest Swedish store. Section 5 shows how a combination of fixed and distance-related travel costs generates an extensive and intensive margin of cross-border shopping in a theoretical framework, which is consistent with the observed patterns. Section 6 concludes.

2 Cross-border shopping in Norway

The main analysis uses a store- and category level data set of Norwegian grocery sales as examined in detail in the next section. First however we paint the background picture of the geography of cross-border shopping in Norway and provide some independent evidence that cross-border shopping is sensitive to exchange rate changes. To provide this background we draw on five data sets: i) price level indexes from Eurostat, ii) the exchange rate between Norwegian and Swedish currency (NOK/SEK) from the Norwegian Central Bank, iii) travel times by road from Norwegian municipalities to the closest Swedish grocery store, iv) a survey of cross-border shopping that was part of this project and v) data on cross-border traffic from the Norwegian Public Roads Administration.

2.1 Prices are high in Norway and many consumers live close to the border

Cross-border trade is motivated by systematic price differences across jurisdictions, typically due to long run politically determined institutional differences across countries such as differences in import tariffs and in tax regimes on e.g. alcohol, tobacco and gasoline. There are many markets where we observe large and persistent price differences and where border stores sell significant volumes to neighboring country customers.[3] Norwegians shop a significant part of their groceries in neighboring Sweden, where prices are substantially lower. Statistics Norway estimates that in 2016 Norwegians cross-border shopped for 13.8 billion NOK, and undertook 7.7 million daytrips to Sweden.[4] For comparison, total domestic sales of groceries amounted to 170 billion NOK in Norway in 2016 (ACNielsen).

Eurostat collects and publishes price level indexes with the explicit purpose of allowing a comparison of price levels across countries and Table 1 presents the price levels in Norway and Sweden for a set of product categories between 2011 and 2016. Price levels are normalized so that the price level in EU15 (EU members prior to 2004) is equal to 100 in each year. We see that prices in Sweden are generally high as the index is above 100 for all the categories, but prices in Norway are higher still. Prices are high in Norway for overall individual consumption as well as for food as an aggregate. Below, we examine some product categories in detail and relative price indexes are given by the indexes for "meat", "milk, cheese and eggs" and "non-alcoholic beverages". As seen price differences are large: for instance a basket of non-alcoholic beverages that on average cost 10 euros in Western European EU member states in 2016 cost 11 euros in Sweden and 18 euros in Norway. Price differences for alcoholic beverages and tobacco (not examined in the present study) are also strikingly large.

[3] Examples include Canadians shopping in the U.S., Spaniards and Frenchmen shopping in Andorra, Danes shopping in Germany, Swedes shopping in Denmark and Swiss shopping in all neighboring countries, just to mention a few.

[4] https://www.ssb.no/statbank/table/08460.

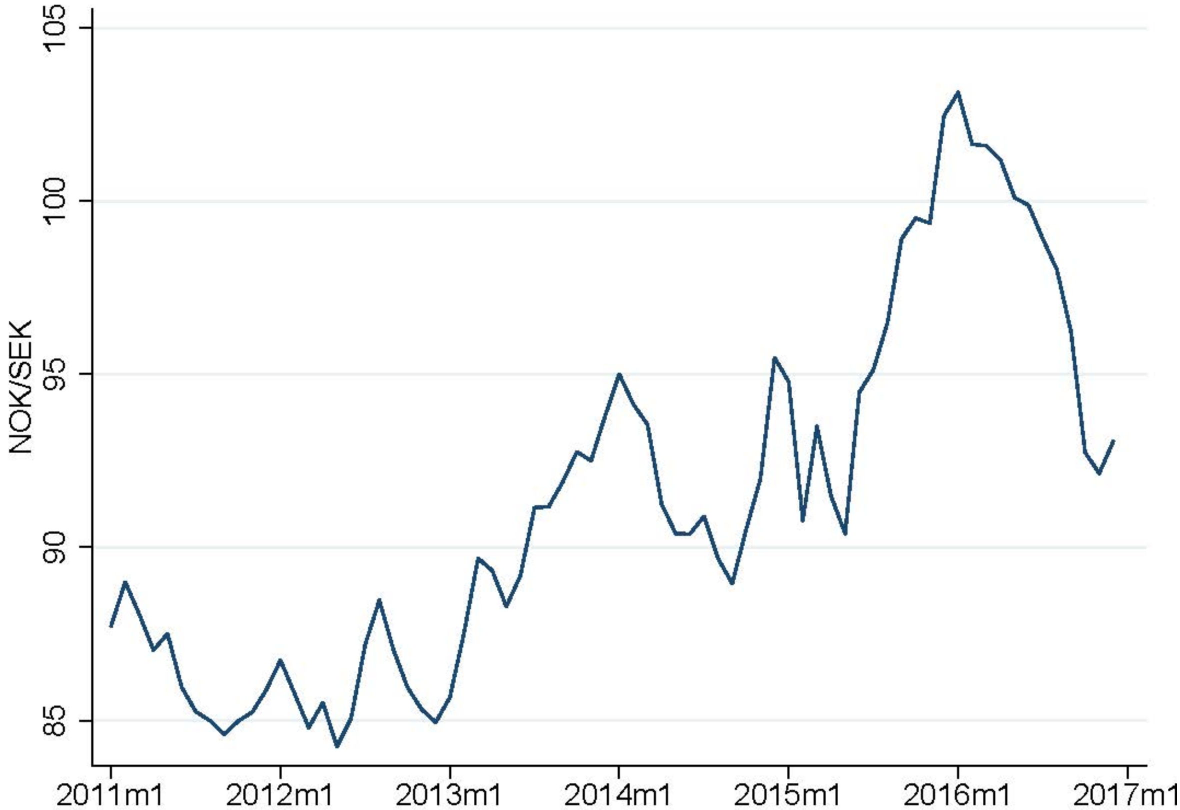
Table 1: Price level indexes of selected product categories in Norway and Sweden 2011-2016 (EU15=100)

Price index	Country	2011	2012	2013	2014	2015	2016
Actual individual consumption	Sweden	123.4	125.2	131.0	124.4	120.9	125.3
	Norway	154.8	160.9	155.7	146.4	136.6	138.6
Food	Sweden	114.4	115.7	117.1	119.2	116.9	119.2
	Norway	170.0	171.4	162.7	156.2	147.6	149.8
Meat	Sweden	112.6	114.6	116.5	120.0	117.1	120.1
	Norway	154.1	154.6	143.8	148.0	140.8	141.0
Milk, Cheese and eggs	Sweden	101.3	104.3	108.2	113.8	111.7	113.8
	Norway	198.2	203.3	192.3	179.1	169.6	170.5
Non-alcoholic beverages	Sweden	120.2	118.7	118.5	109.9	110.3	110.4
	Norway	186.9	189.9	183.3	181.0	176.0	179.0
Alcoholic beverages	Sweden	157.0	157.1	155.2	138.2	135.5	137.7
	Norway	273.9	283.8	278.2	258.5	239.6	241.3
Tobacco	Sweden	112.8	120.5	119.8	108.9	105.5	106.8
	Norway	243.8	245.6	237.9	211.8	196.2	198.4

Notes: The table presents price level indexes (EU15=100) for 2011-2016 (source: Eurostat, "Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates"). The EU15 consists of the member countries of the European Union prior to the accession on 1 May 2004 of ten candidate countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom

In the period we consider in our empirical analysis, most products will always be cheaper in Sweden. How much cheaper will vary over time, however, mainly because of variation in the exchange rate between the Norwegian (NOK) and Swedish (SEK) currencies. Figure 1 graphs the NOK/SEK exchange rate between 2011 and 2016, showing substantial variation as well as a trend-wise depreciation of the NOK which makes Swedish grocery prices less attractive to Norwegian consumers. The exchange rate varies from the case where 85 NOK bought 100 SEK in 2012 to more than 100 NOK being needed to buy 100 SEK during parts of 2016. Price differences induced by the exchange rate will be the main source of exogenous price variation in our analysis.

Figure 1: Exchange rate between Norwegian and Swedish currency (NOK/SEK)



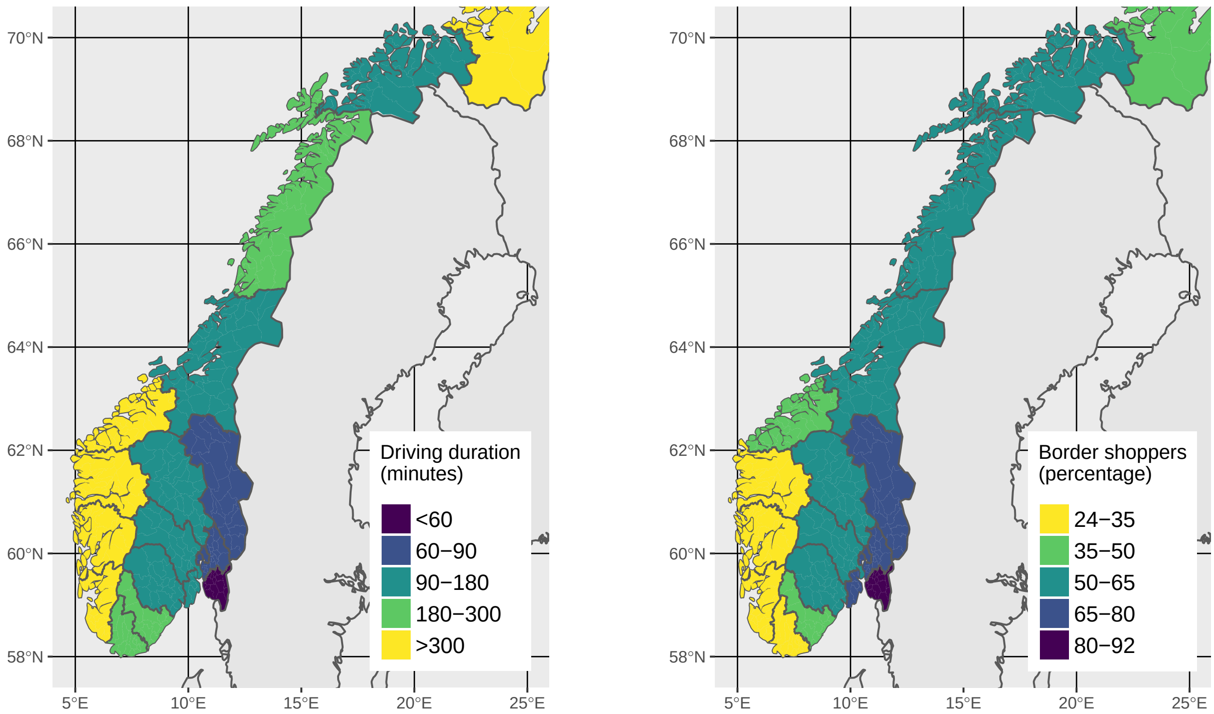
Norway is part of the European common market (EEA) but is not a member of the European Union. The agricultural sector in Norway is protected by substantial import tariffs, which is an important explanation for price differences in for instance meat and dairy products. High incomes, a retail structure dominated by relatively small grocery stores and a dispersed population across a large mountainous country are likely to further contribute to high Norwegian prices. Due to restrictive policies on alcohol and tobacco, and to protect its agriculture, Norway applies quotas for cross-border shoppers.[5] Travelers may, for instance, bring up to ten kilos of meat and cheese (combined), and a restricted quantity of alcohol.[6] Norway is part of the Schengen area with free mobility in Europe however, and border controls are relatively infrequent.[7] It thus comes as no surprise

[5]See https://www.toll.no/en/goods/ for current regulations.

[6]The alcohol quota is either six bottles of wine and two liters of beer, or four bottles of wine, one liter of hard liqueur and two liters of beer.

[7]Norwegian citizens are not entitled to VAT refund for goods bought in Sweden.

Figure 2: Driving duration and border shopping



(a) Driving duration

(b) Border shopper share

Notes: Figure 2a shows the county-level driving duration to the closest store in Sweden, averaged across driving durations of the stores in our sample. Figure 2b shows the county-level proportions of the Norwegian population that have shopped groceries in Sweden during the last 12 months. Numbers based on survey responses from Norwegian respondents. Survey undertaken 22-27 February 2018, n=1009.

that the topic of cross-border shopping is often discussed in Norwegian media and policy circles (see e.g. Lavik and Nordlund (2009) for an overview).

Not only are price differences large, Swedish grocery stores are also relatively accessible since Norway and Sweden share a long border. As described in Section 3 we calculate driving duration from each postal code to the closest Swedish grocery store and Figure 2a graphs the average travel time aggregated to the county level. As seen, large parts of Norway are less than a three hour drive from Sweden. Furthermore, a nontrivial fraction of the Norwegian population live in areas close to Swedish stores. 3.8% of households live less than 30 minutes' drive from the closest Swedish store, 9.6% within 60 minutes' drive and 40.7% within 90 minutes' drive. For a large share of Norwegian households a day-trip to Sweden with car is thus feasible (Figure A.1 in the appendix shows the cumulative distribution of Norwegian households with respect to this measure of travel time).

2.2 Survey evidence on cross border shopping

Large price differences and limited driving duration indicate that cross-border shopping of groceries could be substantial in Norway, something that is confirmed by a survey conducted for this research project in March 2018, where 1009 representative respondents were asked about cross-border shopping in Sweden.[8] A very high share, 59.8% percent of the respondents, had shopped groceries in Sweden during the last 12 months. Furthermore, as is illustrated in Figure 2b, cross-border shopping is not confined to the border counties. Even in the counties furthest from Sweden, between a quarter and a third of the respondents had border-shopped during the last year.[9]

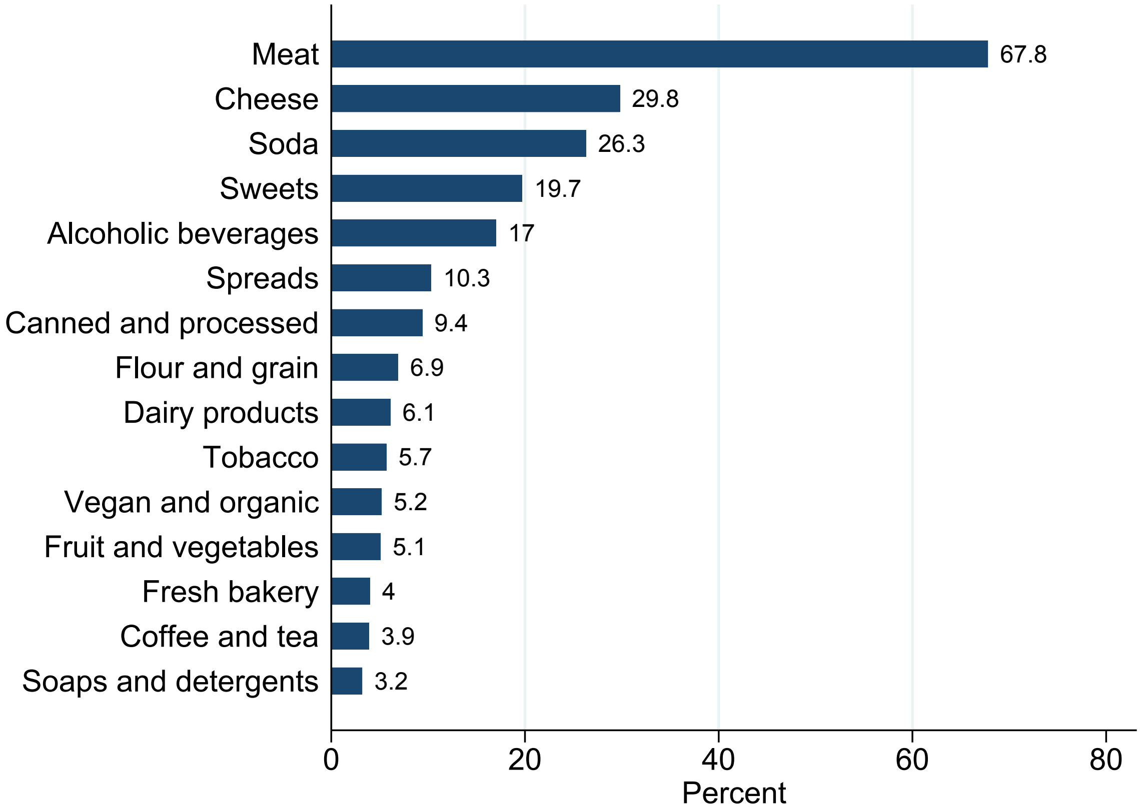
We asked the same respondents which three product categories they typically bought most of when border-shopping in Sweden. Figure 3 shows that 67.8% of the respondents that shopped in Sweden had meat as one of their three choices. In addition, soda, cheese, sweets and alcoholic beverages stand out, with shares between 17% and 30 %. Later we will focus on the four most popular categories. We leave out alcoholic beverages because these are mainly bought in national retail monopoly stores for which we do not have access to store level sales.[10]

[8]The survey was performed by the company Sentio Research Norway (http://sentio.no/en/). The questionnaire was financed as part of the FOOD-research project. The panel asked is representative with regards to regional settlement, educational background, political party affiliation as well as age.

[9]The county with the highest proportion of border-shoppers (92 %) is the south-eastern border county Østfold, while the county with the lowest proportion (24 %) is Vest-Agder, located in far south of Norway. See Figure A.2 for the percentages for all counties.

[10]Vinmonopolet (https://www.vinmonopolet.no) in Norway and Systembolaget in Sweden (https://www.systembolaget.se) are monopoly retailers for all alcoholic beverages. An exception is that Norwegian grocery stores can sell beer with alcohol content up to 4.5% ABV and Swedish grocery stores can sell beer below 3.5% ABV only.

Figure 3: Top product categories for Norwegian cross-border shoppers



Notes: The most popular product groups for border shopping. Numbers based on survey responses from Norwegian respondents. Survey undertaken 22-27 February 2018, n=1009.

2.3 Border traffic and exchange rate variation 2001-2017

As discussed, the main source of variation in relative prices between Norway and Sweden will be the exchange rate. As a first check of the relevance of exchange rate variation as an explanation for cross-border shopping, we examine the relationship between the exchange rate and border traffic. In the context of cross-border shopping between Canada and the US, this relationship has been examined by for instance Chandra et al. (2014) and Baggs et al. (2018). Norway and Sweden share 15 major road-crossings and we have focused on the five major crossings where we have access to weekly traffic data for more than 15 years,[11] shown in Table 2. Data is split according to vehicle length and we refer to

[11]Data has been provided by the Norwegian Public Roads Administration, Statens Vegvesen. Our five crossings account for about 86 percent of the total border traffic for cars in the period we consider. For

vehicles that are less than 5.4 meters long as cars (this is long enough to include all but the very longest SUVs) and to vehicles that are more than 5.4 meters long as commercial vehicles, reflecting that this will mainly be trucks and buses.

Table 2: Descriptive statistics - border crossing stations

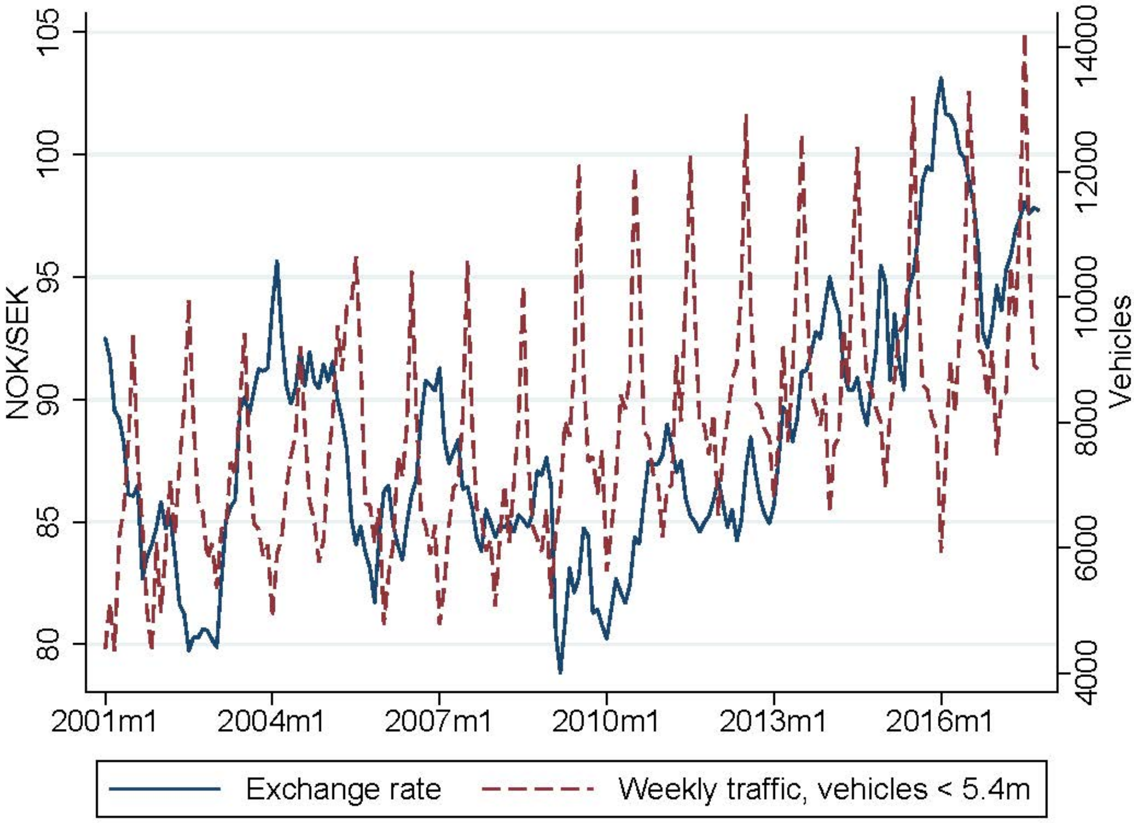
	N	First week	Last week	Weekly traffic (cars)	Weekly traffic (commercial vehicles)
Svinesund	876	2001w1	2017w43	55259.7	7407.4
Ørje	833	2001w1	2016w52	15864.1	2025.8
Morokulien	824	2002w1	2017w43	20818.7	1894.9
Tevjedalen	824	2002w1	2017w43	4011.0	609.0
Graddis	772	2003w1	2017w43	985.67	303.1

We have access to data for 4129 weeks for the period 2001 to 2017. The most busy border crossings are in the south where most of the Norwegian population lives. In our data, Svinesund and Ørje, which are located in Østfold, the southeastern most county neighbouring Sweden, represent 63% of the car traffic. Cars are typically privately owned, and it is within this group we expect to find the strongest effect of the exchange rate on traffic. Commercial vehicles on the other hand should be less affected by the exchange rate.

Figure 4 graphs the NOK/SEK exchange rate and the number of cars at the largest border crossing, Svinesund, which alone represents nearly half of the car crossings between Sweden and Norway.

the other crossings, data is only available for at most six years.

Figure 4: Exchange rate and border crossings



Notes: Development in mean weekly traffic (number of cars) from Norway to Sweden at Svinesund 2001-2017 and the development in the exchange rate between NOK/SEK

There seems to be some correlation in the dynamics of the time series, but here we disregard potential trends due to general economic growth, and short term dynamics due to seasonality and Norwegian holidays. To analyze the relationship properly we estimate a fixed effects model for the period 2001-2017, where we uncover the potential effect of exchange rates on border crossings for both cars and commercial vehicles. We include a time trend, month number dummies to account for seasonality, fixed effects for the border crossing stations, and dummies to account for weeks in which there are Norwegian holidays. The latter is due to the fact that border-shopping increases significantly at certain days (weeks) that are holidays in Norway when local shops are closed, but when Swedish shops remain open. This typically happens during Easter, on some public holidays such as May 1st, and in particular on the Norwegian national day (May 17th), Ascension and Pentecost. The Christmas- and New Year holidays are different, partly since there is no asymmetry in opening hours (shops are mostly closed on the same days in both countries), and also because these holidays take place in winter time when border crossing can be more difficult due to weather conditions. We anticipate less commercial traffic for all public holidays.

Table 3 illustrates that the cross-border traffic of cars is indeed sensitive to the exchange rate: A depreciation of the NOK (which makes shopping in Sweden less cheap relative to shopping in Norway) leads to a decrease in the number of cars passing border traffic stations. As we would expect, we see no effect of the exchange rate on border traffic of commercial vehicles: While a strong NOK may trigger consumers to cross the border in order to shop in Sweden, we do not expect this to be an incentive for commercial traffic. Our findings confirm that national holidays affect border traffic in line with our expectations. Commercial traffic tends to be lower during national holidays, while car traffic is higher than normal during the public holidays that do not take place during wintertime. In particular the first Easter week shows a significant increase in traffic, and a significant increase is also found for the Norwegian national day in May. As anticipated, traffic decreases significantly during Christmas, and also the New Year estimate is negative though insignificant.

Turning to the size of the exchange rate effects we calculate elasticities for both models. As anticipated, the elasticity for commercial vehicles is close to zero and statistically insignificant. For cars, we find that a 10 % depreciation of the NOK (which makes border shopping less attractive) decreases the border traffic to Sweden significantly, with a point estimate of 2.8%.

Table 3: Border traffic

	Small vehicles	Large vehicles
Exchange rate	−61.754***	−1.713
	(19.073)	(2.915)
Trend	12.928***	2.047***
	(0.422)	(0.064)
First easter week	7597.917***	−395.242***
	(840.092)	(101.164)
Second easter week	331.314	−411.304***
	(716.842)	(82.516)
May 1	−152.072	−215.952**
	(449.032)	(84.289)
May 17 (National day)	1565.165***	−92.857
	(430.420)	(88.155)
Ascension	1531.602***	−78.490
	(495.112)	(82.897)
Pentecost	−319.086	−119.552
	(416.982)	(77.449)
Christmas	−3315.500***	−1062.929***
	(698.971)	(176.604)
New Year	−1566.109*	−703.154***
	(875.598)	(182.075)
Constant	−5389.025***	−1200.333***
	(1652.421)	(252.123)
Observations	4077	4077
R^2	0.934	0.928
Month number FE	Yes	Yes
Traffic station FE	Yes	Yes
Elasticity of traffic	−0.279	−0.058
	(.086)	(.099)

Notes: The dependent variable is weekly traffic going from Norway to Sweden. Robust standard errors are reported in parentheses.
* p < 0.1, ** p < 0.05, *** p < 0.01.

3 The grocery data

3.1 Sales data

The main data set contains weekly sales at the product category and store level, from all stores belonging to Norway's largest grocery chain, NorgesGruppen (NG). The data cover the beginning of 2011 until the end of 2016. Like the other Nordic markets, the Norwegian grocery market is relatively concentrated. NG is the largest umbrella chain, with a market share of about 40 percent in our sample period. To limit noise in the data we aggregate sales to the monthly level and we focus the analysis on four product categories that we expect to be particularly interesting for cross-border shopping purposes based on the discussion in Section 2: meat, cheese, soda and sweets.[12] We limit attention to stores located no more than 180 minutes' driving distance from the closest Swedish store.[13] We also limit attention to supermarkets, not analyzing demand at the small convenience stores controlled by NG.[14]

The data set contains the postal code of each Norwegian store. From Delfi Marknadspartner we acquired data on the exact location of all grocery stores in Swedish border counties. Using OpenStreetMap we calculate driving distance in minutes from the center of the postal code of each Norwegian store to the closest Swedish grocery store. We also use mean household disposable income at the municipality level. This is from Statistics Norway and is converted to real 2015 income by the overall consumer price index.

3.2 Price data

We use two sets of measures of prices. The first set builds on data available via Eurostat for all EU and some other European countries, Norway included. The main data set uses disaggregated national price level indexes at the monthly level using the "Classification of individual consumption by purpose (COICOP)". For purposes of comparison (as in Table 4) we rescale these indexes using the price level indexes available at disaggregated levels

[12]Meat consists of non-poultry meat, both fresh and frozen and also includes minced meat and sausages. Sweets contains chocolate as well as other sweets and candy. Soda contains carbonated soft drinks and bottled water, cider and syrups.

[13]Note that Figure 2a illustrates the average driving duration at the county level. Since we include all stores with no more than 180 minutes' travel time to the closest Swedish store, our included stores will not be restricted to the counties with average driving duration of less than 180 minutes.

[14]NG operates under several different brand names and formats. We confine attention to the following eight formats: Spar Market, Spar Supermarket, Eurospar; Kiwi Minipris and Kiwi XL; Meny Basis, Meny Gourmet and Meny Pluss.

where, for each product, the average of the EU 15 (countries belonging to the EU prior to the Eastern expansion from 2004 onwards) is set to 100. In 2015 the differences between the Norwegian and the Swedish price for a good are thus set equal to the difference in the price level index for that year, and the developments over the years in national currency are given by the respective COICOP index. The respective Swedish COICOP price is then translated into NOK using the average monthly NOK/SEK exchange rate from the central bank of Norway.

The COICOP indices are nationwide. Several of the major Norwegian grocery chains state that they impose uniform nation-wide pricing. We therefore expect that prices will not vary systematically across regions, and that the COICOP index for Norway therefore is representative of the price level of stores both close to and far from the Swedish border. However, to corroborate our expectation that Norwegian prices are uniform across regions, we have computed average monthly prices using data from 2016, for which we have access to transaction level data from a sample of 5% of the members of NG's frequent buyer program.[15] As reported in Table A.1 in the Appendix, we find no evidence of cross-regional variation in these prices.

The price level of Swedish stores close to the Norwegian border might however diverge from the national average. As a robustness exercise we therefore use a price index from Swedish border stores as an alternative measure of Swedish prices. This index is calculated using article-level prices and quantities from 14 grocery stores located close to the Norwegian border and identified as targets for cross-border shopping. All 14 stores belong to Sweden's largest association of retailers ICA. ICA does not impose nation-wide prices, which means that these stores can adjust their prices in response to local demand. We use this data to calculate value-weighted (fixed weights) price indices for the same categories as in the COICOP data. This data is available for the years 2014-2016.

4 Cross-price effects and distance to the border

4.1 A first look at the data

Table 4 presents descriptive statistics for some key variables. Driving distance in minutes to the closest Swedish grocery store ranges from a minimum of 4 minutes to a maximum

[15]In 2017, there were more than 2.4 million members of NG's frequent buyer program accounting for almost fifty percent of the total transactions in the chain. The total population in Norway was 5.3 million in 2017.

close to our cut-off at 180 minutes. Mean driving time for these stores is around 90 minutes. The average NOK/SEK rate is 92.5, but there is substantial variation with the exchange rate ranging from 84 to 103. Average household income is around 470,000 NOK (approximately 58,000 USD in 2015) with considerable variation across municipalities. There are 740 stores in the data in a given month.

Table 4: Descriptive statistics

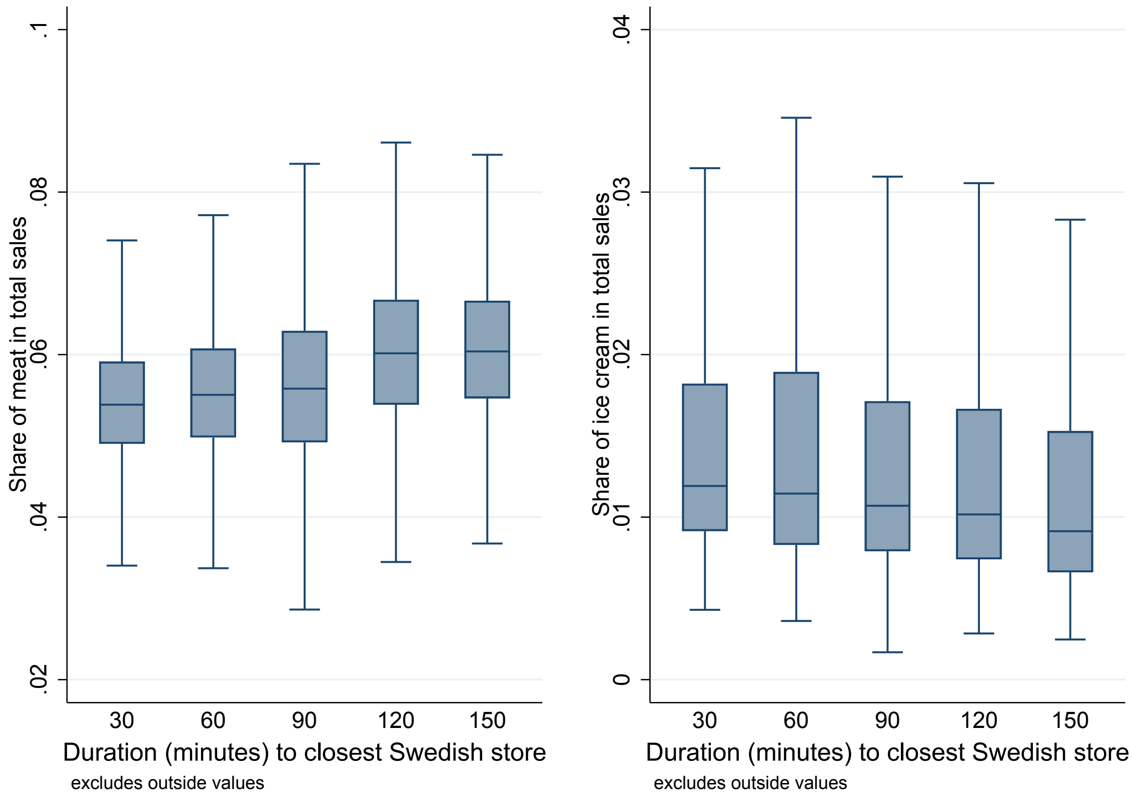
	Mean	Standard deviation	Median	Minimum	Maximum
Duration	90.09	34.28	87.28	4.37	179.38
Exchange rate	92.53	5.09	91.90	84.24	103.14
Median income	472890.58	54977.52	460000	346000	637000
Number of stores	740.00	0.00	740	740	740
Relative prices					
Meat	1.24	0.06	1.22	1.16	1.36
Cheese	1.59	0.09	1.58	1.46	1.77
Soda	1.61	0.03	1.61	1.55	1.68
Sweets	1.13	0.03	1.14	1.04	1.20

Notes: Duration is driving distance in minutes to the closest Swedish store. Exchange rate is nominal exchange rate NOK/SEK and median income is in NOK (real 2015 terms).

The lower panel of Table 4 presents descriptive statistics on the relative prices. A relative price above 1 implies that the Norwegian price is higher than the Swedish price. All observations have a relative price above 1, indicating that for these goods the price is always higher in Norway. The average price level difference ranges from 13% for sweets to around 60% for cheese and soda. Meat has a price difference of on average 24%.

One way to explore the effect of cross-border shopping on local purchases in different locations is to examine the share of sales of e.g. meat in total sales at a store. If Norwegian consumers close to the border cover a substantial part of their meat demand in Sweden the share of meat in total sales should be lower closer to the border. If we instead consider a good that is not suited for cross-border shopping, such as ice cream, we would expect the opposite pattern. As cross-border shopping lowers local demand for many goods these stores should have disproportionately high sales share of non-crossborder goods. The box plots in Figure 5 for average sales shares of meat (left panel) and ice cream (right panel) across different distances support these hypotheses and are consistent with the idea that cross-border shopping affects local sales. The closer to the border, the lower is the share of sales made up by meat and the greater the share of ice cream.

Figure 5: Share of meat and ice cream in total sales in stores across different distances from the nearest Swedish store.



Notes: The figure shows box-plots of store level (belonging to NG as described in the text) share of sales of meat and ice cream over 2011-2016 reported by 30-minute bins to the closest Swedish store. The boxes are bounded by the 25th and 75th percentiles and the horizontal line indicates the median.

4.2 Main analysis

This section uses regression analysis to examine the relation between distance to nearest Swedish store and local sales in Norway. We regress sales in store i in product category j in month t and use the following specification

$$\ln(sales_{ijt}) = \alpha + \sum_{b} \beta_b \ln(P_{njt}/P_{sjt}) \times D_{ib} + \lambda \ln(INC_{it}) + \gamma_t + \kappa_c + \epsilon_{ijt}, \qquad (1)$$

where $\ln(P_{njt}/P_{sjt})$ is the logarithm of the relative price. P_{njt} is the price index in Norway for good j in month t and P_{sjt} is the corresponding index for Sweden. For Swedish price we use two measures, one based on Eurostat indices as explained above and one using prices in Swedish border stores. In both cases the Swedish price is expressed in NOK via the NOK/SEK average monthly exchange rate. The uniform national price policy for the retailer in question (and verification of this policy as reported in A.1 in the appendix) imply that local Norwegian prices will not endogenously respond to local shocks and we rely on exogenous exchange rate shocks to shift relative prices.

To capture potential non-linearities in consumer responses as we move away from the border, we represent the driving duration with 30-minute bins. D_{ib} a dummy variable that equals one if store i is in distance category b, and zero otherwise. We include all stores within 180 minutes' driving distance, giving us six 30-minutes bins. INC_{it} is average household income in the municipality in which the store is located (varies by year). γ_t is a set of month-of-the-year fixed effects to capture cyclical patterns and κ_c are store format fixed effects. Finally, ϵ_{ijt} is an econometric error term that is clustered at the regional level.[16] Equation 1 is estimated separately for each of the product categories of interest.

Column (1) of Table 5 reports results of the estimation of Equation 1 for meat. Across all distances the estimated effect of the relative price is negative and the coefficients are statistically significant at the 1% level up to 120 minutes from the nearest Swedish store. Given that both dependent and explanatory variables are expressed as natural logarithms we may interpret the coefficients as elasticities. Thus for example within 30 minutes' driving distance from closest Swedish store a 1% increase in the Norwegian price relative to the Swedish price is associated with a decrease in local sales of around 1.12%. For distances between 30 and 60 minutes demand becomes more elastic with a point estimate of -1.41 after which it becomes less elastic and tends to around -0.35.

[16]Regions are defined by Statistics Norway's local labor markets. Determining the level of clustering is not obvious (see e.g. Cameron and Miller (2015) for a discussion). Alternatives would be to cluster on the municipal or store level. This would however neglect correlated shocks across municipals and stores facing similar conditions. As the local labor market regions comprise municipals that share local costs and demand conditions our clustering is expected to capture such correlated shocks. There are in total 46 such regions in Norway, whereof 25 are in our sample.

Table 5: Demand regressions

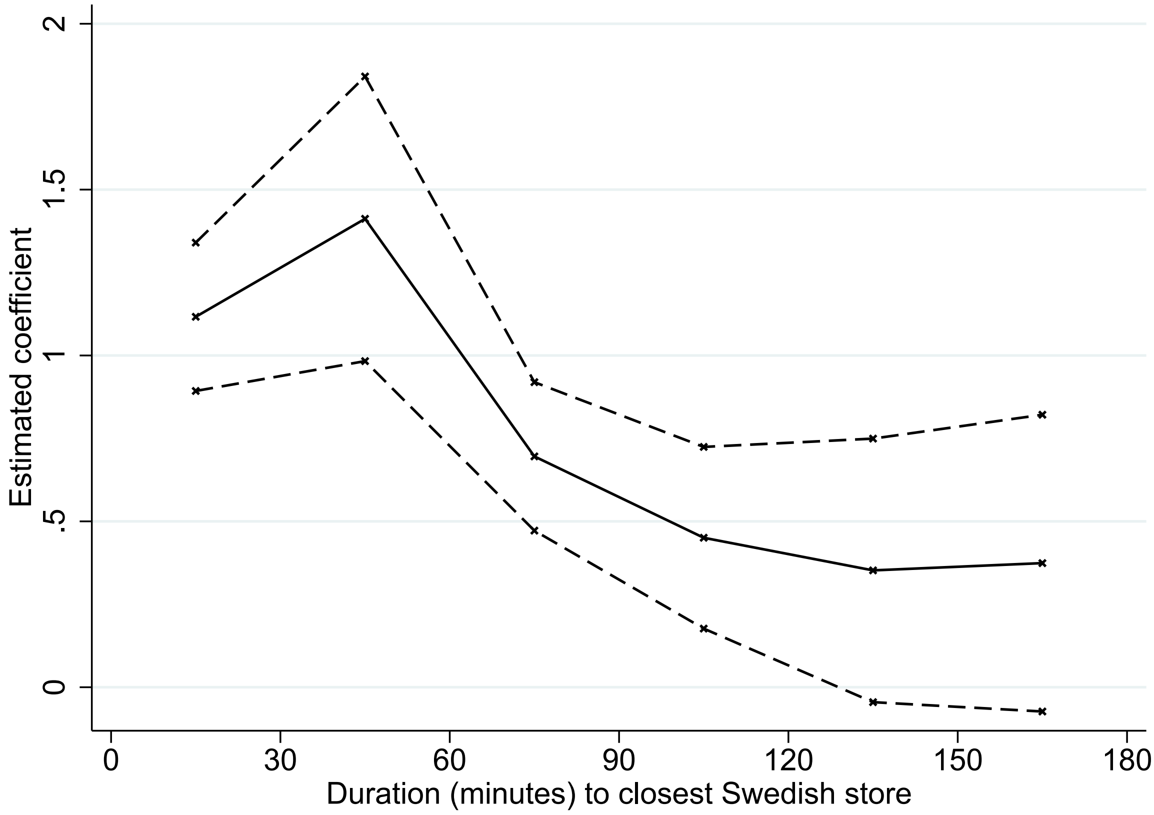
	Meat	Cheese	Soda	Sweets
Duration $<$ 30 $\times$ $\ln(P^N/P^S)$	-1.117***	-0.770***	-2.201***	-0.686***
	(0.108)	(0.081)	(0.177)	(0.192)
30 $<$ Duration $<$ 60 $\times$ $\ln(P^N/P^S)$	-1.412***	-0.918***	-2.322***	-1.287***
	(0.208)	(0.116)	(0.155)	(0.176)
60 $<$ Duration $<$ 90 $\times$ $\ln(P^N/P^S)$	-0.696***	-0.487***	-2.041***	-0.502***
	(0.108)	(0.082)	(0.135)	(0.127)
90 $<$ Duration $<$ 120 $\times$ $\ln(P^N/P^S)$	-0.451***	-0.519***	-1.936***	-0.196
	(0.133)	(0.094)	(0.152)	(0.151)
120 $<$ Duration $<$ 150 $\times$ $\ln(P^N/P^S)$	-0.352*	-0.610***	-1.948***	-0.112
	(0.192)	(0.124)	(0.169)	(0.261)
150 $<$ Duration $<$ 180 $\times$ $\ln(P^N/P^S)$	-0.374*	-0.781***	-2.187***	-0.876**
	(0.217)	(0.109)	(0.174)	(0.334)
Constant	4.900***	5.955***	9.114***	6.858***
	(0.781)	(0.579)	(0.467)	(0.474)
Observations	34389	34389	34392	34391
R^2	0.471	0.439	0.330	0.388
Month number FE	Yes	Yes	Yes	Yes
Store format FE	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes

Notes: This table reports results from an estimation of the model specified in Equation (1). Monthly price indexes are calculated based on COICOP and the sample period is 2011-2016. The standard errors reported in parentheses are clustered at the local labor market level.

* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01.

In Figure 6, we plot the estimated elasticity (absolute value) of local sales of meat against travel time in minutes to the closest Swedish store, where the dashed lines represent the 95 % confidence interval. A clear hump-shape emerges with the greatest sensitivity to relative prices being found some distance inland.

Figure 6: Estimated elasticity of meat sales with respect to relative price (P_N/P_S).



Notes: The figure shows estimated coefficients of the elasticity of meat sales (absolute value) with respect to relative price (P_N/P_S), as a function of driving duration (30-minutes bins to the closest Swedish store). The point estimates are placed at the center of the bins.

Columns (2)-(4) of Table 5 report the corresponding results for cheese, soda and sweets respectively. First note that the qualitative results mirror the demand for meat closely, with a clear hump-shaped relationship between distance and price sensitivity with the greatest sensitivity of sales to relative price between 30 and 60 minutes away from the closest Swedish store. For three out of the four product groups a test of the hypothesis that the coefficient on relative price is the same for the 0-30 minute interval as for the 30-60 minute interval can be rejected at the 5% level of significance, thus confirming the visual pattern.[17]

Second, while all products are sensitive to changes in the relative price between Nor-

[17]When using robust standard errors equality can be rejected at the 1% level of significance for all four product groups (results available on request). Clustering inflates the standard errors and for the case of meat we can't reject the null hypothesis.

way and Sweden, soda stands out as being the most elastic product group. A possible explanation for the high elasticity of soda demand with respect to the relative prices is that it is easier to satisfy the entire demand for soda through personal import than for products like meat and cheese. First, there is no import restrictions on soda, while there is a 10 kilo limit for meat and cheese (combined). In addition, soda is more storable than cheese and meat. These factors can also explain why the hump-shape is less pronounced for soda than for the other products as we move away from the border. Even consumers living relatively far from Sweden can cover much of their demand through infrequent trips across the border. In addition, soda does not deteriorate during transport, which also makes it easier to privately import for consumers living far from the border.

The results thus suggest that the strongest effect on demand is not closest to the border but some distance inland, a result that we will elaborate on in Section 5. Our findings can be related to the study of Chandra et al. (2014) which find average travel costs for Canadian cross-border shoppers of around 30 US dollars per hour. Based on our survey,[18] a Norwegian consumer on average purchases grocery products for SEK 1,390 per trip. With an average price difference of 30% this translates into a break-even point 50 minutes away from the closest Swedish store. Clearly, applying Canadian travel cost estimates to Norway requires a leap of faith. However, if we look at the marginal cost of driving, and a time cost based on median income, we can calculate a rough measure of travel costs based on Norwegian data. Assuming a gasoline price of 12 NOK per liter and an average fuel consumption of 0.08 litres per kilometer, fuel costs are 0.96 NOK per kilometer. In our data the median income is about 473,000 NOK. With an average tax-rate of 27% and full-time yearly working hours of 1,695, the average wage per minute after tax is about 3.4 NOK. With an average speed of 73 kilometers per hour,[19] we get a travel cost equal to 4.56 NOK per minute. With the average cost saving this implies a break-even point of 42 minutes for the average exchange rate and 30 percent price difference.

4.3 Robustness

As seen above the hump-shape is a prominent feature of the data and in the following we explore robustness in some dimensions.

[18] See Section 2.2.

[19] For each store in our data, we have both the driving duration and the driving distance, which allows us to calculate an estimate of the average driving speed from each store to the closest Swedish store. Across the stores in our sample, the average driving speed is around 73 kilometers per hour.

Regional heterogeneity At a general level one may ask whether consumers at different distances from the border are systematically different and whether this might be driving results. To limit such concerns we control for income at the municipal level and we further note that the major population centers in our estimation sample such as the capital Oslo and the third largest city Trondheim are further away than 60 minutes (the second city Bergen is too far away from the border to be in the estimation sample). We have furthermore estimated specifications that also include the municipal share of individuals with university-level education and find that the coefficients of interest are essentially unchanged.[20]

Alternative price indices As discussed and shown in Table A.1 in the Appendix, the evidence does not support the notion that our Norwegian stores differentiate prices according to closeness to Sweden. However, since not all Swedish chains impose uniform national prices, border stores may adapt prices to attract Norwegian customers. Our use of the national COICOP indexes may therefore give a misleading representation of prices in the Swedish stores close to the border. In columns (1)-(4) of Table 6 we therefore use border prices from ICA, as described above, to calculate the relative price. While there are differences in the level of elasticity compared with Table 5, the hump-shaped pattern with the strongest effects 30-60 minutes away from the closest Swedish store remains. For comparison, we also estimate the equivalent of Table 5 on this shorter time period and report results in the appendix in Table A.2. The hump-shaped response is clear also in this specification, with the exception of soda.

In terms of the magnitude of point estimates, a direct comparison between the three models is difficult, given that both the sample size and prices differ between them. For instance, the average level of the exchange rate is significantly higher in 2014-2016 than in 2011-2013 (see Figure 1).

[20] Yearly data on education at the municipal level is provided by Statistics Norway.

Table 6: Demand regressions - prices from ICA

	Meat	Cheese	Soda	Sweets
Duration < 30 × $\ln(P^N/P^S)$	−0.479***	−0.423***	−0.219***	−0.340***
	(0.116)	(0.070)	(0.048)	(0.116)
30 < Duration < 60 × $\ln(P^N/P^S)$	−0.638***	−0.545***	−0.305***	−0.693***
	(0.142)	(0.113)	(0.060)	(0.123)
60 < Duration < 90 × $\ln(P^N/P^S)$	−0.148**	−0.112	−0.052	−0.177**
	(0.054)	(0.069)	(0.052)	(0.065)
90 < Duration < 120 × $\ln(P^N/P^S)$	0.069	−0.116	0.071	0.072
	(0.091)	(0.084)	(0.047)	(0.075)
120 < Duration < 150 × $\ln(P^N/P^S)$	0.122	−0.220*	0.060	0.090
	(0.137)	(0.122)	(0.067)	(0.200)
150 < Duration < 180 × $\ln(P^N/P^S)$	0.091	−0.413***	−0.190**	−0.384*
	(0.140)	(0.102)	(0.089)	(0.201)
Constant	4.859***	5.834***	8.203***	6.627***
	(0.772)	(0.599)	(0.442)	(0.433)
Observations	21166	21166	21168	21167
R^2	0.467	0.432	0.334	0.386
Month number FE	Yes	Yes	Yes	Yes
Store format FE	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes

Notes: This table reports results from a estimation of the model specified in (1). Monthly price indexes are calculated based on COICOP (Norwegian prices) and prices from ICA stores close to the border (Swedish prices). The sample period is 2014-2016. The standard errors reported in parentheses are clustered at the local labor market level.
* p < 0.1, ** p < 0.05, *** p < 0.01.

Alternative distance measure We have used travelling time by the shortest route as our measure of distance, which is particularly appropriate in a mountainous country such as Norway, but this stands in contrast to much of the previous literature which examines distance in kilometers (as the crow flies or by shortest route as in our case). It may therefore be of interest to examine results when using driving distance as well, and, as seen in Table 7, the qualitative results are unchanged.

Table 7: Demand regressions - distance

	Meat	Cheese	Soda	Sweets
Distance < 30 × $\ln(P^N/P^S)$	−1.056***	−0.776***	−2.213***	−0.448
	(0.156)	(0.139)	(0.229)	(0.595)
30 < Distance < 60 × $\ln(P^N/P^S)$	−1.298***	−0.900***	−2.294***	−1.208***
	(0.161)	(0.132)	(0.161)	(0.153)
60 < Distance < 90 × $\ln(P^N/P^S)$	−1.062***	−0.738***	−2.133***	−0.796**
	(0.289)	(0.157)	(0.075)	(0.339)
90 < Distance < 120 × $\ln(P^N/P^S)$	−0.622***	−0.434***	−2.024***	−0.449***
	(0.108)	(0.084)	(0.142)	(0.118)
120 < Distance < 150 × $\ln(P^N/P^S)$	−0.491**	−0.591***	−1.912***	−0.209
	(0.220)	(0.083)	(0.191)	(0.187)
150 < Distance < 180 × $\ln(P^N/P^S)$	−0.338*	−0.614***	−1.961***	−0.193
	(0.164)	(0.108)	(0.168)	(0.224)
180 < Distance < 240 × $\ln(P^N/P^S)$	0.011	−0.575***	−2.046***	−0.337
	(0.226)	(0.111)	(0.183)	(0.391)
Constant	4.539***	5.650***	8.919***	6.591***
	(0.808)	(0.605)	(0.561)	(0.494)
Observations	34389	34389	34392	34391
R^2	0.472	0.441	0.327	0.386
Month number FE	Yes	Yes	Yes	Yes
Store format FE	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes

Notes: This table reports results from an estimation of a model similar to the one specified in (1), but where stores are grouped by driving distance rather than driving duration. Monthly price indexes are calculated based on COICOP and the sample period is 2011-2016. The standard errors reported in parentheses are clustered at the local labor market level.

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

Imposing a linear distance measure A likely important reason why the hump-shaped pattern that we report has not been established before is that the previous literature uses parametric specifications where distance is linearly interacted with relative price (as in e.g. Baggs et al. (2016). Sometimes higher order terms of distance are also included as in Asplund et al. (2007)). A linear specification masks the hump-shaped pattern and for comparison we report the results from a linear specification in Table 8. The result that the sensitivity of demand to the relative price decreases as we get further from the border is clearly seen in this specification as well. To interpret coefficients we may exemplify with meat, at the border the elasticity with respect to the relative price is -1.54, and 100 kilometers inland it is estimated to be -0.78. We also note that (absolute) elasticity is decreasing fastest for meat, which is intuitive given that this product is likely to deteriorate more quickly under transport than the other products.

Table 8: Demand regressions: Linear distance

	Meat	Cheese	Soda	Sweets
$\ln(P^N/P^S)$	−1.540***	−0.780***	−2.266***	−1.172***
	(0.265)	(0.150)	(0.118)	(0.351)
$\ln(P^N/P^S)\times$ Distance	0.008***	0.002	0.002***	0.006**
	(0.002)	(0.001)	(0.001)	(0.003)
Constant	4.888***	5.456***	8.605***	6.600***
	(0.583)	(0.702)	(0.545)	(0.485)
Observations	34389	34389	34392	34391
R^2	0.471	0.429	0.323	0.384
Month number FE	Yes	Yes	Yes	Yes
Store format FE	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes

Notes: This table reports results from an estimation of a similar model to the one specified in (1), but where the price effect is interacted with a linear distance term, rather than duration group dummies. Monthly price indexes are calculated based on COICOP and the sample period is 2011-2016. The standard errors reported in parentheses are clustered at the local labor market level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

5 Intensive and extensive margins and the hump shape

As seen, the estimated response to a relative price change is strongest at intermediate travel times from Swedish stores. A common use of estimated cross-price elasticities is to determine how close substitutes two products are, and to take a higher estimated cross-price elasticity as a sign that the two products are closer substitutes. Duration of travel between two locations is a typical example of product differentiation and hence we are faced with what might appear as a puzzle. To solve the puzzle we note that demand responses in grocery stores will be governed by both the intensive margin (a continuing consumer adjusting their volume in response to price changes) and the extensive margin (changes in the set of consumers who shop at a given store).

5.1 Intensive and extensive margins

Models of continuous demand ((see e.g. Bowley, 1924; Singh, 1984; Amir et al., 2017)) are well-suited to capture the intensive margin whereas models in the Hotelling tradition are natural candidates to capture the extensive margin.

We would therefore like to consider choice in a model that combines the extensive margin of Hotelling-type models with continuous demand for differentiated products. Such models have been proposed and analyzed theoretically in e.g. Stahl (1982) and Rath and Zhao (2001) as well as having formed the basis for structural econometric estimation in e.g. Thomassen et al. (2017). These models feature both an extensive (attracting consumers) and an intensive (consumers buy more) margin in response to price changes. However, the implication that demand responses to price changes can be hump-shaped with respect to distance has not been spelled out in this literature previously. A likely reason is that, as noted by Rath and Zhao (2001, p. 1443), " ...even though one starts with very basic and simplified premises (linear demand for consumers, etc.) the model becomes analytically quite complicated in no time." For instance, they are not able to solve for equilibrium prices.[21]

Chandra et al. (2014), Chen et al. (2017) and Baggs et al. (2018) also model the decision of consumers to shop across the border and allow for intensive and extensive margins of trade.[22] Again however, the implication that demand responses to price changes can be hump-shaped with respect to distance has not been noted. One reason for this may be the complexity of models that include both an intensive and an extensive margin. Another reason may be that the empirical puzzle only emerges with a rich data set that allows estimation of non-monotonic patterns.

To provide intuition, consider a simple stylized setting with consumers spread along

[21] A recent literature in international trade also examines interactions between travel costs on the one hand and intensive and extensive margins of trade on the other hand (see e.g. Chaney (2008)) but the hump-shape of demand responses in distance has not been noted in this literature either.

[22] These are all rich combinations of theory and empirical work that examine cross-border shopping from Canada into U.S. In the model of Chandra et al. (2014) an important margin of adjustment is that exchange rate changes affect the set of products that are attractive to shop across the border. Their empirical implementation examines cross-border travel rather than the effect on local sales however. Chen et al. (2017) develop a similar model and also consider local sales, showing that Canadian retail sales are affected by changes in the exchange rate vis-à-vis U.S. dollars and that effects decrease with distance. Their regressions include (the log of) distance linearly however which precludes an analysis of the hump-shaped patterns that interest us here. Baggs et al. (2018) incorporate a model of search into a similar framework as the previous two articles and use it to e.g. simulate the effects of trade policy shocks. They do report effects on stores at different intervals from the border (8, 50 and 100 kilometers) but no hump-shaped pattern emerges, or is discussed.

a line in the tradition of Hotelling (1929). Assume that a differentiated product may be purchased at endpoint of the line which is just across the border in country S or locally in N. Consumers face travel costs that increase in distance d to S. At each location there is a unit mass of consumers of which a share ω only shop locally and a share $(1-\omega)$ travel to Sweden to shop. For simplicity assume that all consumers at location d have the same demand conditional on shopping locally, they differ however in their fixed cost of cross-border travel and hence some may shop locally whereas others travel to Sweden. Both demand and the share shopping locally depend on own price (p_N) and the price of the substitute (p_S) and the share shopping locally in addition depends on the distribution of fixed costs ($F(\cdot)$). Denote local demand in location d by

$$Q_d(p_N, p_S, F(\cdot)) = q_d(p_N, p_S) \times \omega(p_N, p_S, F(\cdot)) \tag{2}$$

Partially differentiating local demand with respect to the price of the substitute yields[23]

$$\frac{\delta Q_d(p_N, p_S)}{\delta p_S} = \underbrace{\frac{\delta q_d(p_N, p_S)}{\delta p_S} \times \omega(p_N, p_S, F(\cdot))}_{\text{Intensive margin}} + \underbrace{q_d(p_N, p_S) \times \frac{\delta \omega(p_N, p_S, F(\cdot))}{\delta p_S}}_{\text{Extensive margin}} \tag{3}$$

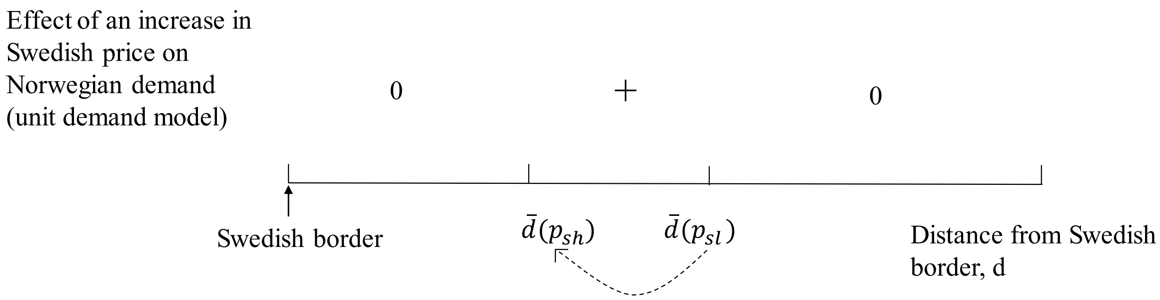
If both terms are positive a positive cross-price effect is assured. Closer substitutes are associated with higher individual cross-price effects ($\delta q/\delta p_S$) but the aggregate cross-price effect is also determined by the extensive margin which may well be having its main impact some distance inland.

The intuition for this is most easily seen in a simple Hotelling model with unit demand and no fixed cost of travel. With a lower price of the good in Sweden, all Norwegian consumers located very close to Swedish stores will buy it in Sweden, and as we move along the line distance and travel costs increase up to the point where we reach the marginal consumer who is indifferent between traveling to Sweden and purchasing the good in Norway. An increase in the price in Sweden from p_{sl} to p_{sh} because of an (exogenous) depreciation of the Norwegian currency would then shift the location of the indifferent consumer (denoted by $\bar{d}$) closer to the border. As the location of the indifferent

[23]To focus on intuition we take the partial differential and thus refrain from the full comparative statics exercise where we also allow local prices to respond. This is in line with the national pricing policy of the retailer in question and has the benefit of avoiding algebraic clutter that would obscure the logic of intensive and extensive margins.

consumer shifts closer to the border we would thus expect the demand pattern indicated in Figure 7. Close to the border there would be no extensive margin as Sweden is still cheaper and far away the extensive margin is also mute as Norway always offers more attractive prices net of travel costs. The greatest sensitivity of demand naturally occurs inland where the marginal consumer resides.

Figure 7: A Swedish price increase in a Hotelling model.



A full model with endogenous prices that allows for both an intensive and extensive margin rapidly becomes unwieldy and analytic results are hard to come by - instead we in the next turn to a calibration exercise to examine the cross-price effects. We essentially adopt a simple structure that allows us to numerically examine the kind of broad intuition that is captured in Equation 3.

5.2 Combining Hotelling with continuous demand

Use q_{Si} and q_{Ni} to denote demand for each of two products from individual i. Following (Bowley, 1924; Singh, 1984) we assume that each individual has the utility function below where m denotes consumption of other goods (at a price normalized to 1), where a and b are given parameters and where $\theta \in [0, 1]$ captures the degree of product differentiation. If θ equals 0 products are independent and as θ approaches 1 products tend to perfect substitutes.

$$U(q_{Si}, q_{Ni}) = a(q_{Si} + q_{Ni}) - 0.5b(q_{Si}^2 + 2\theta q_{Si}q_{Ni} + q_{Si}^2) + m \tag{4}$$

With the exception that we keep track of individuals i, this is a standard formulation of differentiated product demand for a representative consumer (see e.g. Martin (2002, p. 52-54), Belleflamme and Peitz (2015, p. 65-67), Vives (2001, p. 144-147)) and which yields linear demand functions. We think of the product differentiation parameter θ as capturing differences in the physical good, branding and in shopping experience between a store in S selling good S and the local store in N which sells the N version of the differentiated product.

We combine this linear-quadratic utility function with a Hotelling-style setting where consumers are located along a line, face distance d_i to S and incur a travel cost of t per unit of distance. As depicted in Figure 7, we consider a case where good S is only sold by a retailer S located at the endpoint of a line, and that a mass of consumers are distributed at discrete intervals along this line at successively greater distance from S. Good N is always bought locally and the distance associated with purchasing a good locally in N is normalized to 0. We thus combine key elements from the perhaps two most common ways of modeling product differentiation in teaching and in applications.[24]

Assume also that individuals face a fixed (pecuniary) cost F_i of traveling to S, which varies across individuals. Posted prices only differ across countries and are denoted by p_S and p_N respectively but delivered price for the S good will depend on travel costs and the distance traveled. Maximization of utility with respect to quantities subject to the budget constraint will then yield the following linear demand functions for consumer i:

$$
\begin{aligned}
q_{Si} &= \frac{(1-\theta)a - (p_{Si} + distance \times t) + \theta p_{Ni}}{(1-\theta^2)b} \\
q_{Ni} &= \frac{(1-\theta)a - p_{Ni} + \theta(p_{Si} + distance \times t)}{(1-\theta^2)b}
\end{aligned}
\tag{5}
$$

where the only non-standard feature is that the relevant price for good S depends on distance and travel costs. The fixed cost of cross border travel play an important role in the model and if they are high enough for a given consumer she will only purchase good N. To find the quantity q_{Ni}^{ncb} that such a consumer buys (where *ncb* denotes "no cross-border") note that she would maximize utility subject to her budget constraint where utility is given by

$$
U(q_{Ni}^{ncb}) = aq_{Ni}^{ncb} - 0.5bq_{Ni}^{ncb2} + m \tag{6}
$$

leading to demand $q_{Ni}^{ncb} = a/b - p_N/b$.

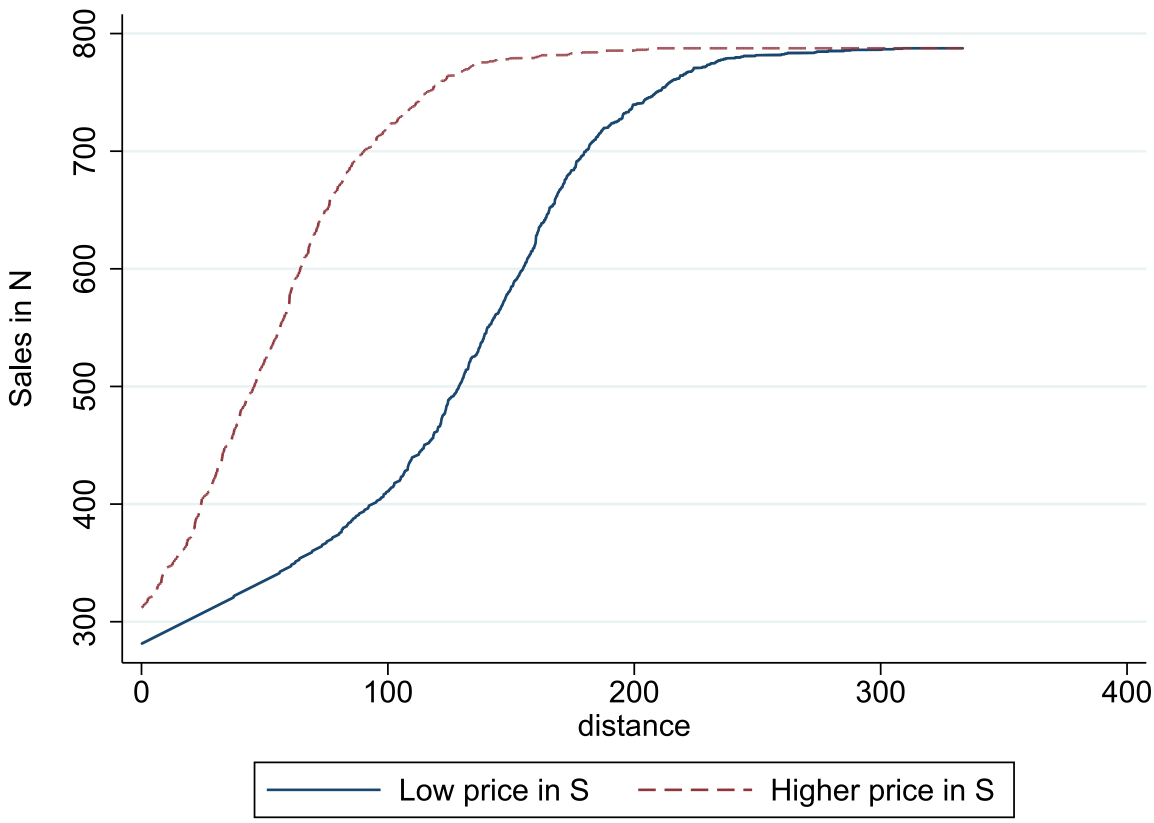
The decision of whether to only purchase good N locally or to also travel to S to purchase some of the differentiated product hinges upon the differences in prices as well

[24]For Hotelling treatments see e.g. Martin (2002, p. 84-94), Belleflamme and Peitz (2015, p. 113-120) or Tirole (1988, p. 279-282).

as on travel costs and on the distribution of fixed costs.

To illustrate the mechanisms we consider a simple numerical illustration. Let distance be discrete and assume that there are 450 consumers located at each distance and assume that fixed costs in each location are drawn from a normal distribution. In the parameterization that we consider $m = 100$, $a = 15$, $b = 4$, $\theta = 0.6$ $t = 0.01$, distance increases in increments of $1/6$, $p_S = 6$ and $p_N = 8$. To consider cross-price effects from a change of p_S on q_N we examine a price increase in S to $p_S = 7$. Fixed costs at each distance are assumed to be drawn from a normal distribution with mean of 2 and standard deviation of 0.5. Figure 8 graphs the relation between sales in N and distance to S for these parameter values and for these two price levels of good S.

Figure 8: Sales in N of good 1 and distance to S at two different price levels in S.



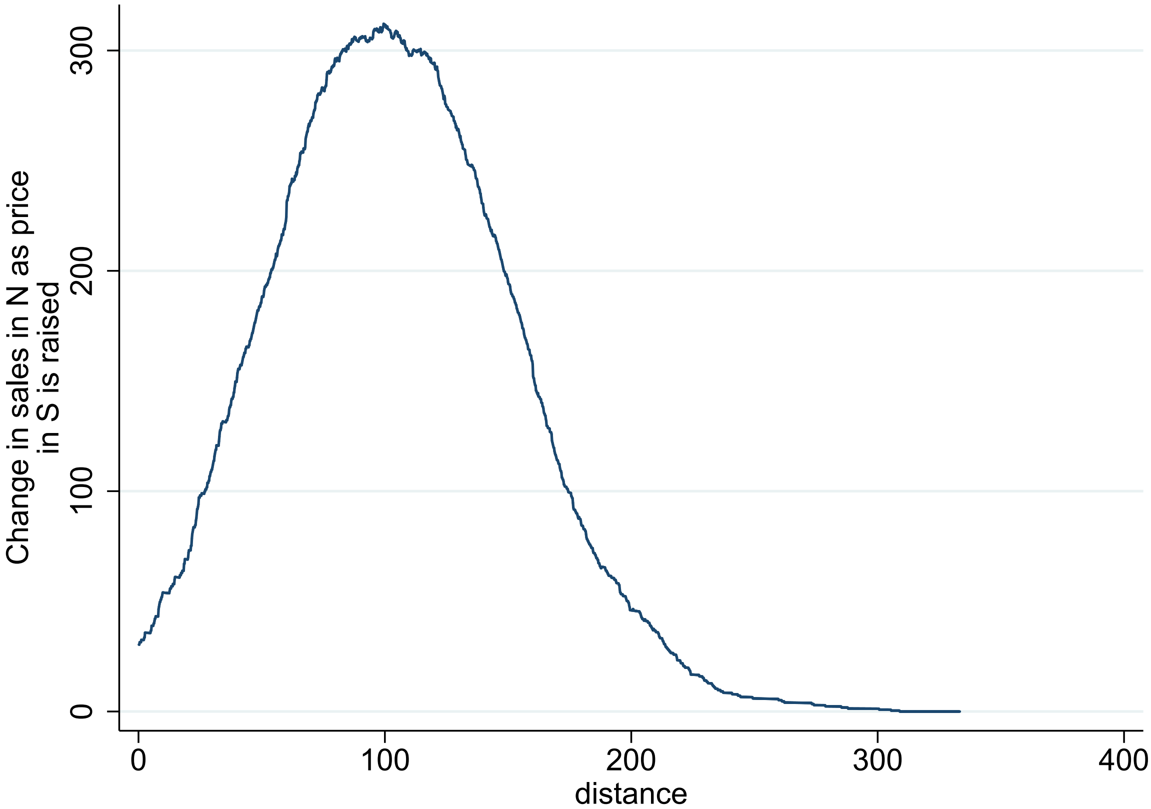
Notes: The graph shows sales volume of good N at different distances from the border (location of good S) as described in text. Parameter values in calibration: $m = 100$, $a = 15$, $b = 4$, $\theta = 0.6$ $t = 0.01$, distance increases in increments of $1/6$, "low price" of $p_S = 6$ and "higher price" of $p_S = 7$. $p_N = 8$. Fixed costs at each distance are assumed to be drawn from a normal distribution with mean of 2 and standard deviation of 0.5.

For both price levels we see that the further a location is from the border, the greater the level of local sales. Consumers at each location have the same preferences, and the same set of draws from the fixed costs of cross-border travel are applied at each location, only delivered prices of good S differ, as they are increasing in the distance from S. Also note that local sales are independent of distance to the border when we consider locations sufficiently inland. This reflects that the price difference is not sufficiently large to warrant the travel costs associated with traveling to S for anyone at these relative prices. Patterns also line up with the evidence presented in Figure 5, that the share of meat in total store sales decreased the closer we were to the Swedish border.

Figure 9 graphs the relation between the *change* in sales in N and distance for an increase in the price of good S, thus simply tracing out the difference between the two lines in Figure 8. A clear hump-shape is seen. Demand in N increases across all distances for which cross-border shopping is relevant as a higher price of S increases demand for good N. Two channels generate the increase: an intensive margin where consumers who continue to purchase both goods will partly substitute away from S to N in response to higher prices of S. The other channel is the extensive margin where some consumers will not find it worthwhile to travel to S at the new higher price in S and thus increase their consumption in N, letting demand for N be governed by Equation 6 rather than by the system of Equations 5. As price in S increases, consumers with relatively high fixed travel costs will be staying home, and this effect is most pronounced at intermediate distances.

This simple exercise shows how a strong effect away from the border arises naturally with a combination of fixed and distance-related travel costs. This pattern of a hump-shaped relationship between the cross-price effect on local demand and distance clearly lines up well with the patterns found in e.g. Table 5 and illustrated in Figure 6.

Figure 9: Change in sales in N in response to a price change of good S and distance to S.



Notes: The graph shows the change in volume of good N at different distances from the border (location of good S) as p_S increases from 6 to 7. Parameter values in calibration (as described in text): $m = 100$, $a = 15$, $b = 4$, $\theta = 0.6$ $t = 0.01$, distance increases in increments of $1/6$ and $p_N = 8$. Fixed costs at each distance are assumed to be drawn from a normal distribution with mean of 2 and standard deviation of 0.5.

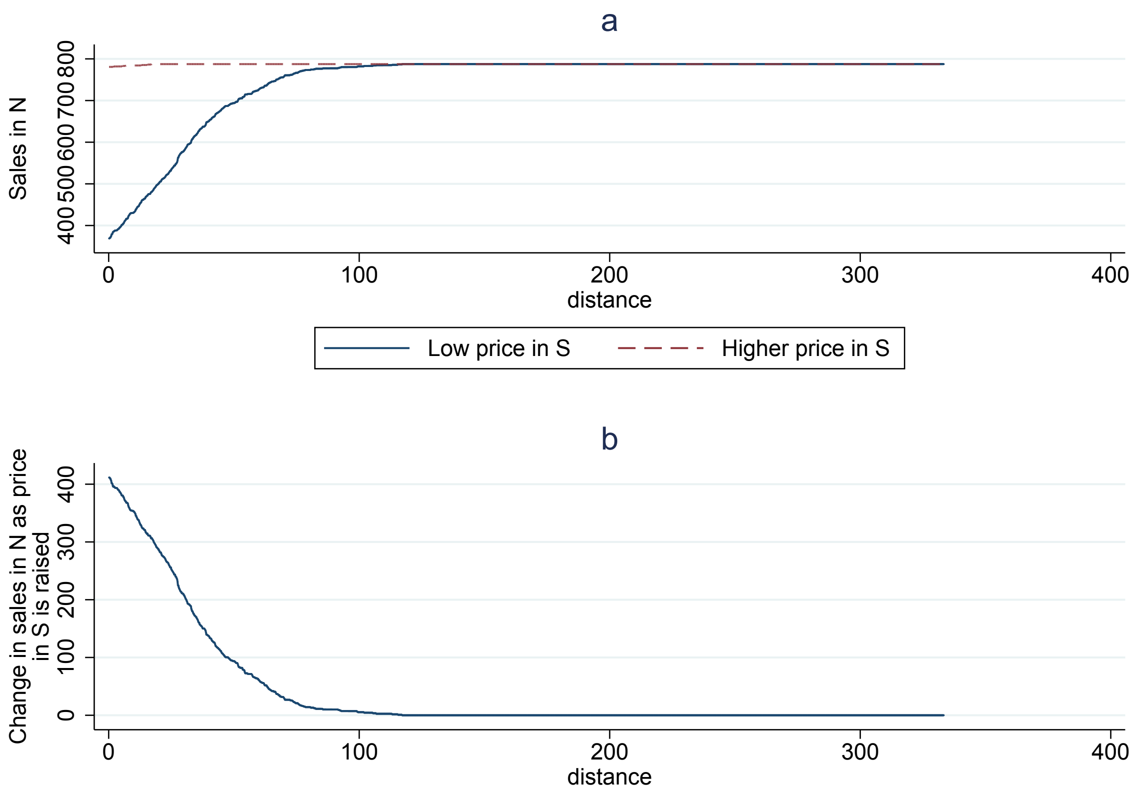
We have purposefully kept the discussion rather simple and combined two very standard models to highlight the intuitive relations between individual-level and aggregate cross-price effects. The assumption of P_N being the same across all locations matches the situation in the Norwegian grocery market but more generally can be thought of as capturing uniform pricing at the grocery chain level or a situation where there is strong competition at each location in N and prices largely determined by wholesale prices that are the same across a country or region.[25]

[25]See Gopinath et al. (2011) for evidence on wholesale prices as a dominant source for price effects of the Canada-U.S. border. In the calibrations we simply assume a set of prices rather than make assumptions that would allow us to explicitly solve for equilibrium prices under some chain/wholesale

The exact nature of results will depend on the full set of assumptions regarding functional forms and the nature of fixed costs. Clearly the result that a hump-shaped cross-price effect can emerge does not imply that it will under all parameter values. Many combinations of parameter values yield the pattern that cross-price effects diminish monotonically as we get further away from the border. Panel a of Figure 10 shows the case where all parameters are as in Figures (8) and (9) apart from that the average fixed cost has been raised from 2 to 4 (but the standard deviation of the random draws is kept the same). The higher fixed costs imply that the effect of cross-border travel on local demand dies off much more quickly. Panel b of 10 shows the demand response in N to an increased price in S. With the high fixed cost relative to (delivered) price differential the extensive margin bites already close to the border and we see the "standard" result where cross-price effects are weaker the further away from foreign stores that we come.

cost/information about fixed cost structure. As discussed above such pricing games are likely to be very hard to solve for but we believe that this does not preclude an interest in demand responses to exogenous price changes. Even so we may note that the calibrations use prices that are close to what the parameter values chosen would imply for a Bertrand equilibrium price for a price setting duopoly in the standard representative consumer case of competition between S and one firm located in N if both firms had constant and equal marginal costs of 0.25 (which yield a price of around 6).

Figure 10: Change in sales in N in response to a price change of good S and distance to S for a case of high average fixed costs of cross-border shopping.



Notes: Panel a shows sales volume of good N at different distances from the border (location of good S) as described in text. Parameter values in calibration: $m = 100$, $a = 15$, $b = 4$, $\theta = 0.6$ $t = 0.01$, distance increases in increments of 1/6, "low price" of $p_S = 6$ and "higher price" of $p_S = 7$. $p_N = 8$. Fixed costs at each distance are assumed to be drawn from a normal distribution with mean of 4 and standard deviation of 0.5. Panel b plots the difference between the two curves in a.

The objective of this section has been to show that a hump-shaped cross-price pattern can emerge as a result of the extensive margin, and to provide intuition for when such a pattern will emerge. Based on the discussion above, and confirmed by experimentation with different parameter values, a hump-shaped pattern is especially likely to appear when fixed costs are relatively low in relation to the difference in delivered prices. In such a case, the extensive margin bites some distance away from the border. If fixed costs in addition have relatively low dispersion then many will be affected in a relatively narrow region and and a hump-shaped pattern is especially likely to emerge. As documented by the survey, with large shares of cross-border shoppers in Norway, and the simple calculations of savings that indicate a break-even a substantial distance away from the border, groceries in Norway is a case where such conditions for a hump-shaped cross-price effect are in place.

Finally one may note that we assumed that the fixed costs of cross-border travel are drawn from a normal distribution. One might wonder whether this distributional assumption is not solely responsible for generating the hump-shaped cross-price effect. To show that this is not the case we redo the calibrations with the same values as above but instead assume that fixed costs are drawn from a uniform distribution. The results shown in Appendix A.5 makes it clear that a normal distribution is not necessary to generate the hump-shaped cross-price effect.

6 Concluding comments

In conclusion, let us highlight three findings from the present study and briefly discuss their implications. First, while a number of previous articles have examined the impact of cross-border shopping on prices and local demand, the previous literature has overwhelmingly focused on goods subject to "sin taxes", such as cigarettes and alcoholic beverages. There is plenty of anecdotal evidence that cross-border shopping of groceries is an important phenomenon in several locations,[26] and a few studies of cross-border grocery shopping use more aggregate data to establish an effect on local grocery purchases of cross-border shopping.[27] To the best of our knowledge this is the first article to use a comprehensive store and category level data set to examine the effect of cross-border grocery shopping. The finding that effect stretch several hours away from the border should be of interest in particular for understanding grocery demand for other high-priced grocery locations.

A second related contribution regards market delineation and competitive effects in grocery retailing. It is typically found that competition in retail grocery markets is highly localized: for instance Ellickson and Grieco (2013) find that the effect of Wal-Mart entry on local supermarkets is confined to competitors within a two-mile radius. Similarly, in their study of a French supermarket merger, Allain et al. (2017) find that a

[26]See e.g. New York Times, December 18, 2008 "A Northern Ireland Town Is a Shoppers' Paradise" which notes that Irish consumers from as far away as Galway, four hours from the Northern Ireland shopping centers, travel to benefit from low grocery prices.

[27]Tosun and Skidmore (2007), for instance use overall per capita food expenditure at the county level to examine differential responses across West Virginia to an increase in the sales tax on food, see also Walsh and Jones (1988) for related evidence on an earlier West Virginia change in sales tax.

market definition of 30 km radius for hypermarkets and 15 km radius for supermarkets is too wide. Using transaction-level credit card data Agarwal et al. (2017) establish that food purchases overwhelmingly are made in stores less than 20 km from home. Clearly the extent to which consumers are willing to travel and stock-pile depends on price differences, and, as illustrated in Table 1, price differences between Sweden and Norway are large. Thus, while a narrow market definition for grocery competition is likely to remain the benchmark, the current evidence emphasizes that when price differences are large, substantial shares of consumers may be willing to travel (very) long distances.

A third contribution, which we find particularly exciting, is showing that a combination of extensive and intensive margins may make cross-price effects hump-shaped in distance. This is found empirically, and we use a simple theory-based discussion to show how a combination of extensive and intensive margins can lead to this outcome. The key insight is that while all consumers are likely to purchase less from any supplier as that supplier's price increases, the marginal consumer, who instead fully switches to another supplier, will be located some distance away. To see why this has not been examined before, we must remember that, as mentioned in the introduction, theory overwhelmingly models product differentiation either via unit demand and transport costs or via representative consumer continuous-demand models. Empirical work on product differentiation also largely follows the same split - either applying discrete choice models as in Berry et al. (1995) or estimating demand systems where quantities depend (linearly) on prices (Deaton and Muellbauer (1980)). In consequence, the combined effects of the intensive and extensive margins on demand have not been in the spotlight.

Several previous theoretical models have combined Hotelling-style transport costs with continuous demand, but such models tend to be complex and the conclusion that cross-price demand can be hump-shaped due to a combination of extensive and intensive margins has, to the best of our knowledge, not been highlighted before. A somewhat related finding is derived in Kolay and Tyagi (2018) who examine a Hotelling duopoly where one of the products has a higher quality. In a calibration exercise they show that when transport costs are quadratic in distance, the cross-price elasticity of the higher quality product can be hump-shaped, i.e., first increase and then decrease, as the degree of horizontal product differentiation increases. The notion that higher cross-price elasticities are a natural sign of less differentiated products is deeply ingrained in economic practice and has been relied on for instance in merger practice (see Kolay and Tyagi (2018) for an extended discussion and references). We believe that this intuition is likely to remain highly useful also in the future, but we hope that the current research will help spur further examinations of the combined effects of how much each consumer purchases and the set of consumers that choose a particular supplier. In our study, product differentiation in geographic space is easy to measure, but it would also be interesting to study the potential for these interactions in the product space.

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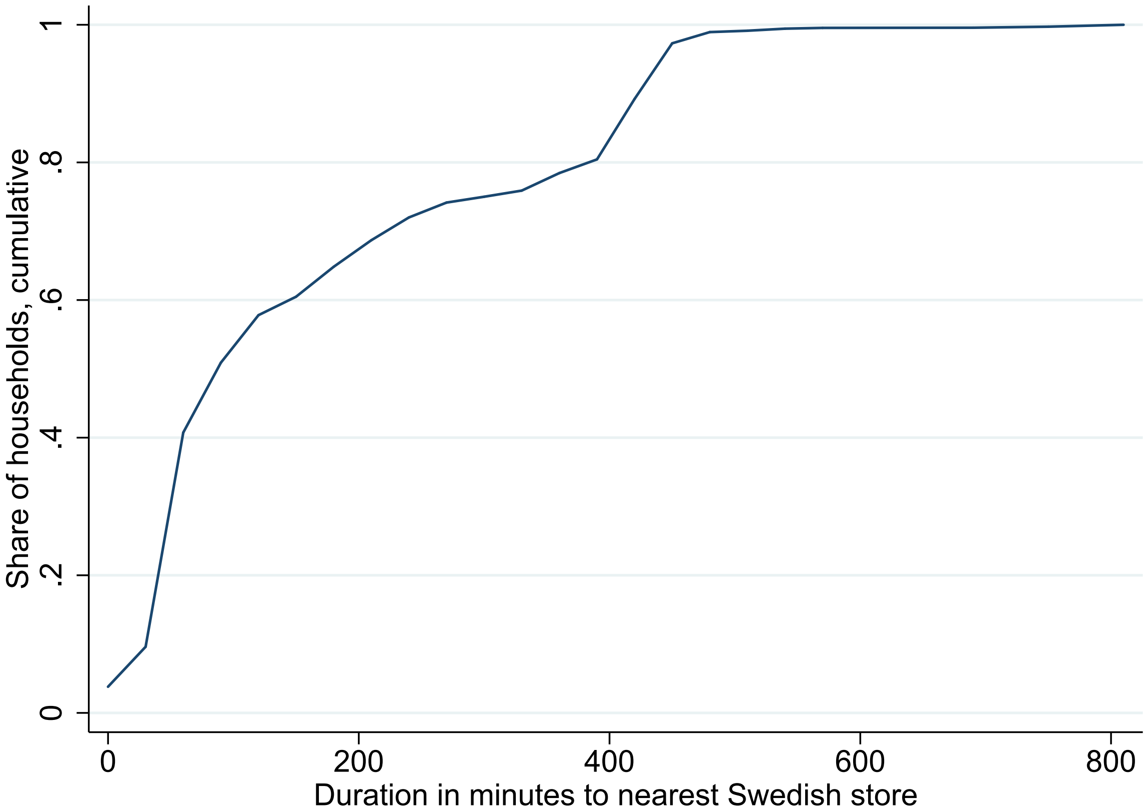
A Appendix

A.1 Cumulative distribution of Norwegian population by driving duration to nearest Swedish grocery store.

Figure A.1: Cumulative distribution of driving duration to nearest Swedish grocery store.



A.2 Cross-regional variation in Norwegian prices

In the empirical analysis we have used a national price index to measure the price level in Norwegian stores. A possible concern is that there could be regional price differences that are not accounted for when we use such a national price index. In particular, one might expect that prices in stores close to Sweden would be systematically different from prices further from the border. On the other hand, anecdotal evidence suggests that Norwegian grocery chains to a large degree impose uniform national prices.

To provide some empirical evidence on this question, we have obtained transaction level data from a random sample of the members of NG's frequent buyer program for the year 2016. We have used this data to compute average prices at the product level for different chains and regions (defined by the same bins of driving duration to Sweden as in the main analysis). We use products from the same categories as in the main analysis (meat, cheese, soda and sweets) and keep only products for which we have observations in all months in all of the chain-region pairs. We then regress the logarithm of the price on month, chain, and region dummies. As reported in Table A.1, there is no indication that prices vary with the distance to Sweden.

Table A.1: Cross-region variation in Norwegian prices

	ln(Price)
30 < Duration < 60	0.00029
	(0.00723)
60 < Duration < 90	0.00012
	(0.00733)
90 < Duration < 120	0.00048
	(0.00731)
120 < Duration < 150	0.00072
	(0.00724)
150 < Duration < 180	0.00182
	(0.00702)
Constant	3.20581***
	(0.00692)
Joint test duration groups (p-value)	0.99986
Observations	3888
Number of products	18
Month FE	Yes
Chain FE	Yes
EAN number FE	Yes

Notes: The dependent variable is the natural logarithm of the average monthly price at the region-chain level. We use data from three different chains within the NG umbrella. The eight chain formats used in the main analysis are nested within these three chains. The sample period is the year 2016. Clustered standard errors are reported in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A.3 Regression with short period and COICOP data

Table A.2: COICOP – short period

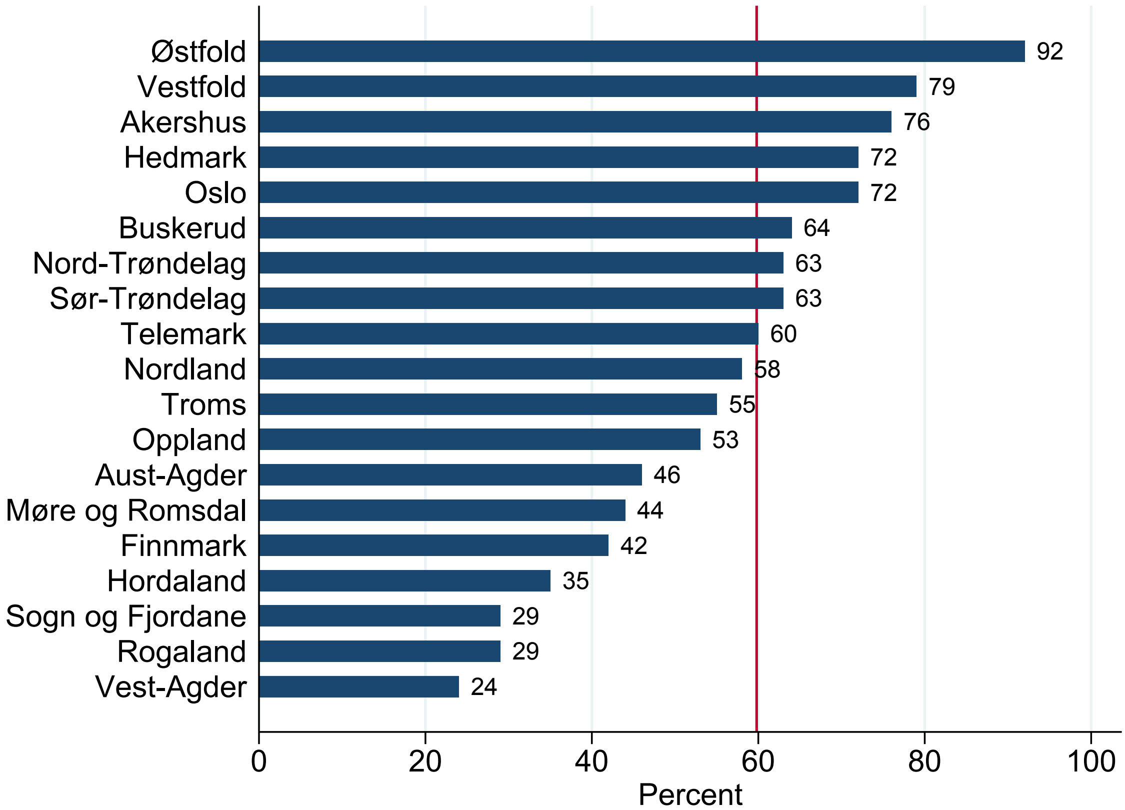
	Meat	Cheese	Soda	Sweets
Duration < 30 × $\ln(P^N/P^S)$	−1.541***	−0.784***	0.048	−1.457***
	(0.172)	(0.169)	(0.228)	(0.240)
30 < Duration < 60 × $\ln(P^N/P^S)$	−1.730***	−0.914***	−0.042	−1.962***
	(0.293)	(0.224)	(0.201)	(0.197)
60 < Duration < 90 × $\ln(P^N/P^S)$	−0.982***	−0.452**	0.243	−1.075***
	(0.179)	(0.182)	(0.193)	(0.114)
90 < Duration < 120 × $\ln(P^N/P^S)$	−0.608***	−0.456**	0.379*	−0.666***
	(0.214)	(0.183)	(0.218)	(0.139)
120 < Duration < 150 × $\ln(P^N/P^S)$	−0.496*	−0.565**	0.368	−0.604*
	(0.267)	(0.203)	(0.224)	(0.332)
150 < Duration < 180 × $\ln(P^N/P^S)$	−0.528*	−0.770***	0.080	−1.461***
	(0.274)	(0.204)	(0.234)	(0.341)
Constant	4.968***	5.961***	8.081***	6.777***
	(0.798)	(0.609)	(0.485)	(0.424)
Observations	21166	21166	21168	21167
R^2	0.470	0.432	0.335	0.389
Month number FE	Yes	Yes	Yes	Yes
Store format FE	Yes	Yes	Yes	Yes
Income	Yes	Yes	Yes	Yes

Notes: This table reports results from an estimation of the model specified in Equation 1. Monthly price indexes are calculated based on COICOP and the sample period is 2014-2016. The standard errors reported in parentheses are clustered at the municipality level.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

A.4 Share of border shoppers by Norwegian regions

Figure A.2: Share of border shoppers

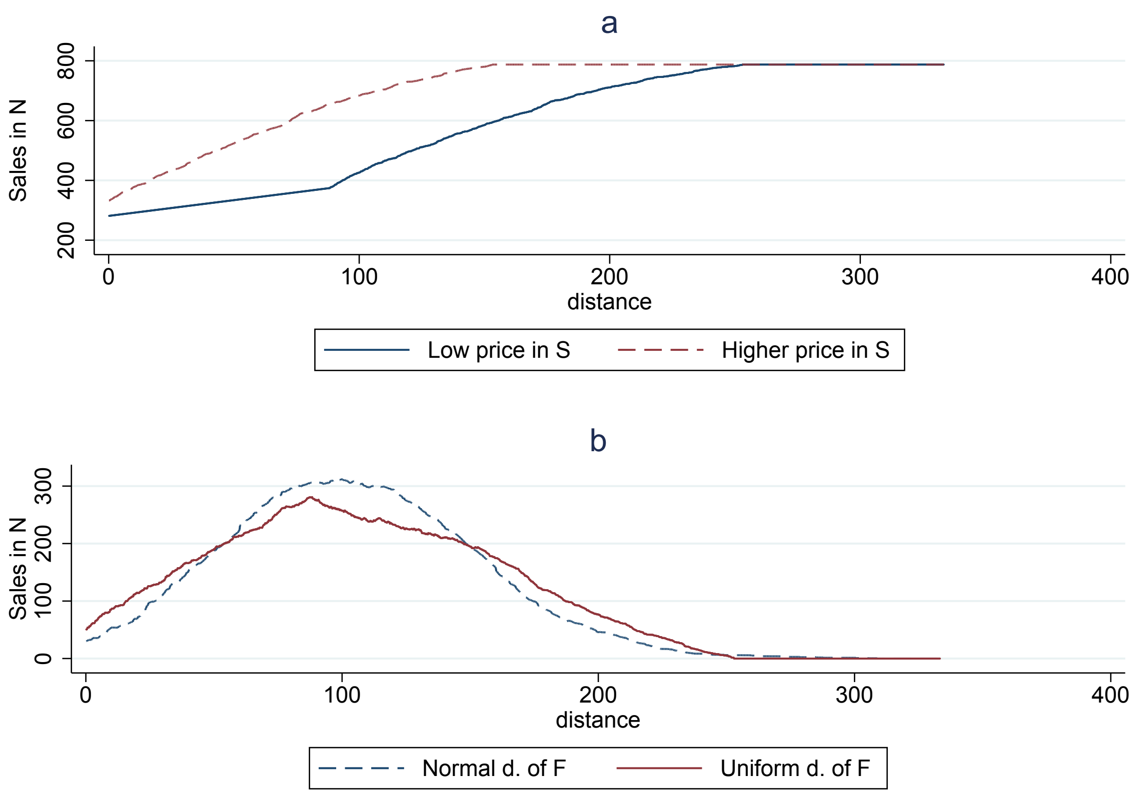


Note: The figure shows the county-level proportions of the population that have shopped groceries in Sweden during the last 12 months. The red line indicates the national average of 59 %. Numbers based on survey responses from Norwegian respondents. Survey undertaken 22-27 February 2018, n=1009.

A.5 Uniformly distributed fixed travel cost

One may note that we assumed that the fixed costs of cross-border travel are drawn from a normal distribution. With the bulk of individuals concentrated around the mean one might wonder if this distributional assumption is not solely responsible for generating the hump-shaped cross-price effect. To show that this is not the case we redo the calibrations with the same values as above but instead assume that fixed costs are drawn from a uniform distribution with approximately the same average and standard deviation as the normal distribution considered in Figures 8 and 9 (the uniform distribution bounded by 1 and 3 which clearly has a mean of 2 and a standard deviation of around 0.5). Panel a of Figure A.3 compares the sales in N as a function of distance for the same two levels of P_S as in the benchmark above. The further away from the border, the greater are local sales in N and an increase in P_S is associated with greater sales in N. The solid line in panel b of Figure A.3 traces out the difference between the two lines in panel a and we again note a hump-shaped pattern. For comparison the dashed line plots the benchmark case with normally distributed fixed costs which yields a more marked hump but it is also clear that a normal distribution is not necessary to generate the hump-shaped cross-price effect.

Figure A.3: A closer examination of the role of the distribution of fixed costs and for a hump-shaped demand response



Notes: Panel a shows sales volume of good N at different distances from the border (location of good S) as described in text. Parameter values in calibration: $m = 100$, $a = 15$, $b = 4$, $\theta = 0.6$ $t = 0.01$, distance increases in increments of 1/6, "low price" of $p_S = 6$ and "higher price" of $p_S = 7$. $p_N = 8$. Fixed costs at each distance are assumed to be drawn from a uniform distribution with bounded by 1 and 3. Panel b plots the difference between the two curves in a (solid line) and a comparison with same parameter values but fixed costs drawn from a normal distribution with mean 2 and standard deviation of 0.5.

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