Cross-country price and inflation dispersion: Retail network or national border?*

Teresa Messner
Oesterreichische Nationalbank

Fabio Rumler
Oesterreichische Nationalbank

Georg Strasser
European Central Bank

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Abstract

(Why) do prices and inflation rates differ within the euro area? We study the relevance of a national border for grocery prices in the otherwise homogenous and highly integrated border region of Austria and Germany. Using transaction data on prices and quantities from a large household panel, we compare the prices of identical products within a narrow band along the Austrian-German border. We find large assortment and price differences between these two regions. Even within multinational retail chains the prices of identical products on the two sides of the border differ on average by about 23%. However, these price differences are not very persistent over time indicating little arbitrage gain by undifferentiated cross-border shopping. Ensuing product-level inflation rates differ only for half of the chains between the two countries. The results highlight the importance of the history-dependent evolution of distribution networks and of the structure of sales organisation as a driver of price and inflation heterogeneity.

Keywords: Price discrimination, goods market integration, border effect, cross-border arbitrage, market power

JEL classification: D12, E31, D43, F15, F4

*Corresponding author: Georg Strasser, European Central Bank, 60640 Frankfurt am Main, Germany (E-mail: georg.strasser@ecb.europa.eu).

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1 Introduction

The law of one price (LOP) states that in the absence of (physical or administrative) trade barriers and shipping costs, identical goods in different locations should have the same price. Across countries, however, prices often deviate considerably and persistently from the LOP even if there are no trade barriers.

This is not surprising, as trading across national borders is often complicated by a wide array of trade frictions. National borders often come with differences in regulations, currencies, preferences, market structures and with obstacles to crossing them such as delays and distance. These can be exacerbated by differences in taxes, in monetary and fiscal policies and by restrictions to the movement of goods, services, and factors of production. Together with potentially higher cross-border search costs, this can wipe out any potential gain from arbitrage. As a result, prices can differ substantially across borders (Crucini et al., 2005; Engel and Rogers, 1996; Gorodnichenko and Tesar, 2009).

Somewhat more recent studies comparing prices of identical products provide mixed evidence on international cross-border price differences, namely differences at the US-Canadian border. Research by Gopinath et al. (2011) and Burstein and Jaimovich (2012), on the one hand, documents within a single retail chain larger price differences between stores in different countries than between stores within the same country. Broda and Weinstein (2008), on the other hand, looking across multiple retail chains, find for a very specific set of goods no major difference in the variation of retail prices across and within countries. Recent research on Switzerland shows that prices of the exact same products are lower in the neighboring countries using the euro as currency (see Burstein et al., 2022).

A takeaway from this literature might be that, indeed, borders matter. They matter because they separate markets. The well-studied border between Canada and the USA separates two economic areas with many well-guarded idiosyncratic rules and regulations. Different tax rates, a different currency, different regulations, the presence of border controls, and so forth fit the textbook description of border frictions. The existence of price differences between Canada and the USA is thus not surprising, and their magnitude might be viewed as a gauge on the severity of these frictions.

Within a monetary union with integrated product markets, such as the euro area, one might expect that the relevance of borders for price differentiation has largely diminished. All euro member countries are part of the single market of the European Union, share the same currency, and have – by global standards – similar consumption tax rates and harmonized regulations. But despite a high degree of economic integration and a common currency, several studies find that borders within the euro area continue to leave their mark on prices: Reiff and Rumler (2014) find that for a narrowly defined set of frequently purchased groceries cross-country price variation in 13 euro area countries is many times larger than within-country price variation and show that neither distance nor tax nor consumption nor income differences fully explain this. Various other studies highlight large price differences between countries within Europe even for identical goods, for example TV sets (Imbs et al., 2010) or cars (Dvir and Strasser, 2018). Beck et al. (2020) document median price differences for identical products between Belgium, Germany and the Netherlands of 15% to 20%.

But what are these frictions? Are the costs of moving people and goods really the cause? Would a random line marked as "border" entail a similar price difference? Similar to the paper by Burstein et al. (2022), who however study a border characterised by classic frictions due to different currencies, we also document that while prices do not vary much with distance to the border within each country, the price gap at the border is substantial. That is, in this paper we show that even borders without relevant trade frictions can entail large price differences and that these price differences are rooted deeply in deliberate price differentiation of retailers.

Recent papers suggest that borders play less of a role in online markets, because search and price comparison is easier and geographic hurdles are less relevant. Cavallo et al. (2014), for example, analyse online prices from large internationally active retailers, such as IKEA and H&M, and find that their prices within the euro area are virtually identical, while they differ outside of this monetary union. They differ even if the currencies are de-facto pegged, as e.g. in the case of Denmark. The prices of multinational online retailers seem to largely obey the LOP (Gorodnichenko and Talavera, 2017).[1]

We complement this literature by studying prices and consumption of identical goods in a highly integrated region which is divided by a national border. The Bavarian-Austrian border region is not only integrated in economic but also in cultural terms. The entire region shares the same language and similar socio-economic characteristics. It is connected by a tight traffic infrastructure, and absent border controls there is a considerable number of cross-border commuters. With a number of retailers operating on both sides of the border, this region constitutes a nearly optimal setting to analyse international price and inflation differences.

We use data from the GfK[2] household panel, which reports barcode-level transactions of participating households in brick-and-mortar stores. The transactions cover primarily

[1] Whereas online pricing affects offline pricing (Jo et al., 2019), offline prices in Europe remain more dispersed than their online counterparts (Strasser and Wittekopf, 2022).

[2] Gesellschaft für Konsumforschung

groceries, household maintenance, and personal care items, commonly dubbed "fast-moving consumer goods" (FMCG). As one would expect, the mode of (crossborder) price differences is zero. But this mode encompasses only 14% of observations and is only observed for around 29% of products (barcodes).[3] In fact, even in this ideal setting which eliminates most prominent factors commonly blamed for LOP deviations, the prices of many products differ substantially in either direction. We show that these price differences are significantly larger than those within either country. The pervasive price differences at the product level partly offset each other, so that the overall price level difference between the two countries is smaller, but nevertheless highly significant. In contrast, the difference in average inflation rates at the product level across the two countries is rather small. Overall, we document a widespread failure of the LOP in its absolute version within this region, whereas LOP in its relative version (the postulation that given a common currency, inflation rates at the product level should be similar in both countries[4]) appears to hold approximately.

In order to understand the origins of these cross-border price differences we examine the pricing *within* international supermarket retail chains. As noted by Burstein and Gopinath (2014), the opposing results in Burstein and Jaimovich (2012) and Broda and Weinstein (2008) might stem from the differences in pricing between retailers. In contrast to the study of Cavallo et al. (2014), who analyse a specific type of online retailer selling distinct, branded products, i.e. large internationally active companies, our focus is on supermarkets and discounters selling FMCG. Compared to (semi-)durables, FMCG have typically a lower price. A customer, pushing the shopping cart from shelf to shelf, is unlikely to gather and evaluate all information on the products available – at least not in a reasonable amount of time – and even less so the prices of stores located in a different country. This opens room for differentiated pricing strategies and pricing-to-market. Indeed, Nakamura et al. (2011) document a vast heterogeneity in pricing across US retailers even for identical products. In this paper, we explore whether there are systematic differences between the within-chain and the across-chain cross-country price differentials. In comparison to Burstein et al. (2022), who provide evidence on the (positive) welfare implication of cross-border shopping amid cross-border price differences (e.g. due to different currencies), we highlight the potential arbitrariness of the sources of price differences due to retailers' pricing strategies and market power.

The analysis in this paper proceeds as follows: Section 2 describes the data and region underlying our analysis. Section 3 establishes the strong economic integration of this border region. Section 4 investigates the large cross-border price and inflation

[3] That is, for 29% of barcodes which are available in our cross-border sample, we observe cross-border region pairs for which the price difference is zero in at least one month.

[4] See Marsh et al. (2012) or Sarno et al. (2003).

differences. Section 5 traces the origin of these differentials to the pricing strategies of retail chains. Section 6 examines whether the border effect differs along household or product characteristics. Section 7 concludes with a summarizing discussion.

2 Data

As other recent studies on international price differences, this paper uses barcode level transaction data. This allows us to identify and compare identical products across different locations and over time.

2.1 Transactions

We use the GfK household panel for Austria and Germany for the period from 2008 to 2018. Households in the panel scan and document their everyday purchases of FMCG, which consist mostly of groceries, personal care items, but contain also some products for household maintenance, pet food, and gardening equipment. Our original sample comprises over 300,000 different products and about 8.5 million transactions summing up to sales of about 17.5 million euro. Most products (barcodes), however, were purchased by consumers in only one of the two countries. Once we restrict the sample to products sold on both sides of the border, we are left with a tenth of products and a fifth of transactions.[5] For each transaction, the data set provides information on the manufacturer, brand, product type (which we map to the corresponding COICOP[6] categories), the product's price (including tax), and the quantity and units purchased. Furthermore, it contains the name and the type of the supermarket where the transaction took place, [7] and the home region of the household. In the Austrian data the lowest regional level is the district area ("Bezirk"), and in the German data the postal area.[8]

2.2 Retailers

The FMCG market in both countries is dominated by a few large chains. Most of the retailers in each country either belong to a parent company that centralizes procurement or use a common sourcing service provider. For some small retailers we were not

[5] This has also been documented in Broda and Weinstein (2008) and Beck et al. (2020). We lose in particular store brands and other local brand products. See Appendix Table 11.

[6] The classification of individual consumption by purpose (COICOP) categories, adapted to the needs of harmonized indices of consumer prices (HICP), is commonly used in inflation statistics.

[7] Unfortunately the exact location of the supermarket, and shopping trips across the border are not documented in the data set.

[8] See Annex A.2 for details on the data cleaning.

able to identify a parent company or sourcing service provider. Because these stores seem to be very local in scope we exclude them from the analysis.

Restricting the sample to transactions at the dominant (in terms of transaction volume) supermarkets leaves us with one large retail chain per country operating only nationally, five international retail chains, which operate in both countries, and one sourcing service provider (Markant) serving a number of smaller retailers in both countries. For the internationally operating retailers and those using a common sourcing service provider, we assume centralized procurement. This implies an identical input price for all outlets of a given retail chain in both countries. A key hypothesis tested in this paper is that cross-country price differences within the *same* retail chain (and among retailers connected by a common sourcing service provider) are small.

2.3 Regional scope

Apart from the product and retailer differences, the main obstacle to isolating the effect of an administrative national border is controlling for other, potentially unobservable, factors that might differ between the two countries. Within the euro area, such factors may include distance, differences in language, but also income and consumption preferences. If there was no cost of arbitrage or if preferences were fully homogeneous across the border, the various retailers should not be able (and not even be trying) to price to market.

To eliminate such differences, we study a region which is as homogenous as possible. The Austrian-Bavarian border region gets very close to the ideal of a homogenous region along many dimensions: It is part of the European Union, the Schengen area,[9] and the euro area and thus free of tariffs, travel restrictions, and currency fluctuations. But not only the currency is the same, also the language (actually even the dialect). It is connected by a tight road, highway and railway infrastructure. Furthermore, regional treaties for cross-border labour mobility have been in place for decades, including a special double-taxation treaty for cross-border commuters.

Focussing on this economically and culturally integrated region eliminates most of the factors commonly used to explain large price differences at borders. We implicitly control for distance, which becomes irrelevant in the limit, by restricting the sample to a tight (approximately 60 kilometers on each side of the border) band along the Austrian-German border.[10] We match the information on the region in which the

[9] The Schengen area covers 22 countries of the European Union and the four member states of the European Free Trade Association. There are no formal border controls between countries in the Schengen area.

[10] A large part of the – in total – 120km-wide band has been a territory of the Prince-Archbishopric of Salzburg. That is, from the 14^{th} until the early 19^{th} century a large part of our sample region was united within a single country. Other parts of the region (e.g. the Innviertel) have switched their country assignment multiple times until the early

household that reports the transaction lives with geo-information to calculate several distance measures. We split the border area in Austria and Germany each in 19 roughly equal-sized regions,[11] resulting in 703 region pairs (171 pairs within each country and 361 across countries). Based on these, we analyse differences in consumption as well as in prices and price changes (inflation) within and across the two countries.

3 The border

There is a multitude of possible reasons for differing prices for an identical product in two countries: They include different taxes, different currencies hampering arbitrage, different preferences, different income levels, different market structures and different local distribution costs. By choosing a highly integrated border region within a monetary and economic union we rule out or reduce most, but not all of them. A retailer charges different prices in a given region pair if it is optimal (profit maximizing) and feasible for him to do so. Separately maximizing profits in each region and thus differentiating prices across regions for a specific product can be optimal if supply or demand differ between the two regions. In this section we document that neither local costs nor consumption preferences can explain the observed price and price change differences. Income differences, however, might well be exploited by retailers.

3.1 Differences in local costs and other supply factors

Value-added tax (VAT) rates in Austria and Germany differ only slightly. With few exceptions, the standard tax rate for most food and personal care items is 20% in Austria and 19% in Germany, while the reduced rate of 10% (7%) applies to most food items in Austria (and Germany). Given these small differences, all results we report refer to gross prices including VAT.[12]

With respect to the cost structure of retailers, the available data allow us to compare the local price of land on which outlets are built and the corporate tax rates in the two countries. Unfortunately there are no harmonized data on local wages in the retail sector in the two countries.

Concerning land prices, we draw on transaction data for properties at the level of counties (Landkreise) for Germany and at the level of political districts (Bezirke) for

19^{th} century as a fallout of wars and deals between the various royal houses of Europe. Since 1815/1816, however, the border has been unchanged. Therefore the industrialization and the evolution of mass retail in that region has been shaped by the borders as they are today.

[11] See Annex A.3 for details on the definition of these regions.

[12] Excluding VAT does not change the results presented in this paper as evident from comparing the first and second rows of Tables 3 and 4.

Table 1: Comparison of cost and demand factors affecting price setting of retailers

	Property prices (euro/m^2)	Corporate taxes (%)	GDP per cap. ('000 euro)	Population ('000)
Austrian border regions				
Northern Upper Austria	151	25.0	43	795
Salzburg and Southern Upper Austria	255	25.0	41	847
(Part of) Tyrol	514	25.0	41	573
German border regions				
Lower Bavaria	76	28.1	32	494
Eastern Upper Bavaria	231	27.7	34	519
Western Upper Bavaria	538	27.8	31	568

Note: Property prices refer to land ready for construction derived from transaction data at the county/district level averaged over the years 2016-2018. Population-weighted averages over counties in Germany and over districts in Austria. Corporate tax rates for Germany are the sum of federal and municipal corporate tax rates for 2018; for Austria it is the federal corporate tax rate effective since 2005. Population counts refer to end of 2018. Appendix A.1 provides details on the data sources.

Austria. As property prices are very heterogeneous at the county/district level, we aggregate them to three big regions on each side of the border and compare the neighboring regions across the border, i.e. Northern Upper Austria with Lower Bavaria, (part of) Salzburg and Southern Upper Austria with Eastern Upper Bavaria and (part of) Tyrol with Western Upper Bavaria. Table 1 lists property prices in euro per square meter, averaged over the years 2016 to 2018 (which is the overlapping period for which data are available in both countries). With the exception of the region pair Northern Upper Austria/Lower Bavaria where property prices are higher on the Austrian side of the border, prices appear to be quite similar in the other region pairs across the border.

Austria features a uniform corporate tax rate of 25%, while Germany's corporate tax rate has a regional element that can vary across communities.[13] But, as can be seen from Table 1, even though corporate taxes may vary across regions in Germany, the effective variation considering both federal and local taxes is small. Total corporate taxes hover around 28% in the German border regions. The difference of about three percentage points relative to Austria, albeit non-negligible, is unlikely to be a major driver of price differences – also because corporate taxes are a minor element of the cost structure of retailers.

Different market structures could be another source of international price differences. For indicators of market structure and competition we draw on national data collected

[13]Germany has a multi-level corporate tax system: corporations paid during most of the sample period a federal base corporate tax rate of 15% plus a solidarity contribution (Solidaritätszuschlag) of 0.825% plus a rate of 3.5% times a local corporate tax multiplier varying between 240% and 400% across the communities in our sample. This implies a variation of the overall effective corporate tax rate between 24.2% and 29.8% across the communities considered which is largely levelled out by aggregating to the regional level – see Table 1.

for the structural issues report of the ECB (2011).[14] In this report, Austria and Germany stick out as the two countries within the euro area with the highest share of discounters (Chart 5b in ECB, 2011). Outlets appear to be bigger on average in Germany as the share of hypermarkets (sales area above 2,500 square meters) is higher than in Austria (Chart 4 in ECB, 2011). Market concentration as measured by the Herfindahl-Hirschman index at the retailer level – called downstream market concentration in the report – is found to be lower in Austria than in Germany while at the parent company and buying group level – called upstream concentration – Austria and Germany are quite similar, ranking in the top group of euro area countries in terms of market concentration (Tables 5 and 6 in that report). These findings document that the structure of the retail markets in Austria and Germany is broadly similar at the national level. Given that retail markets tend to be highly integrated within countries, we do not expect large differences in the retail market structure between our border regions either.

Overall, the cost environment and market structure on both sides of the border is similar. In a nutshell, the supply-side appears largely identical across the border.

3.2 Differences in local demand

Another potential driver of international price differences are different local demand conditions as international suppliers might be tempted to increase profits by pricing-to-market when income levels differ across the border. Comparing regional income levels per capita (from Eurostat) in Table 1, we see that they are quite homogeneous for the three big regions within each country. However, across the border income per capita is found to be about one quarter higher on the Austrian side. This is surprising at first sight as Bavaria overall has one of the highest incomes per capita among German states.[15]

A reason for the difference in income is most likely that there are more urban areas in the Austrian sample than in the German one: In Austria the regions close to the border include three major cities with more than 100,000 inhabitants (Linz, Salzburg and Innsbruck) while in the German border region the biggest cities are Landshut and Rosenheim with roughly 70,000 inhabitants. Additionally, Salzburg and Innsbruck are two well-known touristic centers where tourism contributes an important part to local GDP. Even though there are rural areas in all border regions, the dominance of urban centres with higher income levels in Austria could give retailers some leeway to

[14] Although the report covers only the early years of our sample period, it remains the only comprehensive data source for indicators of the retail market structure in all euro area countries until today.

[15] Over the period 2008-2018 Bavaria's average GDP per capita amounted to 40,900 Euro implying the fourth rank among the German federal states, after Hamburg, Bremen and Hesse.

maintain higher prices on the Austrian side of the border.

3.3 Differences in preferences

Having established that the supply side factors on both sides of the border are similar and that income varies little within each country but differs across, we now turn to another demand side factor. Given the cultural homogeneity – even the local cuisine in the border region is very similar – it is plausible to assume similar preferences for food and beverages, which account for the bulk of products in our sample. To establish this more formally, we compare the consumption baskets given by our data on both sides of the border. Because the actual products (identified by a barcode) might differ on both sides of the border (Broda and Weinstein, 2008) for marketing reasons, we assign all products to COICOP groups at different levels of granularity. This allows us to verify if, for example, the chocolate consumption in the Austrian and Bavarian border regions is comparable, without requiring that both consume the same brands or varieties.[16]

To test the similarity of preferences across the border we calculate the correlation of the consumption baskets for each region pair j for each year t, i.e. the correlation of annual expenditure shares at the 4- and 5-digit COICOP levels. We then study the determinants of this correlation based with the following regression equation.

$$Y_{jt} = \underbrace{\beta_0 + \beta_1 \mathbb{1}^{AT}(j) + \beta_3 \mathbb{1}^{B}(j)}_{\text{border/country effects}} + \underbrace{\gamma_1 t + \gamma_2 t \times \mathbb{1}^{AT}(j) + \gamma_3 t \times \mathbb{1}^{B}(j)}_{\text{border/country trends}} + \epsilon_{jt} \qquad (1)$$

The dependent variable Y_{jt} refers here to the correlation of consumption baskets between region pairs. The effect of the border is captured by the border dummy $\mathbb{1}^{B}(j)$, which takes the value 1 for cross-border region pairs. The other independent variables include a country dummy for Austria $\mathbb{1}^{AT}(j)$, which takes the value 1 for region pairs within Austria, a time trend t, and interactions of the trend with the two dummies to check whether country or border effects changed over time. The constant β_0 captures the correlation of preferences when both regions of the pair are in Germany ("base" level). The "Austria effect" and the "border effect" coefficients reflect the additional correlation of regions within Austrian and within cross-border region pairs, respectively, relative to the within-Germany region pairs.[17]

Table 2 shows that the consumption baskets are highly correlated across the border. The cross-border correlation is 86% at COICOP4 granularity, and still 78% at the more

[16] Local varieties might be – besides the number of panelists being small relative to the number of products – one of the reasons for the small share of common barcodes, as visible in Table 2.

[17] That is, in order to get the correlation of consumption baskets of cross-border region pairs, one has to add the estimated border effect to the base level. The same specification is also applied to price and price change differences in subsequent sections.

Table 2: BORDER EFFECTS

	(1) Basket correlation (COICOP4)	(2) Basket correlation (COICOP5)	(3) Common barcode share	(4) Abs. price difference	(5) Abs. price change difference
Constant	0.89***	0.88***	0.16***	8.11***	11.21***
(Germany)	(0.004)	(0.003)	(0.001)	(0.398)	(1.139)
Austria	0.05***	0.04***	0.08***	2.91***	2.30
	(0.005)	(0.004)	(0.001)	(0.518)	(2.022)
Border	-0.03***	-0.10***	-0.14***	15.3***	4.64***
	(0.004)	(0.004)	(0.001)	(0.695)	(1.410)
Common trend	0.004***	0.004***	0.001***	0.00	0.01
(Germany)	(0.001)	(0.001)	(<0.001)	(0.004)	(0.012)
Austria trend	-0.003***	-0.003***	-0.005***	0.01	0.04
	(0.001)	(0.001)	(<0.001)	(0.006)	(0.026)
Border trend	-0.003***	-0.006***	-0.001*	0.01	-0.01
	(0.001)	(0.001)	(<0.001)	(0.008)	(0.017)
Frequency	year	year	year	bi-month	bi-month
Observations	7,733	7,733	7,733	333,733	44,294
Adj. R^2	0.14	0.49	0.93	0.12	0.07

Note: Sample period 2008–2018. 703 region pairs. Standard errors in parentheses (columns 4 and 5: robust, barcode-clustered standard errors). OLS regressions. Bi-month and retailer controls in columns 4 and 5 not reported. Dependent variables: (1/2) pairwise correlation of COICOP4/COICOP5 composition of (annual) baskets of each region pair, (3) common barcodes in each region pair as share of all barcodes in the region pair, (4) absolute, within-retailer (log) price difference and (5) absolute y-o-y price change difference of each region pair bi-monthly frequency. Germany effect in (1)-(3) is the constant, in (4) and (5) sum of constant + avg. coefficient of retailer controls + avg. coefficient of month controls. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. Test with H_0: border effect = country effect is rejected for price differences (p-value: 0.00), but not rejected for price change differences (p-value: 0.23) detailed COICOP5 granularity (first and second column of Table 2, base plus border effect). The consumption structure across the border is slightly less similar than within each country. The correlation shrinks by at least 0.05 and 0.14, respectively.

A correlation of 78% at the COICP5 level is nevertheless considerable and an indication that differences in consumption should not be of big relevance for cross-border price and inflation differences.[18] The three bottom rows of columns (1) and (2) in Table 2 show how consumption preferences have evolved over the eleven years in our sample. Austria and Germany became more similar in terms of their within-country heterogeneity, but the similarity *across* the border did not increase during the sample period.

4 Border effects

4.1 Basket differences

Despite the similar consumption structure, the set of products consumed and available in each country differs. To show this, we replace the dependent variable Y_{jt} in Equation (1) with the share of common barcodes in a given region pair among all barcodes in that region pair. Because of the fine regional grid in our benchmark specification the number of households per region is limited. As household shopping is very idiosyncratic (Kiss and Strasser, 2022) the share of common barcodes between any two regions in a given year amounts to only roughly 10% of all barcodes.[19] Across the border this subset of common products shrinks even further, as shown by column (3) of Table 2. On average only about 2% of barcodes are available in a given cross-country pair of regions in a given year,[20] i.e. 14 percentage points less than between German regions.[21]

The results in column (3) stand in stark contrast to those in column (2). Even though the households in the two countries share a similar broadly defined consumption basket, the actual items in their baskets are rarely identical. There is only very limited evidence that the items become slightly more similar in the direct proximity of the border (Figure 1). Metaphorically speaking, the dinner tables look very similar on both sides of the border, but the packaged food products are labelled differently. The small share of common barcodes (compared to region pairs within the same country) is a first indication of market segmentation by product differentiation along the border, which

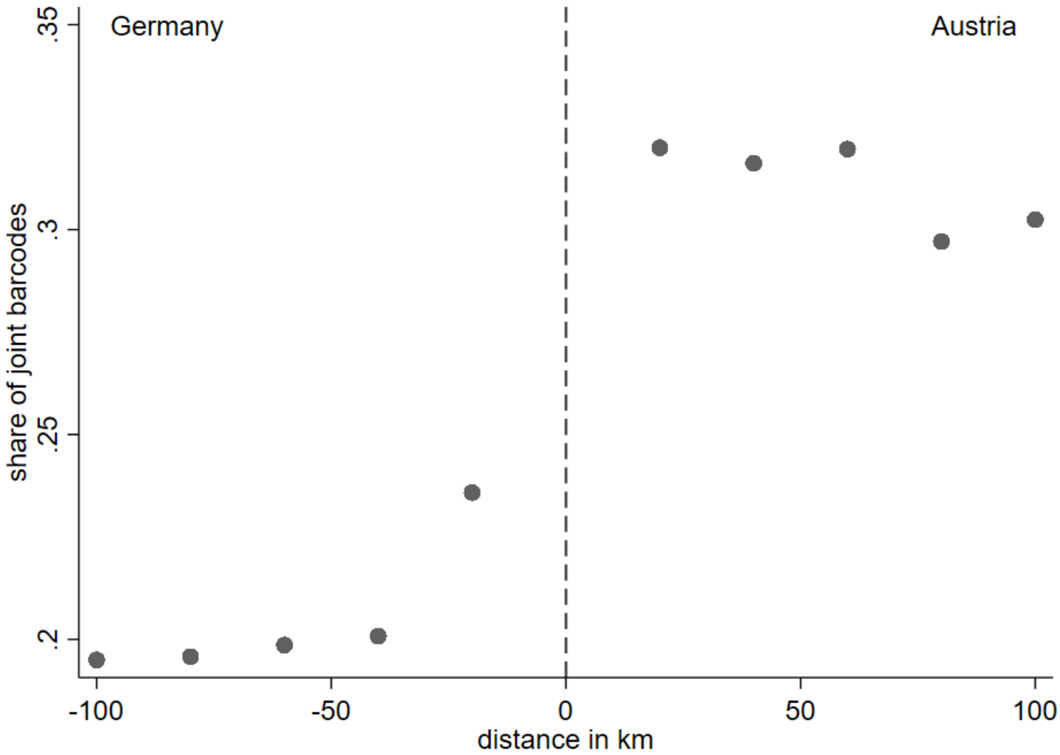
[18] Including a measure for distance between regions in the regressions does not change this picture (see Appendix B.3). In fact, the coefficient on distance is small and insignificant.

[19] Consumers in Germany can choose from a larger set of different barcodes, which results in a lower share of barcodes purchased within a given time interval in two German regions (16%) than those purchased in two Austrian regions (24%). According to Neiman and Vavra (2019), the concentration of aggregate spending on the same products has decreased. Households have increasingly concentrated their spending on a few preferred products, which at the same time may well be increasingly different products from their neighbors. We do not observe such a trend in our sample.

[20] Despite this low share, our cross-country price comparisons are still based on more than 14,000 products.

[21] As with the consumption baskets, including in the regression a measure for distance between regions does not change the border effect for the common barcode share either. See Appendix B.3.

Figure 1: COMMON BARCODES AT THE BORDER



Note: Horizonal axis measures the distance from the Austrian-German border in kilometers, negative distances refer to Germany and positive ones to Austria. Sample period 2008-2018. Bin width 20 km. Based on random subsamples of 48,000 barcodes per bin.

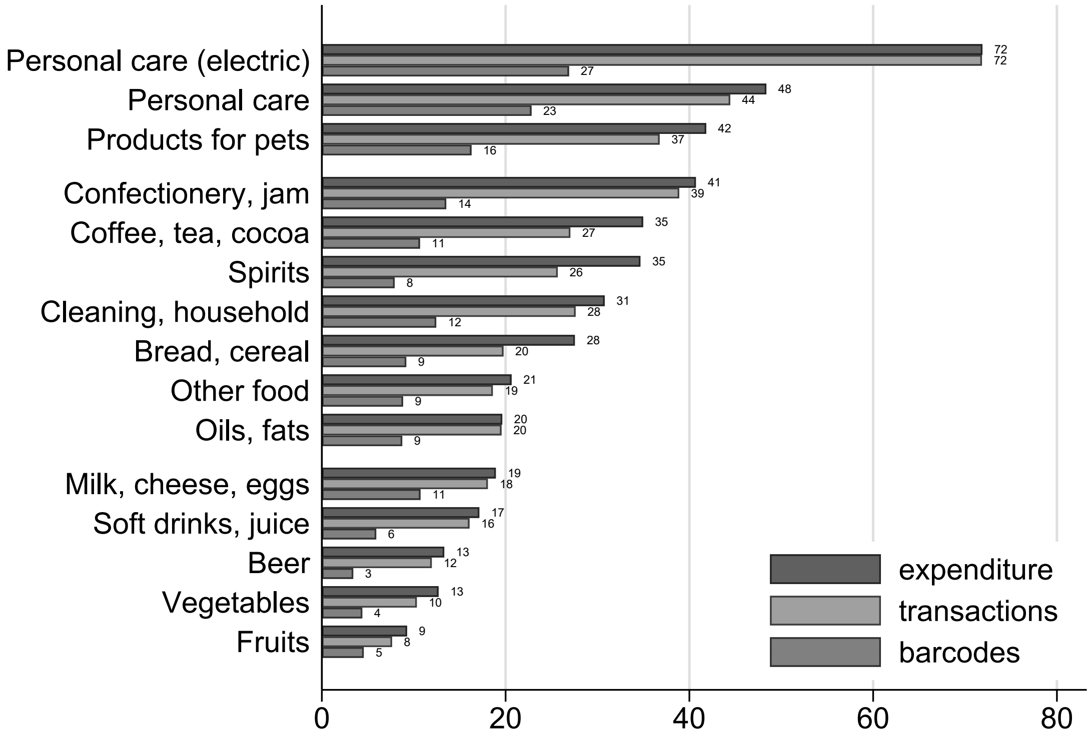
is not grounded in preference differences.

Zooming in on expenditure in common barcodes we see stark differences between product categories. Depending on the product type, Figure 2 shows shares ranging from 9% to 72% of total expenditure. Expenditure on personal care items (in particular electric appliances, such as electric toothbrushes), on products for pets, but also on non-perishable products such as chocolate, coffee, tea and spirits as well as on cleaning and household maintenance products is more concentrated on the same products in both countries than spending on perishable food products and beverages. Fruits and vegetables, which often are loose, unpackaged goods, display the lowest share of expenditure in common barcodes, although households on both sides of the border eat the same types of apples and cucumbers.

4.2 Price differences

As local costs and demand factors are largely similar, there appears to be little reason for strong price differences across this purely administrative border cutting through an integrated region. The close proximity of the regions in our sample – both within and

Figure 2: Products common across the border (percent)



Note: Share of expenditure and transactions in products sold in both regions among all purchases in either region of a given cross-border pair, in percent. Share of barcodes sold in both regions of a given pair relative to all barcodes sold in this region pair. Sample period 2008-2018. Average over all cross-border region pairs.

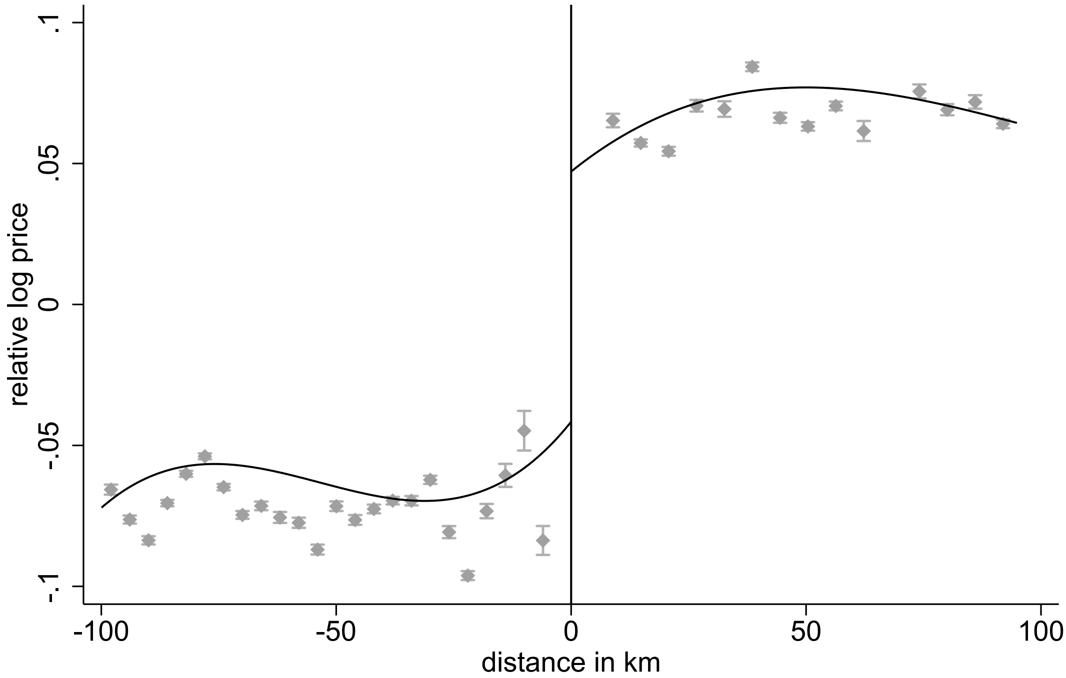
across countries – suggests that transportation costs are likely to be similar, so that distance might not matter for cross-border price differences.

The irrelevance of distance close to the border becomes obvious in a regression discontinuity design (RDD) setting,[22] as applied previously e.g. by Gopinath et al. (2011) and Beck et al. (2020). Exploiting the pseudo-experimental characteristics of our data, Figure 3 shows how the price of product i relative to the products' average price in both countries at time t (in logarithmic terms) behaves given a binary treatment, namely being on one side of the border. The assignment to this treatment is determined by the distance to the border on the horizontal axis in either direction. Figure 3 shows that relative prices are largely constant within each country. Even as we approach the border the prices do not converge. That is, the distance to the border does not seem to matter for prices within the 100 kilometer band. Likewise, (Burstein et al., 2022) document that prices in Switzerland are invariant to distance to the border within the country. What does matter is the side of the border. At the border we observe a large price gap. The figure suggests that prices on the Austria side (on the right hand side of the zero-line) are at least 10% higher than those on the German side.[23]

[22]See Imbens and Lemieux, 2008. This papers uses the Stata implementation by Calonico et al. (2017).

[23]This result confirms evidence by the regional Austrian Chamber of Labor, which provides price comparisons for

Figure 3: Price gaps at the border



Note: Dots show the average log price deviation from the mean for each distance bin, together with 95% confidence intervals. Solid line is a third-order polynomial fitted to these averages. Joint barcodes only. Horizonal axis measures the distance from the Austrian-German border in kilometers, negative distances refer to Germany and positive ones to Austria. Number of bins determined by the integrated mean squared error optimal evenly spaced method, separately for Austria and Germany.

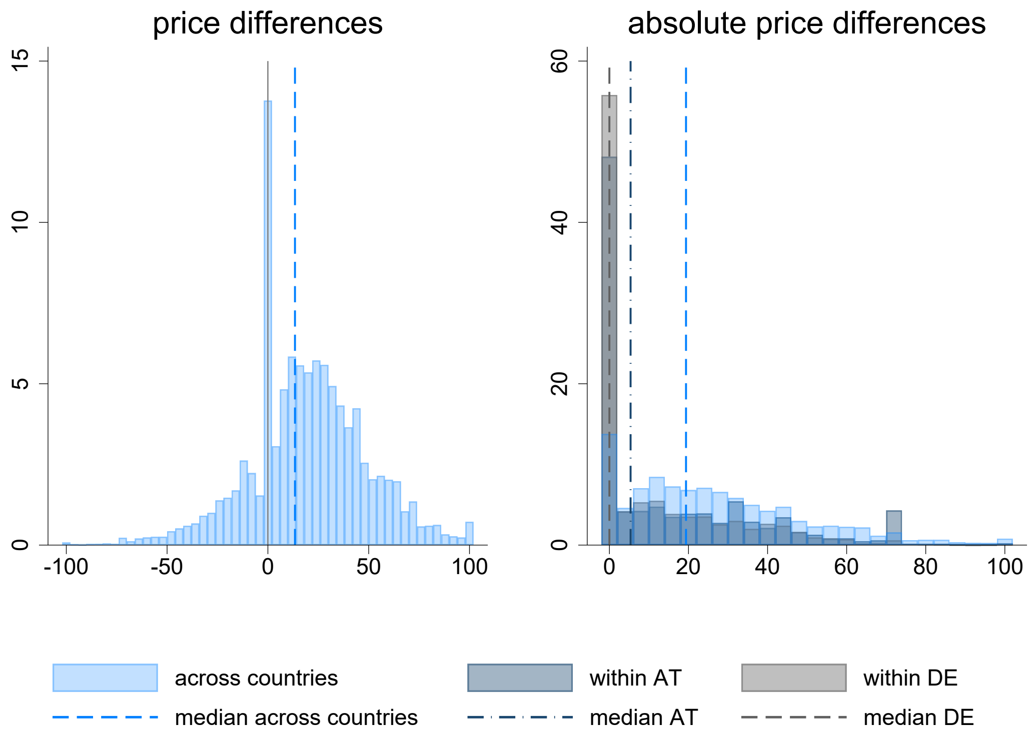
The border is also visible in the distribution of prices of individual products. The left panel of Figure 4 plots the (non-absolute) logarithmic price differences per product in each cross-border region pair (Austrian minus German prices). The panel on the left hand side of Figure 4 shows large price differences on either side of the border. Reassuringly, the mode of price differences is at zero, but the mode represents only about 14% of all cross-border observations. In contrast, for within-country region pairs the mode is far more pronounced (right panel of Figure 4). The share of zero price differences amounts to about 48% within Austria and to about 56% within Germany.

The distribution is not symmetric around the mode. Excluding the probability mass at the mode, the distribution is largely symmetric around a (cross border) price difference of approximately 15% (Table 3), which suggests the existence of an optimal cross-border price differential. The pronounced mode suggests that the benefits of uniform pricing imply a tradeoff for firms, which results in the bi-modality of the price difference distribution.[24] The positive median cross-border price difference of 13% shown as dashed line in the left panel of Figure 4 reflects the overall higher price level in the Austrian regions, in line with the evidence of the RDD analysis.

several product categories. For more information please refer this report (German only).

[24]Normality of the price change distribution is strongly rejected by the test reported in Table 3.

Figure 4: Cross-country price differences



Note: The left histogram shows the distribution of non-absolute cross-border log price differences in percent (Austrian minus German prices). The right histogram shows cross-border and within-country absolute *log price differences in percent. The dashed lines refer to the median of the respective distribution. y-axis: Frequency in percent. Bin width is 4 percentage points, except for the "zero" bin, which only contains zero values. Observational unit: product × region pair × retail chain × bi-month. 19 regions per country.*

The right panel of Figure 4 plots the *absolute* within-country and cross-border price differences. It highlights the small dispersion in prices within countries compared to the large cross-border price dispersion, supporting earlier findings by Reiff and Rumler (2014), Gopinath et al. (2011) and Beck et al. (2020). Table 3 quantifies this observation: Within Germany, the median absolute price difference across regions is zero and within Austria about 5%; across the border, however, it amounts to almost 20%.[25]

Table 3: Moments of price differences between regions

region pairs	Cross-border					Austria		Germany	
	Δp median	Δp mean	Δp std.dev.	Δp normal	$\|\Delta p\|$ median	$\|\Delta p\|$ median	$\|\Delta p\|$ mean	$\|\Delta p\|$ median	$\|\Delta p\|$ mean
overall	13.4	15.8	27.8	0.0	19.4	5.4	15.2	0.0	10.3
excl. VAT	10.8	13.2	28.0	0.0	18.9	5.4	15.2	0.0	10.3
excl. mode	18.3	18.0	29.0	0.0	22.6	22.6	26.6	18.3	21.6

Note: 19 regions per country. Sample period 2008–2018. Cross-border price differences are Austrian minus German prices. The column "normal" reports the p-value of testing the null hypothesis that price differences are normally distributed.

To establish the statistical significance of these price differences, we regress the absolute

[25]The mean absolute difference across border amounts to 24%

log price difference Y_{irjt} (for product i, in retailer r, in region pair j at time t) at bi-monthly frequency on the border dummy:

$$Y_{irjt} = \underbrace{\beta_1 \mathbb{1}^{AT}(j) + \beta_3 \mathbb{1}^{B}(j)}_{\text{border/country effects}} + \underbrace{\gamma_1 t + \gamma_2 t \times \mathbb{1}^{AT}(j) + \gamma_3 t \times \mathbb{1}^{B}(j)}_{\text{border/country trends}} + \underbrace{\lambda_r}_{\text{retailer controls}} + \underbrace{\theta_{m(t)}}_{\text{month controls}} + \epsilon_{irjt} \quad (2)$$

The dummies, trend variables and interaction terms are defined as in Equation (1), augmented by eight retailer and twelve (seasonal) calendar-month effects.

The results in column (4) of Table 2 confirm the significance of the additional price gap at the border. It amounts to 15 percentage points, rendering cross-border price differences on average twice as large as within-country price differences. This result is robust over time, to different regional delimitations and other specifications, including controlling for distance and income. Both distance and income fail to explain the price differences between the regions of the two countries.[26] The overall size of absolute cross-border price differences of approximately 23% (base + border effect) is roughly in line with what Beck et al. 2020 report for Belgium, Germany and the Netherlands.

4.3 Inflation differences

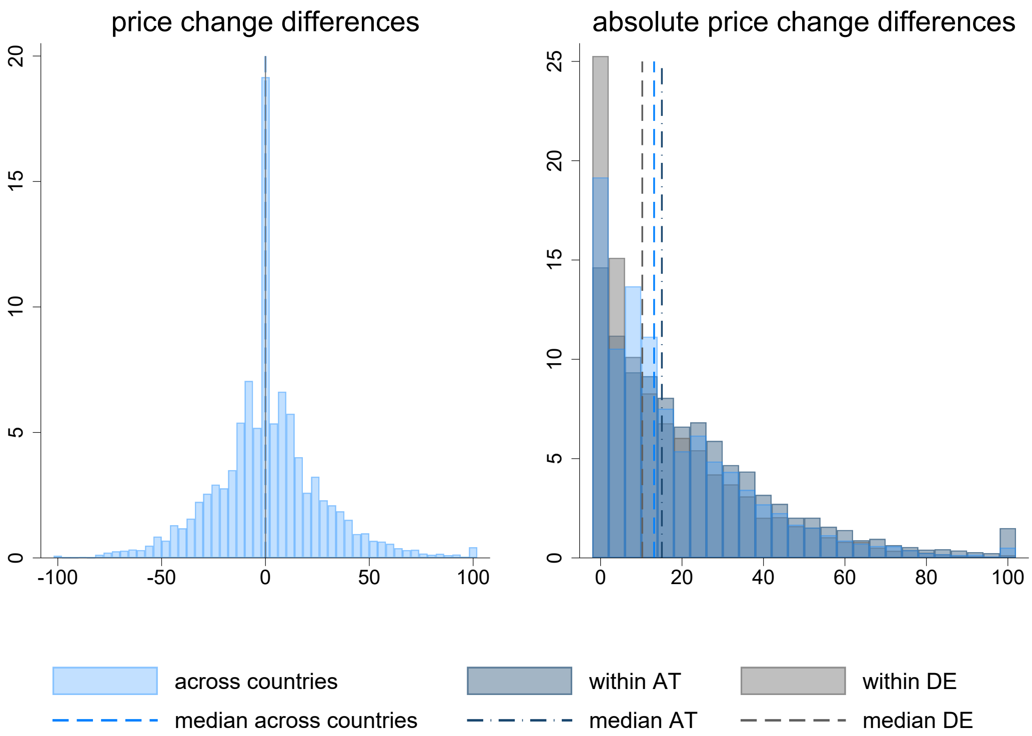
The evidence provided on price differences indicates a failure of the LOP in its absolute form, suggesting that arbitrage is impaired by some frictions. If the arbitrage constraint was binding, the prices of these products could not diverge further. This one-sided bound on changes in relative prices might entail synchronized price changes between countries. To what extent does this weaker condition – LOP in its relative version (e.g. Sarno et al., 2003) – hold between the two countries?

The inflation rates of Austria and Germany are not necessarily synchronized despite the regions' proximity and similarity. Our dataset allows us to calculate inflation rates based on a common basket of identical FMCG products. Doing so, we find that during the period from 2008 to 2018 annual inflation rates have been approximately one percentage point higher in the Austrian border region. By comparison, the official HICP inflation rate of food and beverages is virtually the same in both countries, while the overall HICP inflation rate has only been slightly higher in Austria over the same period.

[26] The coefficient on log GDP per capita differences is small (-0.004 percentage points) and insignificant, the coefficient of distance between each region pair (in kilometers) is also small (0.005 percentage points) but significant. Nevertheless, including either variable in Equation (1) does not improve the adjusted R^2 and leaves the remaining coefficients virtually unchanged.

Looking at aggregate figures conceals, however, the heterogeneity of the underlying price change patterns between the two countries. Let us therefore compare the annual rate of price change for each barcode i and retailer r for each region pair j, both as absolute and non-absolute difference in a two-month period t.

Figure 5: CROSS-COUNTRY PRICE CHANGE DIFFERENCES



Note: The left histogram shows (non-absolute) cross-border y-o-y price change differences in percent (Austrian minus German price changes). The right histogram shows cross-border and within-country, absolute log price differences in percent. The dashed lines refer to the median of the respective distribution. y-axis: Frequency in percent. Bin width is 4 percentage points, except for the "zero" bin, which only contains zero values. Observational unit: product × region pair × retail chain × bi-month. 19 regions per country.

The mode of cross-border price change differences is again zero, which can be seen from the left panel of Figure 5. With 19% of price changes being identical, the mode of price change differences is more pronounced than that of prices. In contrast to price differentials, the price change differentials are symmetric around zero, which suggests that the two countries share a common price trend (or no trend at all) during the sample period. That is, when comparing price changes of common barcodes in our sample at a more disaggregate level, i.e. within region and retailer, we find that prices increased roughly at the same pace in German and Austrian border regions (mean difference 0.3 percentage points p.a., median 0). This small average, however, conceals price change differences of a median size of 13 percentage points in either direction at the product level (light blue line in right panel). Such large differences may easily occur in a panel when irregularly purchased products are occasionally on sale, so that prices vary in both directions both over time and between regions.

Table 4: Moments of price change differences between regions

region pairs	Cross-border					Austria		Germany	
	$\Delta\pi$ median	$\Delta\pi$ mean	$\Delta\pi$ std.dev.	$\Delta\pi$ normal	$\lvert\Delta\pi\rvert$ median	$\lvert\Delta\pi\rvert$ median	$\lvert\Delta\pi\rvert$ mean	$\lvert\Delta\pi\rvert$ median	$\lvert\Delta\pi\rvert$ mean
overall	0.0	0.3	26.3	0.0	13.2	15.1	20.6	10.3	15.8
excl. VAT	0.0	0.2	26.4	0.0	13.3	15.1	20.6	10.4	15.9
excl. mode	0.5	0.3	27.7	0.0	15.7	17.6	22.9	14.1	19.0

Note: 19 regions per country. Sample period 2008–2018. Cross-border price change differences are Austrian minus German prices. The column "normal" reports the p-value of testing the null hypothesis that price change differences are normally distributed.

The medians, shown as dashed lines in the right panel of Figure 5 and printed in 4 , suggest furthermore that the differences in price changes are not much different across than within countries. In fact the median absolute price difference within Austria is larger than across the border.[27] A regression analogous to Equation (2), with absolute price change differences as dependent variable and controlling for retailers and time, shows that price changes are almost 5 percentage points more dispersed across the border than within Germany (rightmost column in Table 2), but not significantly different from within Austria. Overall, we cannot reject the relative version of the LOP.

4.4 Persistence of price differences

Can consumers in our sample actually benefit from these price differences? In the case of Switzerland, where a price gap to neighboring euro-countries persists due to the different currencies, (Burstein et al., 2022) document sizeable welfare effects, particularly for households living close to the border, i.e. those are more likely to cross it. The price differences across the border they analyse appear to be sufficiently persistent, i.e. not due to short-term sales, so that consumers can be certain to benefit from cross-border shopping. Within the same currency area it however may be less clear. Kaplan and Menzio 2015 argue that US households seem unable to time their purchases to fully benefit from temporary sales (in a given store), but that some US households are very good at assigning their purchase to stores with overall lower-than-average prices. From a retailer perspective, however, to discourage cross-border arbitrage, price differences for a given product should not be too persistent.

Estimating persistence of prices at the product level requires price observations for a given product in a region pair in many periods. To increase the number of products we aggregate for this analysis the households to three regions on each side of the border[28] and transactions to a bi-monthly frequency. We regress the price difference between

[27]The mean absolute price change difference is 18.9 percentage points across the border

[28]For comparison, we report the results with 19 regions in each country in Table 20 of Appendix B.

the resulting region pairs separately on selected lagged differences, interacting with the regional dummies, and month and retailer controls.

$$Y_{irjt} = \underbrace{\beta_1 \mathbb{1}^{AT}(j) + \beta_3 \mathbb{1}^{B}(j)}_{\text{border/ country effects}} + \underbrace{\gamma_1 Y_{irj,t-\tau} + \gamma_2 Y_{irj,t-\tau} \times \mathbb{1}^{AT}(j) + \gamma_3 Y_{irj,t-\tau} \times \mathbb{1}^{B}(j)}_{\text{border/ country autoregressive coeff.}} + \underbrace{\lambda_r}_{\text{retailer controls}} + \underbrace{\theta_{m(t)}}_{\text{month controls}} + \epsilon_{irjt} \quad (3)$$

In this equation Y_{irjt} is the absolute log price difference or absolute price change difference (for product i, in retailer r, in region pair j during the two-month period t). $Y_{irj,t-\tau}$ refers to the lagged difference at an offset of $\tau = 1, 2, 3, 6$ periods, corresponding to 2, 4, 6 and 12 months.[29]

The upper panel of Table 5 shows the autoregressive coefficients on price differences within and across countries for each offset. Overall, price differences are only weakly correlated over time within countries (coefficient on first lag for Germany is 0.24), but significantly more so across countries (additional 0.28). The overall autoregressive coefficient of 0.52 over two months remains relatively stable thereafter, which indicates some persistence in cross-border price level differences. This could indeed provide arbitrage opportunities, but they might – in line with Kaplan and Menzio 2015 – still be too small to be recognized and too small to justify a cross-border shopping trip.

In contrast, differences in price changes are no more persistent across the border than within a country. The positive sign of the base coefficient in the lower panel of Table 5 suggests that we observe persistent genuine, i.e. non-sale, price changes. If price changes were largely due to sales, we would expect price changes to reverse. This would imply a negative autoregressive coefficient, which is rejected by the data.

5 Retail network versus national border

Until now we have documented that even though income is somewhat different across the border, preferences in the two countries appear to be similar. The prices and price changes of many products, however, differ considerably between the two countries – in either direction. This suggests that consumers can gain only little from blindly shopping across the border, but more from product-by-product arbitrage. Such cherry-picking requires a careful price comparison. The cost of obtaining the necessary information, e.g. comparing prices and keeping up with promotions across the border, might render

[29] The dummies and interaction terms are defined as in Equation (1). Including several lags into one equation leads to small-sample problems, thus we run a separate regression for each lag here.

Table 5: Persistence of price and price change differences

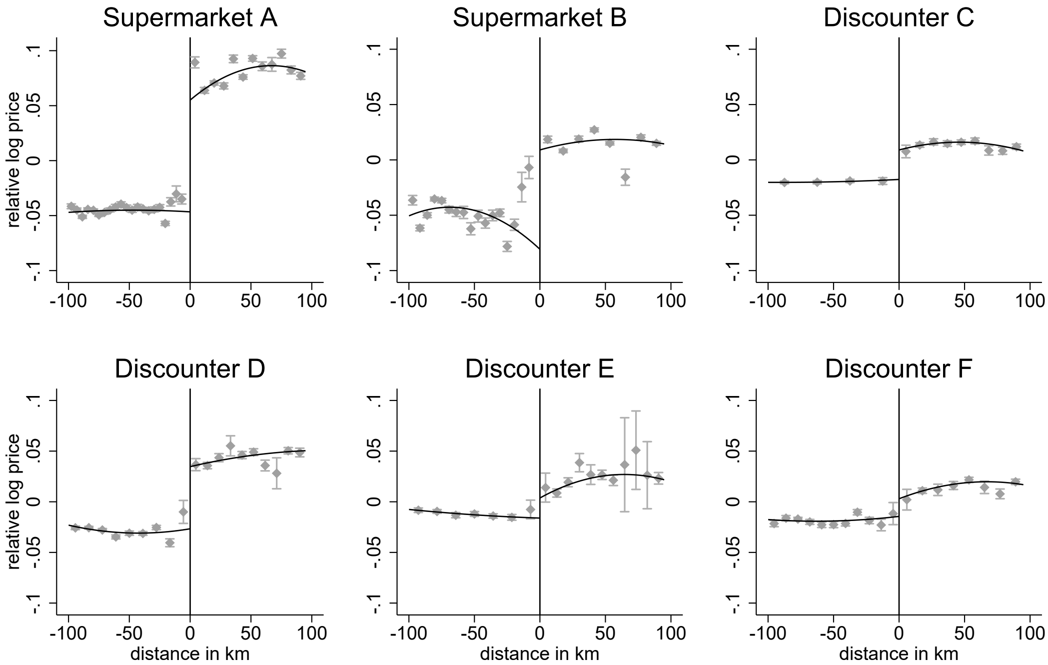
Offset	2 months	4 months	6 months	1 year
		Price differences		
Germany (basis)	0.24***	0.21***	0.19***	0.18***
Austria (additional)	-0.07***	-0.05**	-0.03	-0.03
Border (additional)	0.28***	0.28***	0.29***	0.25***
Observations	57,127	50,956	47,396	44,801
R^2	0.27	0.25	0.25	0.23
		Price change differences		
Germany (basis)	0.25***	0.19***	0.21***	0.35***
Austria (additional)	-0.10**	-0.03	-0.02	-0.01
Border (additional)	-0.06	-0.03*	-0.05	-0.04
Observations	12,779	11,446	10,835	16,903
R^2	0.09	0.08	0.08	0.15

Note: Sample period 2008–2018. 15 region pairs. Bimonthly frequency. The table shows the within- and cross-country autoregressive coefficients of price differences by length of lag from an OLS regression (with robust, barcode-clustered standard errors, not reported). Explanatory variables: interaction of first, second, third and sixth lag of absolute log price difference (columns) with regional dummy (rows). Trend, bi-month and retailer controls not reported. Dependent variable, upper panel: absolute, within-retailer (log) price difference. Dependent variable, bottom panel: absolute, within-retailer y-o-y price change difference. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

cross-border arbitrage so unattractive (Reis, 2006; Nevo and Wong, 2019) that retailers can maximize their margins separately on each side of the border.

There is no plausible reason on the cost side for systematic differences in the wholesale price of goods between retailers. The price difference can hardly be justified by differences in local costs, because prices deviate in both directions across the border and because most of the retailers operate in both countries (e.g., Aldi, Rewe/Billa, Lidl, Penny) or use a common sourcing service provider (Markant). Therefore, Burstein and Gopinath (2014) argue that the differing results in Burstein and Jaimovich 2012 and Broda and Weinstein (2008) might stem from the differences in pricing across retailers. According to Nakamura et al. (2011) price setting varies strongly across retailers. In our sample the presence of two large retailers operating only in either country might then suggest that the two retail markets are not perfectly integrated. Is the border merely a result of different retailer composition of the respective market? Are there systematic differences between within-chain and across-chain cross-country price and inflation differentials? To investigate the role of retail chains further, we restrict the data set to only those supermarket chains which either exist on both sides of the border or use the same sourcing service provider, implying similar input costs for the participating supermarkets. This results in a set of six retailers active in both countries.

Figure 6: Price gaps at the border by retailer



Note: Dots show the average log price deviation from the mean for each distance bin. Solid line is an (unweighted) second-order polynomial fitted to these averages. Joint barcodes only, percentage deviation from mean. Horizonal axis measures the distance from the Austrian-German border in kilometers, negative distances refer to Germany and positive ones to Austria. Number of bins determined by the integrated mean squared error optimal evenly spaced method, separately for Austria and Germany.

We first look at price gaps at the border for each retailer separately in Figure 6 using the same RDD approach as in the previous sections. Within retailers the within-country distance does not seem to matter as price differences remain constant on either side of the border. But at the border the prices of each retailer display a striking, discrete discontinuity. Interestingly, price jumps at the border appear to be larger for supermarkets than for most discounters.

In order to quantify the within-retailer border effects we interact the country and border dummies with the retailer. These interactions capture the within- and across-country effect for each retailer.

$$
\begin{aligned}
Y_{irjt} = & \underbrace{\lambda_r}_{\text{within-retailer DE effects}} + \underbrace{\lambda_r^{AT} \times \mathbb{1}^{AT}(j)}_{\text{additional AT effects}} + \underbrace{\lambda_r^{B} \times \mathbb{1}^{B}(j)}_{\text{additional border effects}} + \\
& \underbrace{\gamma_r t + \gamma_r^{AT} t \times \mathbb{1}^{AT}(j) + \gamma_r^{B} t \times \mathbb{1}^{B}(j)}_{\text{border/ country trends}} + \underbrace{\theta_{m(t)}}_{\text{month controls}} + \epsilon_{irjt}
\end{aligned} \tag{4}
$$

A look at the individual chains in Table 6 reveals that the border effect is significant in all six chains, no matter whether they are discounters or supermarkets. Within Austria, the basic dispersion is about 2.8 percentage points higher than in Germany (on

Table 6: WITHIN-RETAILER BORDER EFFECTS: PRICES

Retailer	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)
Supermarket A	9.85***	3.25***	16.43***	0.00
Supermarket B	11.63***	4.69***	16.46***	0.00
Discounter C	0.47	0.97	18.13***	0.00
Discounter D	6.21***	1.91**	15.10***	0.00
Discounter E	2.97***	3.18**	8.72***	0.00
Discounter F	7.46***	2.83**	12.96***	0.00

This table presents the within-retailer country and border effect coefficients from the OLS estimation of Equation (4) with time trends and barcode-clustered standard errors. Sample period 2008–2018. Dependent variable: absolute, within-retailer (log) price difference of each region pair at bi-monthly frequency. 333,733 observations. Adjusted R^2 = 0.46. Last column H_0: border effect = country effect. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

average 6.4%), but this is dwarfed by the border: On average, prices differ additionally by around 15 percentage points across the border. That is, for identical products the price differences across the border are almost twice as large as within a country. For all retailers, the additional difference at the border is sizeable and significant, ranging from 9% to more than 18%. Interestingly, discounters appear to have a smaller within-country or “basic" dispersion than the two supermarkets (columns 1 and 2), resulting in a border effect that is larger relative to the within-country dispersion. Nevertheless, in absolute terms cross-border price differences are slightly larger for the two supermarkets, in line with the RDD analysis.

The basic dispersion within supermarkets and countries may be stemming from sales, which often follow a specific cycle but are not necessarily synchronized across retailers. If customers arrive at stores at random times, the ones arriving earlier in the week (or month) might obtain a different price than those arriving later. This, combined with ad-personam offers (rebate cards, discounts), generates a basic price dispersion within a chain-country even if prices are compared within shorter time intervals. In our case it is further elevated because we do not distinguish different supermarkets within the parent company (e.g. Billa vs. Merkur within Austrian Rewe), but only store types (e.g. discounter Penny vs. Rewe supermarkets) within a chain. This basic dispersion is small for discounters (between zero and 10 percentage points) but reaches 14-16% for supermarkets. This could be due to the fact that, in contrast to supermarkets, discounters who have lower prices on average (“everyday low prices”) employ less promotional pricing, e.g. weekly sales, which explains a smaller within-country price dispersion. Furthermore, price margins of discounters are smaller and thus store prices may deviate less from wholesale prices, which within our internationally operating chains should be similar across countries. Finally, the prices of the independent retailers using a common sourcing service provider are not more dispersed than those of the other supermarkets.

It is evident from Table 6 that the national retail subsidiaries set their prices (and promotions) rather independently. Recalling that the border in this example does not reflect major differences in preferences, this suggests that the arbitrage cost must be high. Crossing the border between Austria and Bavaria, however, imposes virtually no (additional) cost to the shopper. This implies that for a given product this border features the same cost of arbitrage as the within-country "border" between any pair of same-country regions. The key difference appears to be that the national border has been *chosen* by retailers for differentiating prices. Retailers could differentiate along any other line on the map, but – likely due to their existing logistics network – they chose to follow the national border.

Table 7: Within-retailer border effects: price changes

Retailer	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)
Supermarket A	11.33***	5.21*	5.63**	0.87
Supermarket B	18.90***	1.00	2.12	0.52
Discounter C	0.97	0.48	6.10**	0.04
Discounter D	11.32***	-1.16	3.50*	0.05
Discounter E	6.23**	-3.82	-0.69	0.20
Discounter F	10.52***	1.22	5.12**	0.15

Note: The table shows within-retailer country and border effect coefficients from the OLS estimation of Equation (4) with time trends (barcode-clustered standard errors). Period 2008–2018. Dependent variable: absolute, within-retailer y-o-y price change difference at a bi-monthly frequency. 44,294 observations. Adjusted R^2 = 0.47. Last column H_0: border effect = country effect. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

In a nutshell, retailers differentiate prices – always and everywhere, also within-country – but most extensively across national borders. That is, the subsidiaries of the same retailer charge different prices for the same product in two countries.

What implications can be drawn for price change differences and inflation differences? The previous section has shown that, on average, price changes in Austria and Germany are comparable, and less dispersed across the border than prices. In order to test whether retailers change prices systematically differently across the border, we rerun regression (4) with differences in annual price changes as the dependent variable. Table 7 shows that the additional dispersion across the border is small compared to the basic dispersion (in particular in Austria), and significant in only two of the discounters.

The results suggest that inflation is less dispersed across the Austrian-Bavarian border than the prices themselves. While retailers maintain differences in the price level, we cannot find evidence that they systematically deviate from a common price trend. Both countries appear to share important inflation drivers. We also find that price differences within a given retailer are only weakly correlated over time and more persistent across the border than within a country.[30] Differences across the border in the price of specific products decay rather quickly. Recalling that the correlation of the absolute cross-border price differentials over two months is 0.52, large arbitrage opportunities for consumers for individual products are not too persistent. Therefore, price changes in either direction can offset each other, leading to a less dispersed aggregate inflation.

6 Border effect along household and product characteristics

6.1 Household-specific price differentiation

A legitimate question is, whether the border effect is equally strong across different households, that is, whether any differences in household characteristics can explain within or cross-country price differences. Given that the elasticity of substitution varies by income (Auer et al., 2022; Burstein et al., 2022), we could expect that households also vary in the extent to which they are able to gain from arbitrage (within or across countries). Establishing a causal relationship between household characteristics, such as income or age, and location and prices paid (i.e.the border effect) is, however, not trivial, as any differences in cross border price gaps across households could also reflect differences in their preferences or product availability, i.e. differences in which products and where those products were bought by a household. Handbury (2021) indeed documents that grocery costs vary with income and location: low-income households face less advantageous grocery costs in wealthier cities as stores product assortments represent more the consumption of wealthier households (for which they also charge relatively less). However, she also finds that most of the variation in these costs does not derive from prices being different across two locations, but from cross-city differences in product variety. In the preceding analysis of this paper, we found that the border effect is, in relative terms, largest for discounters. As such it might be that we observe a larger border effect for those households shopping more frequently at discounters, but not necessarily because the household shopping at the discounter is in a specific income group.

Our data set allows us to calculate price differences within income groups (see Table 16 in the Appendix for details on the variable definition). We calculate the absolute log

[30] The extent of persistence within and across countries differs somewhat across retailers. There are, however, no systematic differences in how persistent price differences are across retailers. These results can be found in Table 22 in the Appendix.

price difference Y_{irjyt} (for product i, in retailer r, in region pair j, in income group y at time t) at bi-monthly frequency[31] and again estimate the border effect by interacting the region pair dummy with the income group variable similar as in Equation 4.

Table 8: Within income group border effect: price differences

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Income group 1	9.22***	6.39***	15.71***	0.00	(base)
Income group 2	9.03***	6.70***	15.06***	0.00	0.22
Income group 3	9.14***	6.35***	15.64***	0.00	0.90
Income group 4	10.34***	4.63***	14.80***	0.00	0.14

Note: The table shows country and border effect coefficients of the OLS estimation of Equation (4), where the income variable replaces the shop group variable in the interaction term. Barcode-clustered standard errors not reported. Period 2008-2018. Dependent variable: absolute within-retailer and income group y-o-y price difference at a bi-monthly frequency. 196,914 observations. Adjusted R^2 = 0.38. Second last column H_0: border effect = country effect. Last column: H_0: product group border effect = border effect for food. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

As can be seen from Table 8 the border effect does not vary significantly across the four income groups (neither in total or just the additional difference). In line with the Handbury (2021) result, our analysis indicates that the difference in prices in two location across the border (i.e. the border effect) is invariant to income. Similarly, we find no evidence that age – another household characteristic – affects the household-specific border effect.[32] Any variation in the price differences across household may be rather explained by the variation in retailers, where households buy their groceries. In the subsequent section we examine whether the border effect varies with product characteristics.

6.2 Product-specific price differentiation

Given the significant border effect within retailers, one might wonder if the border is visible in the entire assortment or limited to a few categories or products. We now assess whether product-specific price differentiation plays a role, i.e. whether retailers employ product- or product-group-specific pricing strategies, such as maintaining a (persistent) price gap across the border only for specific product groups, including products of a certain origin, despite being sourced at the same cost.

To delve into these issues, we first look at differences across product categories and replace the explanatory retailer variable in Equation (4) with a product category variable

[31]In order to still have sufficiently many observations we loosen the latter part of the restriction of a product being available in both countries AND in the same month, before calculating price differences on a bimonthly basis, at the cost of increasing price variation due to sales and promotions etc.

[32]The definition of the age group variable and regression results can be found in Tables 16 and 17 in the Appendix.

Table 9: WITHIN COICOP BORDER EFFECT: PRICE DIFFERENCES

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Food (11)	10.7***	4.9***	13.9***	0.00	0.00
Non-alc. beverages (12)	6.1***	10.7***	11.7***	0.39	0.00
Alc. beverages (21)	9.8***	3.8	14.7***	0.00	0.02
Household maint. (56)	3.8***	6.6***	15.2***	0.00	0.00
Garden and pets (93)	9.4***	3.4***	16.3***	0.00	0.00
Personal care (121)	4.2***	7.1***	21.1***	0.00	(base)

Note: The table shows country and border effect coefficients of the OLS estimation of Equation (4), where the COICOP 3-digit variable replaces the shop group variable in the interaction term. Barcode-clustered standard errors not reported. Period 2008-2018. Dependent variable: absolute within-retailer y-o-y price difference at a bi-monthly frequency. 333,733 observations. Adjusted R^2 = 0.44. Second last column H_0: border effect = country effect. Last column: H_0: product group border effect = border effect for food. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

and interact it with the border dummies. As Table 9 shows, the (total) cross-border price differences are similar in all product groups. The additional price difference at the border is, however, significantly larger for personal care items (additional 21 percentage points) and particularly smaller for food and (non-alcoholic) beverages (12-14 percentage points). That is, prices of personal care items exhibit a significantly larger additional price gap than food products.

For retailers to profit from such price-differentiation, i.e. for consumers across the border not to detect and exploit this price gap, the differences should not be too persistent. When looking at the first-order autoregressive coefficient for broader product groups,[33] however, we find that personal care items appear to exhibit above average persistent price differences.[34] Price differences of food and beverage products, conversely, which exhibit a smaller additional price gap at the border, are also slightly less persistent across the border. Customers could indeed gain from “cherry-picking” personal care products. They will, however, likely benefit less (or not at all) if they also buy products from other product groups, e.g. food products.[35]

We furthermore look at the products’ origin. As shown, distances do not play any role in explaining the price gap at the border. But in case of a home bias, the origin of the product might do. Unfortunately, the location of the producer is not part of the data set, but a link to the trademark owner can be established via the product’s barcode. We match the barcode with the online GTIN database, the GS1 GEPIR (Global Electronic

[33] Due to small number of observations in COICOP-groups 12, 21, 56 and 93 we merge them into broader groups: “Food & beverages” including alcoholic beverages, “Household & garden” including items for household maintenance, gardening equipment and pet food. We repeated the product category regressions in Table 9 for these groups for comparison, see Appendix Table 18.

[34] Additional autoregressive coefficient at lag one across the border 0.45, in total 0.71 in Table 19 in the Appendix

[35] According to anecdotal evidence from Austrians living in the border region, personal care items are indeed most often named as products with the largest price gap.

Party Information Registry). We then translate the retrieved postcodes[36] into the geo-location of where the product comes from. For simplicity, we distinguish only Austrian, German and third country products. We furthermore use the geo-location within Austria and Germany to identify products originating from the border region, i.e. regional products.[37]

To quantify this, we modify regression Equation (4), now interacting the border and country dummies with the product origin variable instead of a retailer or product group variable. The product origin variable takes five values and distinguishes Austrian and German products originating from the border region, Austrian and German products from outside the border region, and products that originate from a third country. As evident from Table 10, the border effect is again significant, but does not significantly vary by product origin with the exception of Austrian products from the border region which are marginally different from other groups.[38] That is, Austrian products produced close to the border are more uniformly priced in Austria and Germany, than products produced in Germany or in third countries.

While this particular (slightly asymmetric) variation is puzzling and requires further analysis.[39] It might result from bimodal pricing, i.e. that retailers apply a certain (different) mix of uniform pricing and price differentiation to those products. It might be that some companies in this region are able to negotiate uniform prices (and sales prices) with the retailers. It might also be the companies serve the retailers in both countries from a single distribution centre. If both countries are served with the same logistic chain, it may be counter-intuitive or even inefficient (i.e. in terms of an additional accounting effort) to charge different prices on two sides of a border that has no relevance for their business.

7 Conclusion

This paper examines a specific aspect of price and inflation differences for individual products in the euro area. Using a large household panel we compare the transaction prices on both sides of the Austrian-German border. Restricting the sample to a narrow

[36] A barcode or GTIN (Global Trade Item Number) consists of two parts: a company-specific prefix and several product-specific digits. The company prefix has between 7 and 11 digits and reveals the location of the company in terms of its trademark ownership.

[37] We visually inspect cross-border price differences for different product origins and product categories by looking at the distribution of cross-border price differences for Austrian, German and third-country products. In line with the previous results, we find that prices for all products, regardless of origin and type, are more expensive in Austria. See Figure 8 in Appendix B.4.

[38] I.e. third country or German products. If we did not distinguish regional and non-regional products, the border effect of Austrian products overall would still be significantly smaller than those of German and third country products.

[39] Eliminating international brands from the German border sample, for example, reduces the border effect of products from the German border region as well, but it remains significant.

Table 10: Border effect by product origin: price differences

Product origin	within Germany	within Austria (additional)	Cross-country (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
AT, non-border region	8.80***	8.38**	13.52***	0.00	0.15
AT, border region	10.51***	2.62*	9.71***	0.00	0.01
DE, non-border region	9.76***	4.40***	15.18***	0.00	0.76
DE, border region	10.29***	5.46***	17.58***	0.00	0.36
Third country	9.98***	4.81***	14.93***	0.00	(base)

Note: The table shows country and border effect coefficients of the OLS estimation of Equation (4) with product origin dummy entering the interaction term instead of the shop groups, and time trends. Barcode-clustered standard errors not reported. Period 2008–2018. Dependent variable: absolute within-retailer y-o-y price difference at a bi-monthly frequency. 333,327 observations. Adjusted $R^2 = 0.44$. Second last column H_0: border effect = country effect. Last column: H_0: group border effect = "third country" border effect. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

band on both sides of the border combined with the cultural homogeneity and strong economic integration of the region effectively eliminates the most prominent causes of price differences, such as different currencies, distance, preferences and language.

Many products are priced exactly the same on both sides of the border at a given point in time. But most prices differ – in either direction, and many by a significant amount. As the paper shows, neither differences in local costs nor in the composition of retail markets explain these differences.

Rather, we provide evidence that an important part of the "border effect" is present even *within* retailers operating in both countries. That is, households pay significantly different prices for *identical* products at the same retailer depending on the side of the border. Ceteris paribus, the border effect might therefore be the effect of price discrimination. Whereas retailers price-discriminate also within countries, they do so most extensively across the border. The price differences of specific products are not very persistent. The high variation suggests that marketing, i.e. non-fundamental, factors dominate the price setting process.

On top of price differentiation for identical products, we observe vast product differentiation. The similar expenditure shares on product categories point towards similar preferences on both sides of the border. In stark contrast to this, however, the share of products consumed in both countries (under the same barcode, and in particular same branding) is quite small.

Overall, the significance of the pure border effect points towards considerable market power of retailers vis-à-vis consumers. Retailers appear to maximise margins separately on either side of the border. The respective pricing strategies might vary and can imply both uniform pricing with zero price difference and price discrimination with some (optimal) price difference. Given the similarity of preferences in the region, this requires a high cost of arbitrage. Such a cost factor might be the time variation in price differences at the product level. Consumers would gain little from randomly shopping cross-border. Exploiting the price differences would entail the effort of price comparisons at each point in time, and might be feasible only for certain product categories.

Combining the evidence presented in the paper puts the relevance of national borders into perspective. Ceteris paribus, national borders might not matter that much. The cost of spatial arbitrage is non-negligible, even within a country, reflected in smaller, but non-negligible price differences between same-country regions. Crossing the Austrian-German border imposes virtually no additional cost on the shopper, implying a similar cost of arbitrage between cross-border and same-country regions. We argue that given the cost of spatial arbitrage, retailers can freely choose where to differentiate prices, if they intend to do so. Their choice to differentiate prices exactly along the national border – as opposed to some other random line on the map – is most likely due to their existing logistics network and thus history-dependent.

Unlike the LOP in its absolute version, which fails to hold within our border region, the LOP in its relative version appears to hold approximately. As a result, price changes are less dispersed across the Austrian-Bavarian border than price levels. Similar aggregate inflation rates in both countries conceal large, asynchronous price changes in the two countries. Common cost shocks, e.g. to the price of energy or other commodities, move prices in both countries in the same way. At the product level, this common factor is dwarfed by product-specific pricing. Two countries can therefore share similar price-setting and a similar inflation process despite a large "border effect" in price levels. As the pure border effect identified in this paper does not involve any form of price stickiness, cross-country price heterogeneity is unlikely to affect the transmission of monetary policy.

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A Data appendix

A.1 Data sources

A.1.1 Regional statistics

Real estate prices for Austria are based on the real estate price statistics by Statistik Austria. For Germany, they are based on the regional statistics database GENESIS. The data source for municipal corporate tax multipliers in Germany is Destatis. GDP per capita is obtained from Eurostat (harmonized definition) at the NUTS3 level and mapped to our regions.

A.1.2 Distances

We assign the regional information of each household to geographical coordinates (latitude and longitude). In Austria, the coordinates of the geographical center point of each political district are computed from the official shape file of Austrian provinces, augmented by information on OpenStreetMaps. In Germany, the geographical center point coordinates are taken from the "list of municipalities information system" of Destatis. Unlisted postal codes are manually translated into the name of the municipality using information from OpenStreetMaps and other public sources.

The distance to the border is calculated as the linear distance – more precisely the length of the shortest curve along the surface of the earth – to the nearest region in the other respective country.

A.2 Data preparation

The household panel for Germany is available for a longer time period than for Austria. In this paper, we restrict the data to the common sample period from January 2008 until December 2018. Products without a barcode are excluded. Where necessary, we align the Austrian and German price reporting based on the volume per unit information.[40] If the reported price per unit for a given barcode differs between the two countries by more than a factor of four, while the reported volume per unit differs only little, we consider these two as different products and therefore exclude that barcode from the cross-country analysis.

The 60km sample contains German households in Bavaria (postal areas starting with 82, 83, 84, 85, and 94) and Austrian households in parts of Upper Austria (political

[40] For identical products, i.e. products with the same barcode, the two countries might differ in their reporting. One country might report the price per multipack, whereas the other might report the price per individual item.

districts Braunau am Inn, Eferding, Grieskirchen, Linz (Stadt und Land), Ried im Innkreis, Rohrbach, Schärding, Urfahr (Umgebung), Vöcklabruck, Wels (Stadt und Land)), part of Salzburg (districts Hallein, Salzburg (Stadt und Umgebung), St. Johann im Pongau, Zell am See) and part of Tyrol (districts Innsbruck (Stadt und Land), Kitzbühel, Kufstein, Schwaz).[41] We exclude an observation if the reported postal code (in Germany) or the reported political district (in Austria) does not fit to the reported federal state.

A.2.1 Product categories

To ensure consistency of the Austrian and the German dataset, we manually align the classification of products into COICOP categories between Austria and Germany down to the five-digit level. The analysis uses only the COICOPs which are well represented in the sample, that is, the COICOPs 1.1 (food), 1.2 (non-alcoholic beverages), 2.1 (alcoholic beverages), 5.6 (household maintenance), 9.3 (recreational items/equipment and pet food) and 12.1 (personal care). We exclude meat and fish (COICOPs 1.1.2 and 1.1.3), because these categories are not part of the Austrian sample. Furthermore, we exclude 9.3.3 (garden, plants and flowers) and 12.1.1 (hairdressing salons and personal grooming establishments) because of very few products in the sample.[42]

A.2.2 Retailers

Our focus is on stationary retailers present in both countries. Accordingly, we do not consider transactions in speciality stores, such as bakeries, gas stations, or hardware stores. Likewise, we exclude a transaction if the store name is unknown – typically because the store does not belong to a national chain. We do not consider the (small amount of) sales via self-service (vending machines) and home delivery (door-to-door). To augment our sample of international retail chains, we keep the largest single-country retailer in each country for the within-country statistics.

The restrictions on key COICOPs and key retailers reduce the number of barcodes by about one third in Austria and by about one forth in Germany, as shown in the upper part of Table 11. The upper part also shows that the number of transaction shrinks less, reflecting that the excluded items and stores are indeed somewhat exotic. The relatively strong decline of expenditure in Germany is due to outliers.

[41]In Austria we exclude political districts if their driving distance to the border is disproportionally larger than the linear distance. The 100 km sample considered in Figures 1 and 3 for Austria covers 38 political districts (including those listed in the main text), and the 100 km sample for Germany covers parts of the postal areas 80, 81, 86, 87, and 93 (in addition to those listed in the main text).

[42]When assessing cross-border product or category shares, we exclude also 2.1.2 (wine), because this category appears underreported in the Austrian sample.

Table 11: DATA PREPARATION

Border region	Product subset (after ... selection)	Austria trans-actions (count, '000)	Austria expen-diture (euro, '000)	Austria bar-codes (count)	Germany trans-actions (count, '000)	Germany expen-diture (euro, '000)	Germany bar-codes (count)
	all	49.4	124.4	184,591	113.1	228.8	331,655
100 km	main COICOPs	47.2	118.1	175,641	98.8	196.9	296,694
	+ main retailers	42.3	98.6	131,623	90.1	170.4	260,705
	main retailers	28.5	66.4	120,077	29.8	56.1	196,732
	+ in both countries	5.6	15.7	34,110	7.5	16.6	34,110
60 km	+ within same month	2.5	6.4	18,479	2.5	5.4	18,479
	+ within same retailer	2.1	5.2	14,469	2.0	4.3	14,449
	+ cross-border	0.9	2.1	12,546	0.9	1.9	12,546

Note: Sample period 2008–2018. 19 regions per country within a 60 km band. Only products with a barcode. The columns "transactions" and "expenditure" report the average per month. The column "barcodes" reports the number of unique barcodes during the entire sample period. Product selections are incremental from row to row. For example, the first column of row "60 km + in both countries" reports the number of transactions in the 60km-wide border region of Austria of products (belonging to one of the COICOPs listed in section A.2) sold in both the Austrian and the German 60km-wide border regions. The selection criterion "within same retailer" applies to the respective country only. The final selection criterion "cross-border" requires the product to be purchased at the same retailer in the same month in both countries.

The lower part of the table restricts the sample to the 60 km band along both sides of the border, which we use in the main analysis. Thereafter, the sample shrinks already by a non negligible amount. However, once we restrict the sample to those products that are available on both sides of the border, the sample in terms of unique products decreases to not even a third in the case of Austria and to less than a fifth in the case of Germany. Restricting the sample to occur in both countries in a given month almost halves the sample. In order to obtain the final dataset and calculate price and price change differences, products need to occur at least twice within the same retailer and twice in any two different regions (e.g. in two German regions). A further specification, which is printed in the last row of Table 11, is that a given product needs to be purchased in two regions that lie on each side of the border.

A.3 Regions

We distinguish 38 regions, 19 in Germany and 19 in Austria. In Austria we use as regions the political districts ("Bezirke"), in Germany the two-digit postal areas. To obtain regions of similar size and compact shape we combine and split some of these districts respectively postal areas. Except in the regression discontinuity graphs we include only households which reside less than 60 kilometers away from the border.

Table 12 shows how the typical sample size per region in 2018 shrinks as we require purchases in both countries, in a narrower time interval, within the same retailer and

Table 12: Region summary statistics (average per region, 2018)

Product subset (after ... selection)	Austria trans-actions (count)	Austria expen-diture (euro)	Austria bar-codes (count)	Germany trans-actions (count)	Germany expen-diture (euro)	Germany bar-codes (count)
main retailers	1490	3756	7159	1727	3397	9319
+ in both AT+DE	302	874	1696	435	976	2257
+ within 1 month	142	381	806	155	335	851
+ within same retailer	116	305	623	125	266	638
+ cross-border	49	128	333	51	107	348

Note: Main COICOPs and retailers during 2018. 19 regions per country within a 60 km band. The columns "transactions" and "expenditure" report the average per month during 2018. The column "barcodes" reports the number of unique barcodes among the transactions during the year 2018. Product selections are incremental from row to row. Quantities are averages per region in the respective country. See notes to Table 11 for more details.

in two different locations. The average transaction (i.e. the purchases of some amount of a given barcode at a given retailer in a given month) amounts to about 2.5 euros in Austria and to about two euros in Germany.

As a robustness check, we use a coarser regional split, distinguishing only 6 regions (3 in Germany, 3 in Austria). These are also the regions for which we show the regional statistics in Table 1. For Austria we use "Northern Upper Austria", "(part of) Salzburg and Southern Upper Austria", and a "(part of) Tyrol". Likewise we use in Germany "Eastern Upper Bavaria", "Western Upper Bavaria", and "Lower Bavaria". Again we restrict the sample in most analyses to regions which are less than 60 kilometers away from the border.

A.4 Barcodes

Table 13 shows the composition of the sample of products sold in both the Austrian and the German border region during two-month intervals at least twice within the same retailer and available in at least two regions (see restrictions of Table 12) by COICOP 3-digit group. Expenditure is dominated by food, followed by personal care. The transactions in food amount to only approximately two euros each, and are thus much smaller than in beverages, where a single transaction amounts to about 4.5 euros (non-alcoholic) and about nine euros (alcoholic). With more than 4500 barcodes, personal care offers the largest variety (and thus heterogeneity between households) relative to the number of transactions.

Table 13: Barcode summary statistics (joint barcodes)

product category	bar-codes (count)	Austria trans-actions (count)	Austria expen-diture (euro)	Germany trans-actions (count)	Germany expen-diture (euro)
Food	6,647	1,489	3,287	1,393	2,479
Non-alcoholic beverages	683	86	386	81	372
Alcoholic beverages	149	16	141	17	156
Household maintenance	1,194	65	203	81	189
Hobbies and pet food	850	123	377	136	275
Personal care	4,612	171	524	198	506

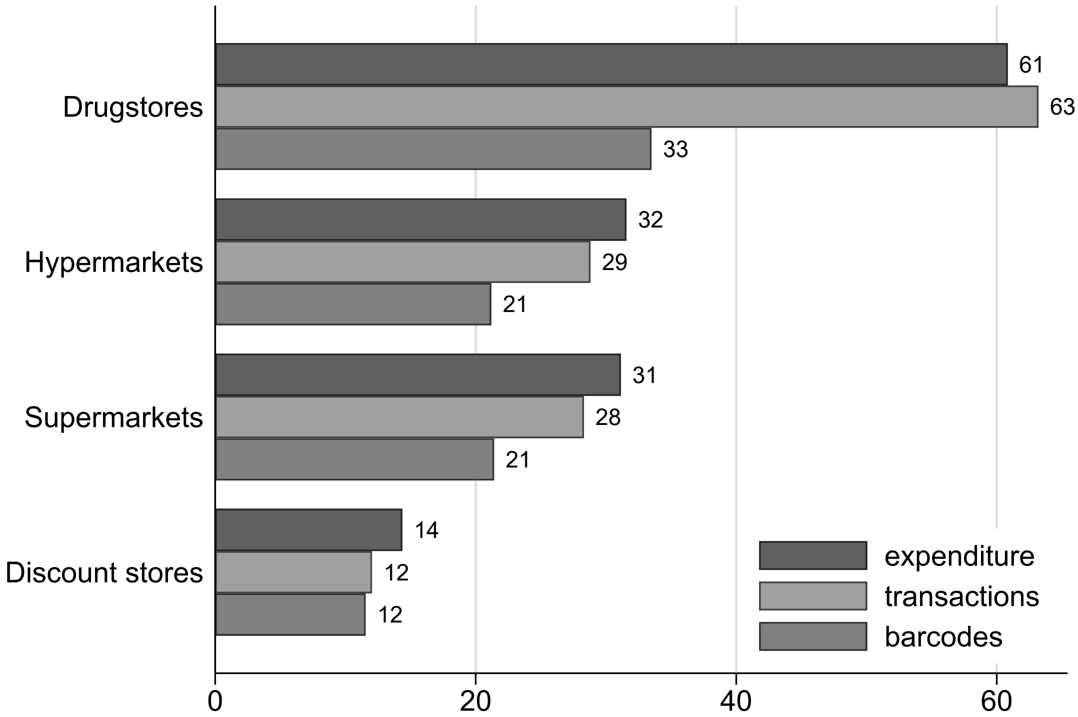
Note: Sample period 2008–2018. 19 regions per country within a 60 km band. Only joint barcodes within two-month intervals. The column "barcodes" reports the number of unique joint barcodes during the entire 2008–2018 period and the columns "transactions" and "expenditure" the average per month.

B Robustness and further results

B.1 Common barcodes by retailer type

Figure 7 shows that drug stores have the highest share of products sold in both countries, most likely due to the large share of internationally branded items in their assortment. Discounters mark the opposite end of the scale. Their store brands are often country-specific, and therefore available in only one of the two countries.

Figure 7: Common barcodes by retailer type (percent)



Note: Share of expenditure and transactions in products sold in both regions among all purchases in either region for a given cross-border pair, in percent. Share of barcodes sold in both regions for a given pair relative to all barcodes sold in this region pair. Sample period 2008-2018. Average over all cross-border region pairs.

At all types of retailers expenditure and transaction shares are roughly equal, which means that products available in both countries have a similar price distribution as the remaining products. The common products in drugstores attract an even larger share of shopping expenditure, i.e. they are high-turnover products. This applies to common products in the other store types as well, but is there less pronounced than for drugstores.

B.2 Coarser regions

The more finely we break up the border region, i.e. the more regions we distinguish, the more homogeneous are the resulting regions. In the main text of the paper we distinguish 38 regions, 19 in Germany and 19 in Austria. The homogeneity of the spatial strata comes at the cost of fewer transactions within a given time period, and therefore fewer contemporaneous cross-region price pairs. In this section we verify the robustness of our results to a coarser regional split, which distinguishes only three regions on each side of the border, but on the upside allows comparing prices within a narrow time window. Six regions allow nine pairwise cross-country comparisons, plus three within each country.

Table 14 shows that despite the different aggregation the magnitude of the border effect is similar as in the main specification (Table 2). The higher aggregation entails very high within-country basket correlations (columns 1 and 2) and common barcodes shares (column 3). The border effect in baskets changes relatively little, but remains significant. In common barcodes, however, it is now twice as big as in the less aggregated setup.

B.3 Controlling for distance

Table 15 repeats the regressions in columns (4) and (5) of Table 2, now including the distance between regions as control variable.

The results show that the absolute price difference increases with distance, but the magnitude of the border effect remains unchanged.

B.4 Price differences by product origin

In this section we distinguish products by their origin (as in section 6.2). In line with the previous results, we find that the prices for all products – regardless of origin and type – are more expensive in Austria. Furthermore, the median (non-absolute) price differences (solid blue lines in Figure 8) are largely similar across product groups.

Table 14: Border effects (15 region pairs)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Basket correlation		Common barcode share	Absolute price difference		Abs. price change difference	Abs. price change difference
	(COICOP4)	(COICOP5)					
Constant	0.98***	0.97***	0.40***	5.74***	7.22***	12.16***	12.28***
(Germany)	(0.006)	(0.006)	(0.006)	(0.376)	(0.339)	(1.185)	(0.753)
Austria	0.01*	0.01	0.08***	3.00***	2.12***	-0.59	1.80
	(0.008)	(0.008)	(0.008)	(0.528)	(0.425)	(2.019)	(1.019)
Border	-0.06***	-0.17***	-0.34***	16.23***	14.705***	5.53***	4.31***
	(0.006)	(0.001)	(0.007)	(1.039)	(0.585)	(1.506)	(0.791)
Common trend	0.00	0.00	0.002**	-0.003***	0.01**	0.02	0.03**
(Germany)	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.013)	(0.009)
Austria trend	-0.00	-0.00	-0.002**	0.01***	0.01*	0.04	0.02
	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)	(0.022)	(0.012)
Border trend	-0.01***	-0.01***	0.00	0.01***	0.01	-0.04	0.00
	(0.001)	(0.001)	(0.00)	(0.003)	(0.007)	(0.023)	(0.011)
Frequency	yearly	yearly	yearly	weekly	monthly	monthly	bi-monthly
Observations	165	165	165	101,518	215,565	13,161	44,696
Adj. R^2	0.92	0.98	0.99	0.17	0.14	0.07	0.04

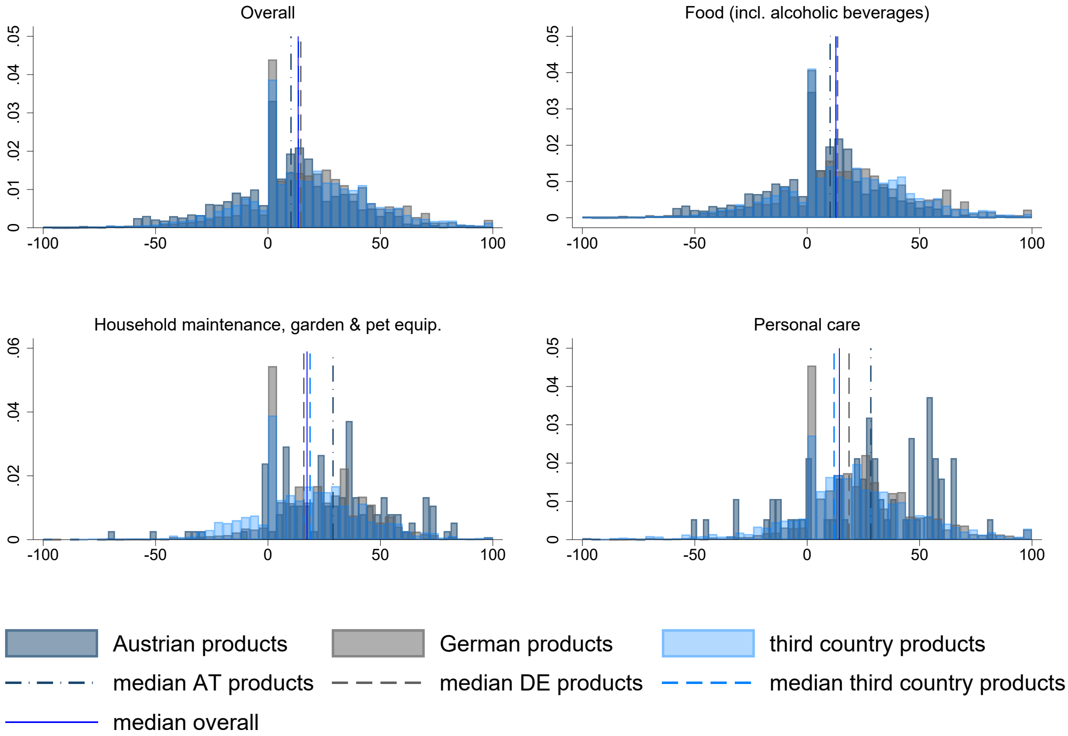
Note: Sample period 2008–2018. 15 region pairs. Standard errors in parentheses (columns 4-6 robust, barcode-clustered standard errors). OLS regressions. Time and retailer controls in columns 4-6 not reported. Dependent variables: (1/2) pairwise correlation of COICOP4/COICOP5 composition of (annual) baskets of each region pair, (3) common barcodes in each region pair as share of all barcodes in the region pair, (4-5) absolute, within-retailer (log) price difference of each region pair at weekly and monthly frequency, (6-7) absolute, within-retailer y-o-y price change difference at a monthly and bi-monthly frequency. Germany effect in (1)-(3) is the constant, in (4)-(7) sum of constant + avg. coefficient of retailer controls + avg. coefficient of month controls. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Table 15: Border effects

	(1) Abs. price difference	(2) Abs. price change difference
Constant	7.78***	11.08***
(Germany)	(0.404)	(1.159)
Austria	2.82***	2.25
	(0.519)	(2.008)
Border	15.16***	4.57***
	(0.695)	(1.412)
Common trend	0.00	0.01
(Germany)	(0.008)	(0.012)
Austria trend	0.01	0.04
	(0.006)	(0.027)
Border trend	0.01	-0.01
	(0.008)	(0.018)
Distance	0.004***	0.002
	(0.001)	(0.002)
Frequency	bi-monthly	bi-monthly
Observations	333,733	44,294
Adj. R^2	0.12	0.07

Note: Sample period 2008–2018. 703 region pairs. Robust, barcode-clustered standard errors in parentheses. Estimation by ordinary least squares. Bi-month and retailer controls not reported. Dependent variables: (1) absolute within-retailer (log) price difference and (2) absolute y-o-y price change difference of each region pair bi-monthly frequency. Germany effect is the sum of constant + avg. coefficient of retailer controls + avg. coefficient of month controls. "Distance" refers to the distance between two regions of a region pair in kilometers. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Figure 8: Price differences by product origin



Note: The histograms show the (non-absolute) cross-border log price differences in percent (Austrian minus German prices) for Austrian, German and third-country products overall and by product category. The dashed lines refer to the median of the respective distribution

The distributions of overall and food price differences exhibit a more pronounced bimodal distribution for products originating from Austria, with one mode at zero and a second one at the median, i.e. at a – potentially – optimal value in terms of price discrimination. This pattern could indicate that for certain products and under certain circumstances, both pricing strategies, i.e. uniform pricing and price differentiation can be optimal. Overall, cross-border price differences seem to be somewhat smaller for products originating from Austria. This result is driven by food products, while for personal care, household and garden items the price differences are larger for products originating from Austria.

B.5 Border effect along household and product characteristics

Table 16 shows the definition of age and income groups of the households in our sample used to compute log price differences, Y_{irjyt}, within income and age groups. The groups were chosen according to quartiles. The age variable is defined as age of household head in years, which is a continuous variable in the Austrian, but grouped in age brackets in the German dataset. The income variable is defined as monthly income in euro of the head of the household. The income brackets provided in the raw data differ between the two countries and are therefore combined in such a way that they roughly align across the two countries.

Table 16: Age and income groups in Austria and Germany

			Age (of household head, in years)			
		Bracket	Obs.	Mean	Min	Max
AT	1	$\geq p25$	190,838	32	16	37
	2	$> p25 \wedge \leq p50$	185,645	42	38	47
	3	$> p50 \wedge \leq p75$	178,274	53	48	58
	4	$> p75$	182,531	66	59	94
DE	1	$\leq p25$	288,253	33	18	37
	2	$> p25 \wedge \leq p50$	241,342	45	42	47
	3	$> p50 \wedge \leq p75$	241,316	54	52	57
	4	$> p75$	215,168	67	62	77

			Income (of household head, in euro)			
		Bracket	Obs.	Mean	Min	Max
AT	1	$\leq p25$	225,741	1,551	400	2,025
	2	$> p25 \wedge \leq p50$	151,223	2,384	2,175	2,550
	3	$> p50 \wedge \leq p75$	207,175	3,132	2,850	3,450
	4	$> p75$	153,149	5,000	5,000	5,000
DE	1	$\leq p25$	280,964	1,459	300	1,875
	2	$> p25 \wedge \leq p50$	277,278	2,366	2,125	2,625
	3	$> p50 \wedge \leq p75$	230,491	3,089	2,875	3,375
	4	$> p75$	197,346	4,571	3,625	6,250

Table 17 suggests a marginally larger border effect in the purchases of older shoppers.

Table 17: Within age group border effect: price differences

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Age group 1	8.88	5.69	15.11	0.00	(base)
Age group 2	9.33	6.20	14.83	0.00	0.62
Age group 3	9.77	6.47	15.26	0.00	0.83
Age group 4	8.22	6.36	16.71	0.00	0.09

Note: The table shows country and border effect coefficients of the OLS estimation of Equation (4), where the age variable replaces the shop group variable in the interaction term. Barcode-clustered standard errors not reported. Period 2008-2018. Dependent variable: absolute within-retailer and income group y-o-y price difference at a bi-monthly frequency. 206,320 observations. Adjusted R^2 = 0.38. Second last column H_0: border effect = country effect. Last column: H_0: product group border effect = border effect for food. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Tables 18 and 19 show the most permanent border effect within personal care items.

Table 18: WITHIN BROADER COICOP BORDER EFFECT: PRICES

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Food & beverages	10.5***	5.2***	13.8***	0.00	0.00
Household & garden	6.4***	5.4***	15.6***	0.00	0.00
Personal care	4.2***	7.1***	21.1***	0.00	(base)

Note: The table shows country and border effect coefficients of the OLS regression as in Equation (4) with time trends (barcode-clustered standard errors) by product group, where "food & beverages" refers to COICOP groups 11, 12 and 21, "household & garden" to the COICOPs 56 and 93 and "personal care" to COICOP 121. 703 region pairs. Period 2008–2018. Dependent variable: absolute, within-retailer y-o-y price difference at a bi-monthly frequency. 333,733 observations. Adjusted $R^2 = 0.44$. Second last column H_0: - country effect + border effect = 0. Last column: H_0: - base group border effect + other group border effect = 0. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Table 19: WITHIN COICOP FIRST LAG AUTOREGRESSIVE COEFF. OF PRICE DIFFERENCES

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Overall	0.24***	-0.07***	0.28***	0.00	0.00
Food & beverages	0.19***	-0.05**	0.25***	0.00	0.00
Household & garden	0.33***	-0.08	0.30***	0.00	0.01
Personal care	0.26***	0.003	0.45***	0.00	(base)

Note: The table shows the within- and cross-country autoregressive coefficients of price differences between the 15 region pairs from an OLS regression by product group. "Food & beverages" refers to COICOP groups 11, 12 and 21 (46,212 observations), "household & garden" to the COICOPs 56 and 93 (5,828 observations) and "personal care" to COICOP 121 (5,087 observations). Dependent variable: absolute log price differences. Explanatory variables: interaction of first lag of absolute log price difference with regional dummy. Sample period 2008–2018. Trend, bi-month and retailer controls not reported. Second last column H_0: - country effect + border effect = 0. Last column: H_0: - base group border effect + other group border effect = 0. Robust standard errors (not reported). Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. Bi-monthly frequency.

B.6 More granular regions (price difference regression)

Table 20 repeats the persistence analysis, distinguishing 19 instead of three regions per country.

Table 20: PERSISTENCE OF PRICE AND PRICE CHANGE DIFFERENCES

Offset	2 months	4 months	6 months	1 year
Price differences				
Germany (basis)	0.24***	0.19***	0.23***	0.17***
Austria (additional)	-0.06	-0.01	-0.08*	-0.03
Border (additional)	0.35***	0.38***	0.33***	0.36***
Observations	10,883	9,070	8,095	7,614
R^2	0.24	0.22	0.21	0.13
Price change differences				
Germany (basis)	0.25***	0.24***	0.24***	0.38***
Austria (additional)	-0.17***	-0.08	-0.11	-0.05
Border (additional)	0.01	-0.08	-0.04	-0.06
Observations	5,917	5,315	4,834	9,247
R^2	0.12	0.12	0.13	0.17

Note: Sample period 2008-2018. 703 region pairs. Bimonthly frequency. The table shows the within- and cross-country autoregressive coefficients of price differences by length of lag from an OLS regression. Explanatory variables: interaction of first, second, third and sixth lag of absolute log price difference (columns) with regional dummy (rows). Trend, bi-month and retailer controls not reported. Dependent variable, upper panel: absolute, within-retailer (log) price difference. Dependent variable, bottom panel: absolute, within-retailer y-o-y price change difference. Robust, barcode-clustered standard errors (not reported). Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

Table 21: Within COICOP first lag autoregressive coeff. of price differences

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within-ctry (p-value)	Test border effect diff. (p-value)
Overall	0.24***	-0.06*	0.35***	0.00	0.30
Food & beverages	0.21***	-0.03	0.34***	0.00	0.33
Household & garden	0.30***	-0.07	0.33***	0.00	0.26
Personal care	0.21*	0.33*	0.48***	0.44	(base)

Note: The table shows the within- and cross-country autoregressive coefficients of price differences between the 703 region pairs from OLS regression by product group, where "food & beverages" refers to COICOP groups 11, 12 and 21 (8,864 observations), "household & garden" to the COICOPs 56 and 93 (985 observations) and "personal care" to COICOP 121 (1,034 observations). Dependent variable: absolute log price differences. Explanatory variables: interaction of first lag of absolute log price difference with regional dummy. Sample period 2008–2018. Trend, bi-month and retailer controls not reported. Second last column H_0: - country effect + border effect = 0. Last column: H_0: - base group border effect + other group border effect = 0. Robust standard errors (not reported). Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. Bi-monthly frequency.

Table 22: Within-retailer first lag autoregressive coeff. of price differences

Product group	within Germany	within Austria (additional)	Cross-ctry (additional)	Test cross-ctry = max. within (p-value)	Test border effect diff. (p-value)
Overall	0.24***	-0.07***	0.28***	0.00	0.00
Supermarket A	0.29***	0.00	0.23***	0.00	(base)
Supermarket B	0.19***	-0.11	0.20***	0.00	0.41
Discounter C	0.03	0.03	0.78***	0.00	0.00
Discounter D	0.28***	-0.15***	0.30***	0.00	0.06
Discounter E	0.01	0.00	0.38***	0.00	0.14
Discounter F	0.28***	-0.13	0.26***	0.00	0.68

Note: The table shows the within- and cross-country autoregressive coefficients of price differences between the 15 region pairs from OLS regression by retailer. Dependent variable: absolute log price differences. Explanatory variables: interaction of first lag of absolute log price difference with regional dummy. Sample period 2008–2018. Trend, bi-month and retailer controls not reported. Second last column H_0: - country effect + border effect = 0. Last column: H_0: - base group border effect + other group border effect = 0. Robust standard errors (not reported). Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level. Bi-monthly frequency.