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Teresa Messner, Fabio Rumler, Georg Strasser

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

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This paper contains research conducted within the Price Micro Setting Analysis Network (PRISMA). PRISMA consists of economists from the ECB and the national central banks (NCBs) of the European System of Central Banks (ESCB).

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PRISMA collects and studies various kinds of price microdata, including data underlying official price indices such as the Consumer Price Index (CPI) and the Producer Price Index (PPI), scanner data and online prices to deepen the understanding of price-setting behaviour and inflation dynamics in the euro area and EU, with a view to gaining new insights into a key aspect of monetary policy transmission (for further information see https://www.ecb.europa.eu/pub/economic-research/research-networks/html/researcher_prisma.en.html).

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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 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 21%. These price differences are not very persistent indicating little arbitrage gain from undifferentiated cross-border shopping. Ensuing product-level inflation rates differ for only half of the chains. The results highlight the importance of the history-dependent evolution of distribution networks and of the structure of the sales organization 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

Non-technical summary

The "law of one price" (LOP) states that in a frictionless world the price of a product traded in two countries is the same. The "frictionless world" refers to a hypothetical, limiting case – a stylized world free of administrative, cultural, or technical trade restrictions, with free movement of goods and perfect competition, in which market participants can exploit any looming arbitrage opportunity right away. But country pairs with entirely frictionless cross-border markets are rare. Numerous studies have documented persistent deviations from the LOP, even among neighboring countries. There is yet no definite answer whether purely administrative national borders can cause such deviations.

This paper studies the causes of price differences at a border within an almost ideal setting: a national border dividing an otherwise largely integrated region. The border region of Austria and Germany is not only characterized by strong economic and cultural ties, such as a common currency and language and being part of the European Union, but constitutes also an integrated retail market as several retail chains are active in both countries. To rule out confounding factors as far as possible, we limit the sample region to a 60 kilometer wide band along both sides of the border. Within this region, classical trade barriers, exchange rates, and distance should therefore not matter for the pricing decisions of retailers.

The sample builds on the GfK household panel for Austria and Germany from 2008 to 2018. It covers transaction-level prices of fast-moving consumer goods, which are primarily food and personal care items sold in supermarkets. The barcode information ensures a comparison of identical products across multiple locations in both countries. As six of the eight retail groups in our study operate (not necessarily under the same name) in both countries, our setting allows for a comparison of prices across the border even *within* retail groups.

The cross-border differences in local costs and supply factors, such as taxes, land prices and retail structure, are minor. Differences in high-level consumption preferences can also be ruled out as source of price differences because the consumption baskets at the product-group level (COICOP-4 and 5) are highly correlated across the border between the regions. Despite the similar preferences, the share of products (identified by their barcode) available in both countries is relatively small.

But even those products which are sold on both sides of the border are not sold at the same price. We find substantial differences in prices of identical products across the border which are significantly larger than within either country. The price differences

go in either direction, but on average, prices are about 13% higher on the Austrian side. The distribution of price differences displays a pronounced mode at zero with about 14% of all products being equally priced. Disregarding the observations at the mode, cross-border price differences are centered around a 15% to 18% premium on the Austrian side, suggesting the existence of an optimal (non-zero) cross-border price differential. In absolute terms (positive and negative differences taken together), prices differ on average by 23% between the two countries.

The discrete price jump right at the border is a clear violation of the (absolute) LOP. For price changes, however, we do not find a strong border effect. As the differences in price changes across the border are not significantly stronger than within countries, the LOP seems to hold approximately in its relative version, hinting at common inflation drivers. This suggests that the border effect by itself is unlikely to affect the transmission of monetary policy.

The price differences are not due to differences in retail structure. We trace the border effect to price differences within retail chains. Even retail chains that operate in both countries charge different prices on the two sides of the border. Such systematic differences do not exist for price changes.

We find no evidence that specific household groups (defined by age or income) are disproportionally exposed to price differences. Cross-border price differences are relatively larger for personal care than for food items. This indicates that whereas consumers could realize some arbitrage gains by "cherry-picking" specific products, they would not gain from randomly shopping across the border. Exploiting these arbitrage opportunities would thus require the acquisition of a lot of information by the consumer.

Retailers differentiate prices always and everywhere, also within countries, but they do so most extensively across national borders. Their market power allows them to price discriminate between countries and maximize profits separately on each side. The resulting pricing strategies might differ by product: uniform pricing (zero price difference) for some and price differentiation for other products. The choice to differentiate prices exactly along national borders is most likely due to the retailers' existing logistics networks. Parts of these networks evolved at a time when regulatory differences rendered country-specific distribution networks advantageous. An important part of the border effect might thus be a remainder of the historic evolution of retail markets.

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 barely 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 further 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 U.S.-Canadian border. Gopinath et al. (2011) and Burstein and Jaimovich (2012), on the one hand, document 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 versus within countries. Recent research on Switzerland shows that the exact same products are cheaper in its neighboring countries (Burstein et al., 2022) – but also these prices are quoted in a different currency, which might complicate the cross-border price comparison for the consumer.

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. Mejean and Schwellnus (2009) document that between 1995 to 2004, European economic integration nurtured price convergence as higher arbitrage pressure restrained the firms' choice of pricing strategies – but by no means wiping out price differences completely. 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 for some frequently purchased groceries that price variation between 13 euro area countries is many times larger than the price variation within these countries 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 prices do not vary much with distance to the border within each country, but display a substantial price gap at the border. We show in this paper 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 there. 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

[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).

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 groceries, household maintenance, and personal care items, commonly dubbed "fast-moving consumer goods" (FMCG). Somewhat reassuringly, 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 between the two countries is rather small. Overall, we document a widespread failure of the LOP in its absolute version within this region, whereas the 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 causes 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 vast heterogeneity in pricing across U.S. 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

[2] Gesellschaft für Konsumforschung.

[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).

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 location of price differences reflecting the retailers' pricing strategies and market power (documented by e.g. Mejean and Schwellnus, 2009 for an earlier period of the European Union).

The analysis in this paper proceeds as follows: Section 2 describes the data and region on which our analysis is based. Section 3 establishes the strong economic integration of this border region. Section 4 investigates the large cross-border price and inflation 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. The paper concludes with a discussion of the implications of the main results.

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. The focus on identical products eliminates the heterogeneity bias identified by Handbury and Weinstein (2015) in spatial price index comparisons.

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 and personal care products, but contain also some household maintenance products, pet food, and gardening equipment. The raw 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 trans-

[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.

action 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 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 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

[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.

[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.

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. There are very few border regions in the world where demand and supply conditions on both sides of a national border are that similar. This motivates our use of a regression discontinuity design (RDD), which rests on the assumption that unobserved characteristics do not jump at the discontinuity point.

We implicitly control for distance 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 household that reports the transaction lives with geo-information to calculate several distance measures. We split the border area in Austria and Bavaria 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. 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 taxes nor local costs nor different market structures nor consumption preferences can explain the observed price differences. At best, differences in the local economic power as measured by GDP might be exploited by retailers.

[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 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 have been shaped by the borders as they are today.

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

3.1 Differences in local costs and other supply factors

The value-added tax (VAT) rates differ only slightly between Austria and Germany. With few exceptions, the standard tax rate for 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 for the two countries.

Table 1: Cost and demand factors potentially affecting price setting of retailers

	Property prices (€/m^2)	Corporate taxes (%)	Med. household income ('000€)	GDP per cap. ('000€)	Population ('000)
Austrian border regions					
Northern Upper Austria	151	25.0	33	43	795
Salzburg and Southern Upper Austria	255	25.0	34	41	847
(Part of) Tyrol	514	25.0	34	41	573
German border regions					
Lower Bavaria	76	28.1	30	32	494
Eastern Upper Bavaria	231	27.7	32	34	519
Western Upper Bavaria	538	27.8	34	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. Median household income is the annualized midpoint of the (net) income bracket of the median household covered by the GfK sample. Population counts refer to the end of 2018. Appendix A.1 provides details on the data sources.

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 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, prices appear to be quite similar in the other cross-border region pairs.

[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. The VAT rates in both countries have been constant for the products covered during the entire sample period 2008-2018.

Austria features a uniform corporate tax rate of 25%, while Germany's corporate tax rate contains 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 in the cost structure of retailers.

Different market structures could be another source of international price differences. In the structural issues report of the ECB (2011)[14] Austria and Germany stick out as the two countries within the euro area with the highest share of discounters (Chart 5b ibid.). 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 ibid.). 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 (Tables 5 and 6 ibid.). These findings document that the structure of the retail markets in Austria and Germany at the national level is broadly similar. 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 are similar. Thus the supply side can be viewed as largely identical across the border.

3.2 Differences in local demand

Another potential driver of international price differences are differences in the local demand conditions. When income levels differ, international retailers might be able to increase profits by pricing to market. The net income of the households in our sample, however, is very similar at this aggregation level in both countries (column 3 of Table 1).

Rural areas are spread throughout all border regions, with somewhat more urban cen-

[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 (second column of Table 1).

[14] The structural issues report combines a wide range of national data. Although it 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.

tres on the Austrian side. This might be reflected in the GDP per capita reported in column 4. It is quite homogenous within each country across the three big regions, but about one quarter higher on the Austrian side. This is surprising at first sight as Bavaria as a whole reports a higher income per capita than Austria.[15] Within the border region, however, the situation is reversed. The Austrian regions close to the border include three major cities with more than 100,000 inhabitants (Linz, Salzburg and Innsbruck) while in the respective German border regions (which do not include Munich) the biggest cities (Landshut and Rosenheim) count only around 70,000 inhabitants. Additionally, Salzburg and Innsbruck are well-known tourist centers which contribute heavily to local GDP.

The difference in GDP per capita could incentivize retailers to differentiate prices between the two countries. The direction, however, is not obvious. On the one hand, it is optimal for a retailer to charge higher prices in less densely populated, rural areas (Adams and Williams, 2019), and recent research has shown that food prices in the USA indeed decrease with city size (Handbury and Weinstein, 2015). But as, on the other hand, even the more remote parts of our sampling regions are well connected and economically vibrant, the income difference might dominate the demand elasticity, which would suggest on average higher prices in Austria.

3.3 Differences in preferences

Another key demand-side factor which is in general hard to capture is preferences. However, given the cultural homogeneity of our sample region – 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 on both sides of the border. Because the actual products (identified by a barcode) might differ on both sides of the border for marketing reasons (Broda and Weinstein, 2008), 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] Based on this, we calculate the correlation of the consumption baskets for each region pair j

[15] Over the period 2008-2018, the average GDP per capita amounted to approx. 39,000 euro in Austria and to approx. 41,000 euro in Bavaria. The difference applies to both gross and net income: OECD (2019) reports a similar overall taxation of labor in the two countries. The overall tax on wages including social security contributions amounts to 48.5% in Austria and to 49.7% in Germany (for single earners of average income, sample period 2008-2018).

[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 in Table 2. Furthermore, different package sizes or sometimes even different vintages of the same product carry different barcodes, and are thus excluded. Matching by barcode is the strictest possible mapping of products: It requires the *identity* of products, even in terms of package size. Different package sizes would require the household to calculate the price per unit and potentially to consume the product at different rates. The restriction to identical barcodes excludes such frictions to arbitrage.

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 with the regression equation

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

where for now the dependent variable Y_{jt} refers to the correlation of consumption baskets between region pairs and ϵ_{jt} to independent and identically distributed residuals. The effect of the border is captured by the border dummy $\mathbb{1}^{B}(j)$, which assumes a value of one for cross-border region pairs and zero otherwise. The other independent variables include a country dummy for Austria $\mathbb{1}^{AT}(j)$, which assumes a value of one if the region pair j is within Austria, a time trend t, and interactions of the trend with the two dummies to account for a possible change of country or border effects 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 between within-Austria and between cross-border region pairs, respectively, relative to the within-Germany region pairs.[17]

The first two columns of Table 2 show that the consumption baskets are highly correlated between Bavarian and Austrian border regions. The cross-border correlation is 86% (base plus border effect) at COICOP4 granularity, and still 78% at the more detailed COICOP5 granularity. The consumption structure across the border is slightly less similar than within each country. The correlation shrinks by 0.03 and 0.10, respectively.

A correlation of 78% at the COICP5 level is nevertheless considerable and an indication that differences in consumption are of minor relevance for cross-border price and inflation differences. The three lower rows of columns (1) and (2) in Table 2 show how consumption preferences have evolved over the eleven years in our sample. Whereas Austria and Germany converged in terms of their within-country heterogeneity, the similarity *across* the border did not increase.

4 Border effects

Despite the similar consumption structure, the set of products consumed and available in each country might differ. Prices and price changes might differ as well. In this section we show that this is indeed the case, even in a highly integrated region.

[17] That is, the correlation of consumption baskets of cross-border region pairs is the sum of the estimated border effect and the base level. Specification (1) is applied analogously to price and price change differences in subsequent sections.

Table 2: Border effects

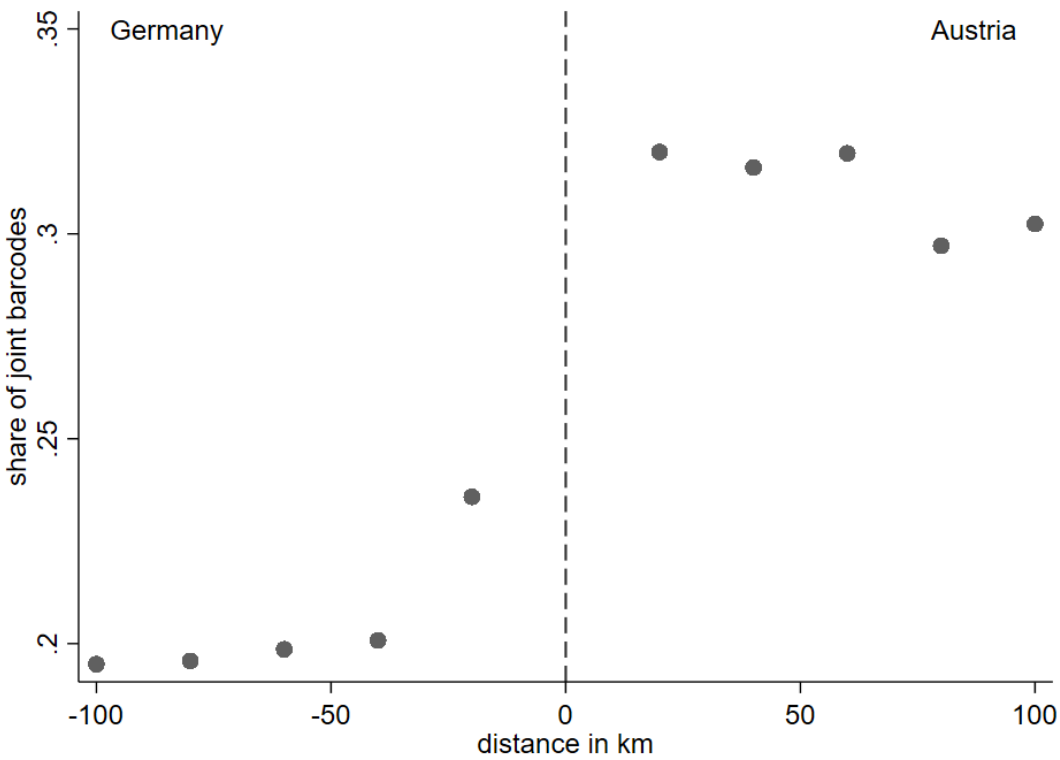
	(1) Basket correlation (COICOP4)	(2) Basket correlation (COICOP5)	(3) Common barcode share	(4) Abs. price difference	(5) Abs. price change difference
Constant	0.89***	0.88***	0.16***	8.11***	11.21***
	(0.004)	(0.003)	(0.001)	(0.40)	(1.14)
Austria	0.05***	0.04***	0.08***	2.91***	2.30
	(0.005)	(0.004)	(0.001)	(0.52)	(2.02)
Border	-0.03***	-0.10***	-0.14***	15.31***	4.64***
	(0.004)	(0.004)	(0.001)	(0.70)	(1.41)
Common trend	0.004***	0.004***	0.001***	0.00	0.01
	(0.001)	(0.001)	(<0.001)	(0.004)	(0.01)
Austria trend	-0.003***	-0.003***	-0.005***	0.01	0.04
	(0.001)	(0.001)	(<0.001)	(0.006)	(0.03)
Border trend	-0.003***	-0.006***	-0.001***	0.01	-0.01
	(0.001)	(0.001)	(<0.001)	(0.008)	(0.02)
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 at bi-monthly frequency. Germany effect in (1)-(3) is the constant, in (4) and (5) the sum of constant, avg. coefficient of retailer controls and avg. coefficient of month controls. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

4.1 Basket differences

We start by comparing products, i.e. barcodes, available in both countries. To do so, 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.[18] 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,[19] i.e. 14 percentage points less than between German regions.

Figure 1: Barcodes common across 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.

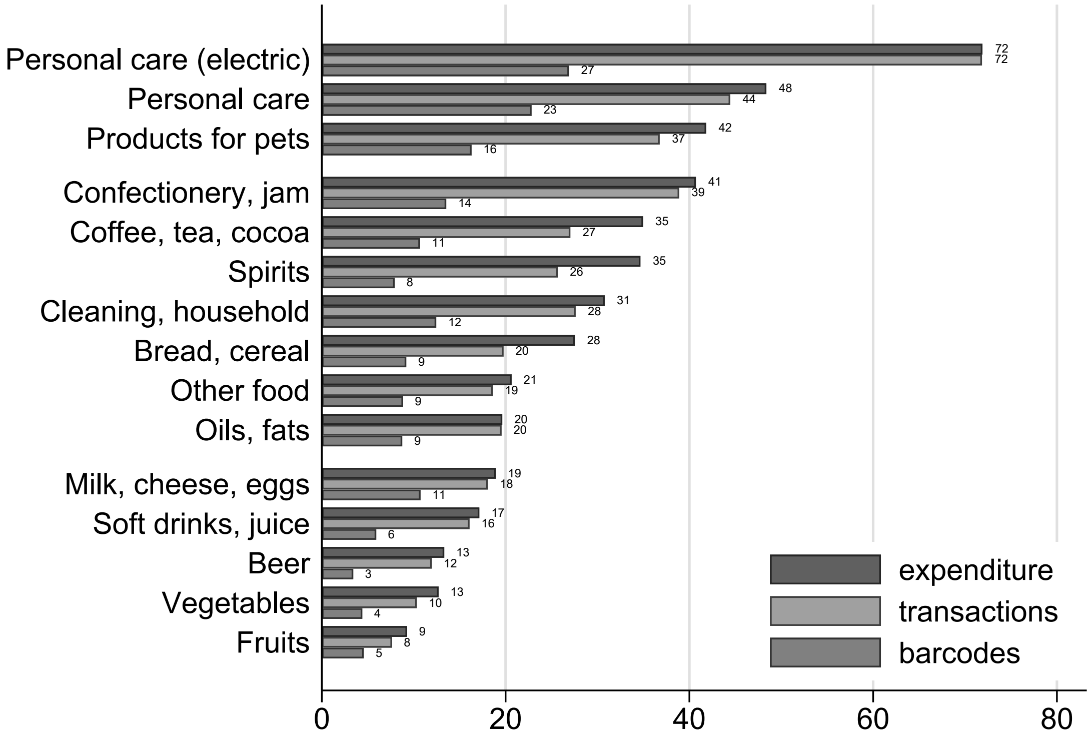
The results in column (3) stand in stark contrast to those in column (2). Even though the households in the two countries share a similar broadly defined consumption basket,

[18] 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 of 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.

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

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 is not grounded in preference differences.

Figure 2: Products sold in border regions of both countries (percent)



Note: Average over all cross-border region pairs. Share of expenditure and transactions in products (barcodes) 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.

Zooming in on expenditure in common barcodes we see stark differences between product categories. Figure 2 shows shares ranging from 9% to 72% of total expenditure depending on the product type. 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 proximity of the regions in our sample – both within and across countries – suggests that transportation costs are also similar, so that distance might not matter for cross-border price differences.

The irrelevance of distance close to the border becomes obvious in a RDD setting,[20] 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 role of distance to the border for prices within a 100 kilometer band is negligible. This mirrors the finding of Burstein et al. (2022) 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 Austrian side (on the right of the zero line) are at least 10% higher than those on the German side.

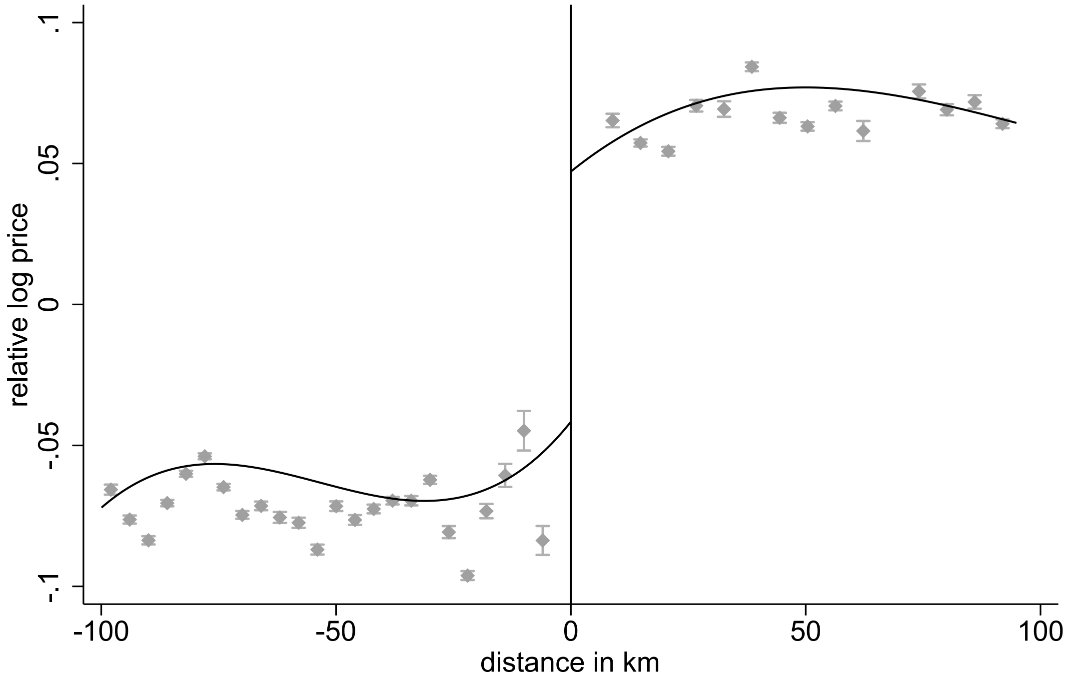
The border leaves its mark on the distribution of prices of individual products. The left panel of Figure 4 plots the (non-absolute) logarithmic price differences per product in each cross-border region pair (Austrian minus German prices). Cross-border price differences are large and go in either direction. Reassuringly, the mode of price differences is at zero, but the mode represents only about 14% of all cross-border observations. The mode for within-country region pairs is far more pronounced. The bar at zero in the right panel of Figure 4 shows a share of zero price differences of about 48% within Austria and of about 56% within Germany.[21]

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

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

[21] See Table 14 in the Appendix for descriptive statistics on barcodes that are always, sometimes or never at the mode of zero. More uniformly priced products, i.e. products which are observed more often at the mode of price difference distribution, tend to be on average somewhat cheaper and more frequently purchased.

Figure 3: Price gaps at the border



Note: Each dot shows the average log price deviation from the mean for each distance bin, together with the respective 95% confidence interval. The solid lines are third-order polynomials 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.

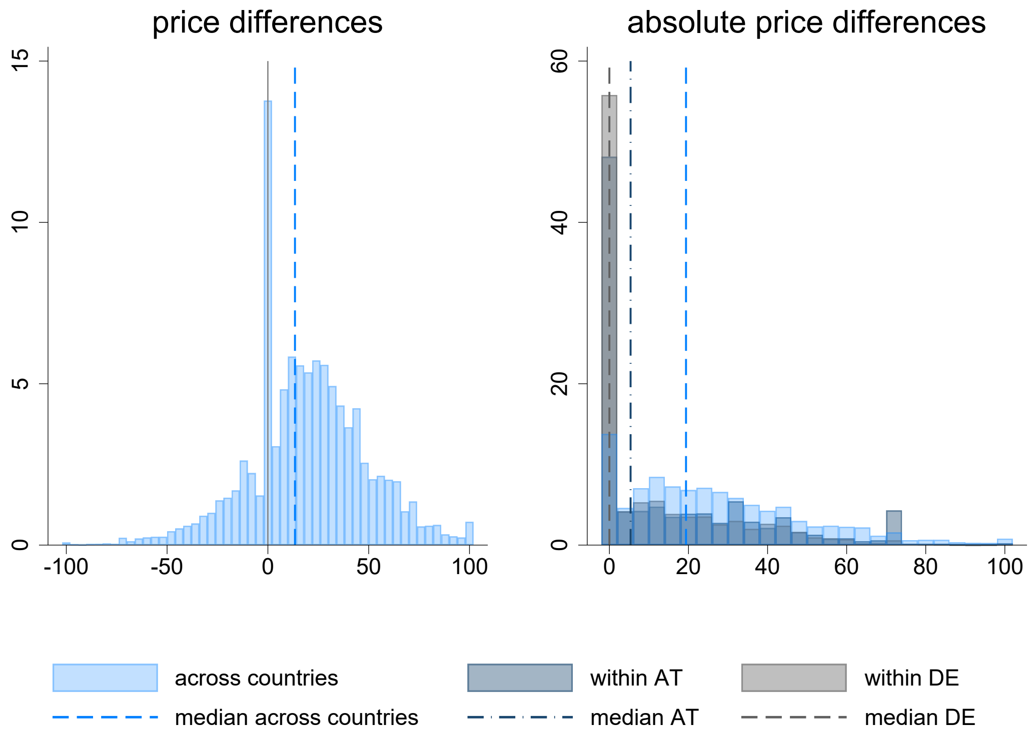
within Austria about 5%; across the border, however, it amounts to almost 20%.

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 18% (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. 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.

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

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

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 dummies, trend variables and interaction terms are defined as in Equation (1), augmented by retailer and (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. The test of the null hypothesis that the border effect equals the Austrian, i.e. largest, country effect is rejected at any common level of significance (p-value: 0.00). This result is robust over time, to different regional delimitations and other specifications, including controlling for distance and income. Both distance and the differences in GDP per capita fail to explain the price differences between the regions of the two countries.[22]

[22] 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 (0.004 percentage points) but significant. Including either variable in Equation (1) does not improve the adjusted R^2 and leaves the remaining coefficients virtually unchanged. Appendix B.5 assesses the link between regional characteristics (income, income growth, age, distance to the border) and the price level directly. Differences in the average income level between the regions do not explain price level differences between Austrian and German regions beyond what is already captured by the border effect.

Table 3: Moments of price differences between regions

	Cross-border					Austria		Germany	
	Δp med.	Δp mean	Δp std.dev.	Δp normal	$\lvert\Delta p\rvert$ med.	$\lvert\Delta p\rvert$ med.	$\lvert\Delta p\rvert$ mean	$\lvert\Delta p\rvert$ med.	$\lvert\Delta p\rvert$ 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: Medians, means, and standard deviations of price differences between regions by type of region pair. 19 regions per country. Sample period 2008–2018. Δp are log price differences. Cross-border price differences are Austrian minus German prices. The column "normal" reports the p-value of testing the null hypothesis that the respective price differences are normally distributed.

4.3 Inflation differences

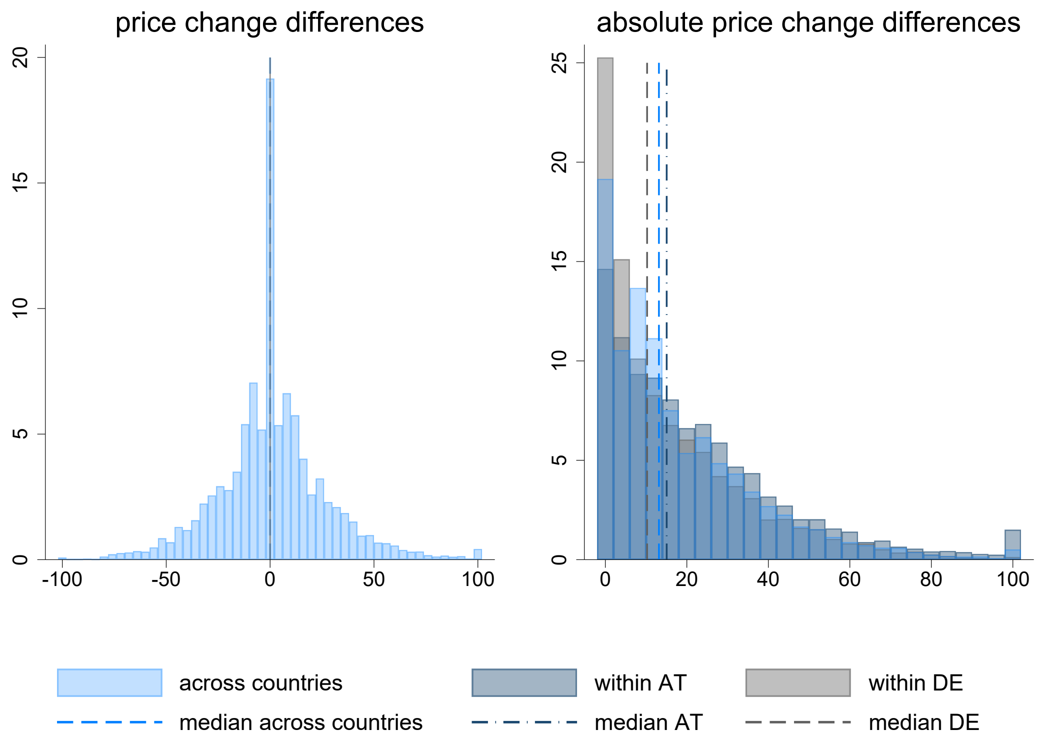
The inflation rates of Austria and Germany are not necessarily synchronized despite the regions' proximity and similarity. The evidence on price differences indicates a failure of the LOP in its absolute form, suggesting that arbitrage is impaired by some frictions. The cost of arbitrage entailed by these frictions bounds the range of arbitrage-free international price differences. If the price differences are already at the no-arbitrage constraint, i.e. if that constraint is binding, the prices of these products will not diverge further. This one-sided bound on relative prices might entail synchronized price changes between countries. In this section, we explore to what extent this weaker condition – LOP in its relative version (e.g. Sarno et al., 2003) – holds between the two countries.

Our dataset allows us to calculate sample inflation rates based on a common basket of identical FMCG products. During the period from 2008 to 2018 these annual inflation rates have been approximately one percentage point higher in the Austrian border region. By comparison, over the same period the official HICP inflation rate of food and beverages is virtually the same in both countries, while the overall HICP inflation rate has been only slightly higher in Austria.

Looking at aggregate figures conceals, however, the heterogeneity of the underlying price change patterns between the two countries. Figure 5 compares 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.

The mode of cross-border price change differences is again zero, which can be seen from the left panel. 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.

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.

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.

The medians, shown as dashed lines in the right panel of Figure 5 and explicitly given in Table 4 suggest furthermore that price changes do not differ more across than within countries. 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 more dispersed across the border than within Germany (rightmost column in Table 2), but this is not significantly different from within Austria (p-value: 0.23). Overall, we cannot reject the relative version of the LOP.

Table 4: Moments of price change differences between regions

	Cross-border					Austria		Germany	
	$\Delta\pi$	$\Delta\pi$	$\Delta\pi$	$\Delta\pi$	$\lvert\Delta\pi\rvert$	$\lvert\Delta\pi\rvert$	$\lvert\Delta\pi\rvert$	$\lvert\Delta\pi\rvert$	$\lvert\Delta\pi\rvert$
	med.	mean	std.dev.	normal	med.	med.	mean	med.	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: Medians, means, and standard deviations of price change differences between regions by type of region pair. 19 regions per country. Sample period 2008–2018. $\Delta\pi$ are price change differences in percentage points. Cross-border price change differences are Austrian minus German prices. The column "normal" reports the p-value of testing the null hypothesis that the respective price change differences are normally distributed.

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 is sustained by different currencies, Burstein et al. (2022) document sizeable welfare effects, particularly for households living close to the border who are more likely to cross it for shopping. The price differences across the border in their study 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 a currency area, however, this may be less clear. Kaplan and Menzio (2015) argue that U.S. households seem unable to time their purchases to fully benefit from temporary sales (in a given store), but that some U.S. 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 the 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 in this analysis we aggregate the households to three regions on each side of the border[23] and transactions to a bi-monthly frequency. We regress the price difference between 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 dif-

[23]For comparison, we report the results with 19 regions in each country in Table 22 of Appendix B.

ference (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 offsets of $\tau = 1, 2, 3, 6$ periods, corresponding to 2, 4, 6 and 12 months.[24]

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.

Table 5: PERSISTENCE OF PRICE AND PRICE CHANGE DIFFERENCES

Offset	2 months	4 months	6 months	1 year
	Price differences			
Germany (base)	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 (base)	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.

In contrast, differences in price changes are not more persistent across the border than within a country. This reflects that spells of price changes in the same direction are constrained by the arbitrage bounds on price differences. 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

[24]The dummies and interaction terms are defined as in Equation (1). Including multiple lags in a single equation leads to small-sample problems. For this reason, we run separate regressions for each lag here.

is rejected by the data.

5 Retail network versus national border

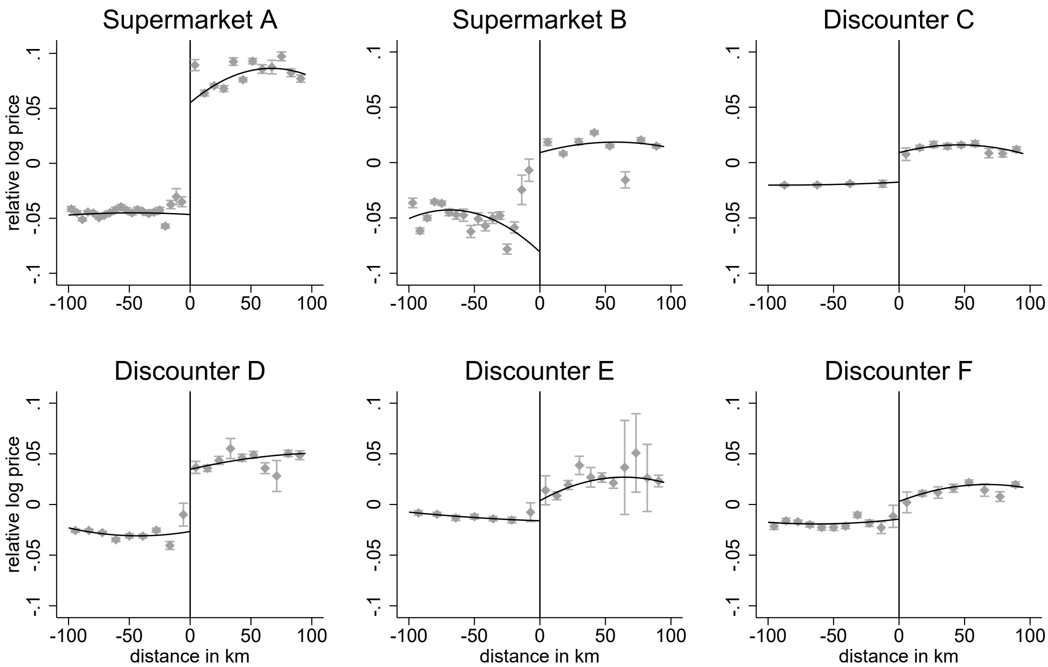
We have documented that even though GDP per capita is slightly different across the border, preferences in the two countries appear to be similar. The prices and price changes of many products, however, differ considerably between the two countries – in either direction. This suggests that consumers 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 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.

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

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.

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 = largest country effect. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

border dummies with the retailer. These interactions capture the within- and across-country effect for each retailer.

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

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 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 somewhat 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.[25] The basic dispersion is small (0-11%) for discounters but reaches 10-16% 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. fewer 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 should be similar across countries within our internationally operating chains. 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

[25] 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.

high. Crossing the border between Austria and Bavaria, however, imposes virtually no (additional) cost on the shopper. This implies that for a given product this national 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.

Uniform pricing *within* countries is very common. DellaVigna and Gentzkow (2019) find substantial unexploited variation in price elasticities across stores within a chain. Uniform pricing entails higher prices in more densely populated (due to more outside options) and in poorer regions (due to tighter budget) than under more granular region-specific pricing, because uniform pricing cannot account for the more elastic demand in these regions. Adams and Williams (2019) show that uniform pricing emerges naturally from strategic complementarities. Competition between chains might reduce the possible extra profit from more price differentiation, and a complete decentralization of pricing might trigger even competition between stores of the same chain. If consumers expect a certain standard of fairness and are able to at least partially monitor compliance, e.g. by easy access to online price information of other stores of the same chain (Ater and Rigbi, 2022), then retailers might adjust their pricing behavior along the lines of Kahneman et al. (1986). Hitsch et al. (2021) even argue that proper store-by-store price differentiation might not be feasible given the estimation uncertainty at such fine granularity, an argument which might extend to price differentiation between very granular regions as well.

Given this within-country evidence and the tight integration of our sample region, why do chains refrain from extending uniform pricing also across the border? There are at least three reason for this, which differ in persistence.

Eizenberg et al. (2021) document that household demand is spatially segmented. They present an example where chains differentiate prices within a city, exploiting the heterogenous mobility of the population. Despite the integration of our sampling region, despite busses and trains connecting towns on both sides in short time intervals, it is likely that mobility across the border is still weaker than within borders. This difference in mobility might make price differentiation profitable, but over time the remaining mobility difference might disappear and with it the basis for price differentiation.

Another cause of spatial segmentation are heterogeneous information sets. Ater and Rigbi (2022) stress how informative advertising can stimulate competition. Cross-border advertising, however, seems to be still uncommon. The information flow across borders requires more than just broadband cables (as in Akerman et al., 2022), but rather an easy information exchange. International price comparison websites, which are not well-established at this point, could reduce information frictions and give bite to the fairness considerations which appear to influence domestic pricing.

Most persistent, however, is the incentive to differentiate prices "somewhere". A country (or relevant part thereof) is large enough to estimate demand elasticities at sufficient precision.[26] National borders might act like pre-set boundaries of marketing regions, which are common knowledge, and can thus simplify coordination between retailers on less granular pricing (see, e.g., Dobson and Waterson, 2005).

Today, the national border between Austria and Bavaria in itself has little economic substance. In the past, however, it did matter for economic activity. It is well known that small variations in historical conditions can affect economic geography down to the present day (Allen and Donaldson, 2020). In their survey, Lin and Rauch (2022) point out that the substantial (historical) sunk costs of creating a hub – in our case the cost of setting up of a national distribution network – can dominate current economic conditions. Legacy (distribution) networks might not be optimal any more, but can remain in place for a very long time and influence economic activity today.[27]

To put this all in a nutshell: Retailers differentiate prices – always and everywhere, also within-country – but most extensively across national borders. The subsidiaries of the same retailer charge different prices for the same product in two countries. This indicates, in line with Mejean and Schwellnus (2009), that the ability of individual firms to differentiate prices across countries and to segment markets is at the core of (the lack of) price convergence between countries.

What implications can be drawn from this 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 on the two sides of 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 (sample) inflation is less dispersed across the Austrian-German

[26] In each country, the regions with uniform prices are larger than the border regions studied here. Obviously, the retailer will pick the optimal uniform price in each country based on the demand characteristics of the entire region. The demand characteristics along the border subregion might well differ from those in the rest of the region (with the same uniform price) and might in fact – as in our example – resemble more those right on the other side of the border. From this it follows that the incentive for retailers to price to market is not necessarily evident from the demand characteristics of the narrow border regions.

[27] Michaels and Rauch (2018) describe this in the context of town locations and traffic routes in France and the UK.

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 = largest country effect. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

border than the prices themselves. While retailers maintain different price levels, we find no evidence that they systematically deviate from a common price trend. Both countries appear to share important inflation drivers. Price differences within a given retailer are only weakly correlated over time and more persistent across the border than within a country.[28] 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 persist not for very long. The price changes in either direction can offset each other, leading to a less dispersed aggregate inflation.

6 Border effect along household and product characteristics

One might wonder whether the border effect is equally strong for all households, that is, whether household characteristics matter for within- or cross-country price differences. Likewise, market segmentation might be limited to a few product categories. The first part of this section studies the relevance of household characteristics. The second part looks for differences between product categories and studies if the origin of the product matters.

6.1 Household-specific price differentiation

It is well known that the elasticity of substitution varies by income (Auer et al., 2022; Burstein et al., 2022). One might expect an analogous heterogeneity in the households' efforts in arbitrage, within and across countries. Establishing a causal relationship

[28]The degree of persistence within and across countries differs somewhat across retailers. See Table 24 in the Appendix.

between household characteristics, such as income or age, and location-specific prices paid (i.e. the border effect) is in general non-trivial, as any differences in cross-border price gaps across households could also reflect differences in their preferences or product availability. Handbury (2021) documents that grocery costs vary with income and location: low-income households face less advantageous grocery offers in wealthier cities because the product assortment there matches the consumption habits of wealthier households better. Most of this variation is driven by cross-city differences in product availability, not by differences in prices. We have shown in the preceding analysis that the border effect is relatively larger for discounters. As such it might be that we observe a larger border effect for households shopping more frequently in discounters, and if these were low income households, it would reflect both an assortment and a price effect of the border concentrated at low income groups.

To explore this, we calculate price differences within income groups. We use the absolute log price difference Y_{irjyt} (for product i at in retailer r in region pair j for income group y at time t) at bi-monthly frequency to re-estimate – analogous to Equation (4) – the border effect by interacting the region pair dummy with the income group variable.[29]

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 = largest country effect. Last column: H_0: product group border effect = border effect for income group 1. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

The results in Table 8 show that the border effect does not vary significantly across the four income groups. In line with Handbury (2021), the difference in prices of an identical product in two locations across the border (i.e. the border effect) is largely invariant to income. Also the different frequency of shopping at discounters does not seem to matter, which might be due to the growing upscale assortment in many Austrian and German discounters. Another household characteristic, age, might be somewhat more relevant. For households aged 60 and above the border effect is marginally larger than

[29] See Table 18 in the Appendix for details on the variable definition. To ensure a sufficient number of observations per subgroup we loosen in the following the restriction of a product being available in both countries *and* in the same month, before calculating price differences on a bimonthly basis. This increases price variation due to sales and promotions.

for younger households.[30] Most variation in the price differences across households may nevertheless be explained by the variation in retailers, where households buy their groceries. The subsequent section examines 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. Do retailers employ product- or product-group-specific pricing strategies? Do they maintain 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?

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	(base)
Non-alc. beverages (12)	6.1***	10.7***	11.7***	0.39	0.17
Alc. beverages (21)	9.8***	3.8	14.7***	0.00	0.75
Household maint. (56)	3.8***	6.6***	15.2***	0.00	0.31
Garden and pets (93)	9.4***	3.4***	16.3***	0.00	0.01
Personal care (121)	4.2***	7.1***	21.1***	0.00	0.00

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 = largest 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.

We first look at differences across product categories and replace the explanatory retailer variable in Equation (4) with a product-category variable and interact it with the border dummy. 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, garden and pet products than for food products.

For retailers to profit from such price-differentiation, i.e. for consumers across the border not to detect and exploit the wedge, the differences should not be too persistent. When looking at the first-order autoregressive coefficient for broader product groups,[31] however, we find that personal care items appear to exhibit above-average persistence of price differences.[32] Price differences of food and beverage products, conversely, which

[30] The definition of the age group variable and regression results can be found in Tables 18 and 19 in the Appendix.

[31] 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. For comparison, Appendix Table 20 repeats the product category regressions of Table 9 for these groups.

[32] Table 21 in the Appendix reports an additional autoregressive coefficient at lag one across the border of 0.45, in

exhibit a smaller price gap at the border, are also slightly less persistent across the border. Consumers might 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.[33]

As we have shown, distances do not play any role in explaining the price gap at the border. In presence of home bias, however, the origin of the product might. 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 Party Information Registry).[34] We then translate the retrieved postcodes 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 within the border region, i.e. regional products.[35] The resulting 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. In regression (4) we now interact the border and country dummies with this product origin variable instead of a retailer or product group variable.

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 = largest 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.

As evident from Table 10, the border effect remains significant no matter where to

total 0.71.

[33] 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.

[34] 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.

[35] 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.

product comes from. It does not vary significantly by product origin with the exception of Austrian products from the border region itself which are marginally different from other groups.[36] 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,[37] 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 negotiate uniform prices (and sales prices) with the retailers. It might also be that companies serve the retailers in both countries from a single distribution centre. If both countries are served by the same cross-border delivery journey, it might be inefficient (e.g. in terms of additional accounting effort) to charge different prices on the two sides of a border – of a border without fundamental relevance for their business.

7 Conclusion

This paper examines the country dimension of price and inflation differences in the euro area. Using a large household panel we compare transaction prices on both sides of the Austrian-German border. The focus on a narrow band along the border combined with the cultural homogeneity and strong economic integration of the region eliminates the most prominent explanations of price differences at borders, such as currencies, preferences, distance, and language.

While many products are priced identically on both sides of the border, most prices differ. These 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 can explain this wedge.

We show that this "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 within countries as well, they do so most extensively across the border. The price differences of specific products are not very persistent and their high variation suggests that marketing, i.e. non-fundamental, factors dominate the price setting

[36] 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.

[37] 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.

process.

The similar expenditure shares by product category point towards similar preferences on both sides of the border. This stands in stark contrast to the small share of identically labelled products consumed in both countries. Thus, on top of price differentiation for identical products, the border also entails vast product differentiation.

The significance of the 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 resulting pricing strategies might differ by product: uniform pricing (zero price difference) for some, and price discrimination with some (optimal) price difference for other products. Given the similarity of preferences, the latter pricing choice points to a high cost of arbitrage. A relevant 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.

The evidence 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 small price differences between same-country regions. Crossing the Austrian-Bavarian border imposes virtually no *additional* cost on the shopper, implying a similar cost of arbitrage between cross-border as between same-country region pairs. 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-German 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. This suggests that the border effect by itself 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.[38] 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

[38] 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).[39] 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.[40]

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.

[39] In Austria we exclude political districts if their driving distance to the border is disproportionately 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).

[40] 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 region. 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 border 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 approximately only 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 4,500 barcodes, personal care offers the largest variety (and thus heterogeneity between households) relative to the number of transactions.

Table 14 shows key characteristics of barcodes grouped by their proximity to uniform pricing. We define these groups based on the share of within-country or cross-country price differences (at the mode) of zero, ranging from never observed to observed in all instances. Products that are more uniformly priced across the border tend to be

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

rather low in price (in particular in comparison to the respective within country group). Products which are sometimes (but not always) sold at the same price in two regions tend to be frequently purchased products.

Table 14: Barcodes with zero price difference

region pair	share of zero price differences $\psi = P(\Delta p = 0)$	bar-codes (count)	trans-actions (count)	expendi-ture (euro)	expendi-ture per barcode (euro)	transact. per barcode (count)
cross-border	always	520	33,897	59,447	1.8	65
	$66\% \leq \psi < 100\%$	257	47,305	82,493	1.7	184
	$33\% \leq \psi < 66\%$	370	74,145	156,966	2.1	200
	$0\% < \psi < 33\%$	703	369,365	820,155	2.2	525
	never	8,714	581,866	1,497,731	2.6	67
within Austria	always	830	25,123	62,043	2.5	30
	$66\% \leq \psi < 100\%$	754	94,764	187,156	2.0	126
	$33\% \leq \psi < 66\%$	1,267	311,378	722,694	2.3	246
	$0\% < \psi < 33\%$	339	81,457	205,538	2.5	240
	never	1,171	22,569	58,820	2.6	19
within Germany	always	1,181	95,697	206,626	2.2	81
	$66\% \leq \psi < 100\%$	803	179,473	382,968	2.1	224
	$33\% \leq \psi < 66\%$	1,302	537,658	1,172,488	2.2	413
	$0\% < \psi < 33\%$	248	78,256	191,255	2.4	316
	never	1,303	97,295	264,281	2.7	75

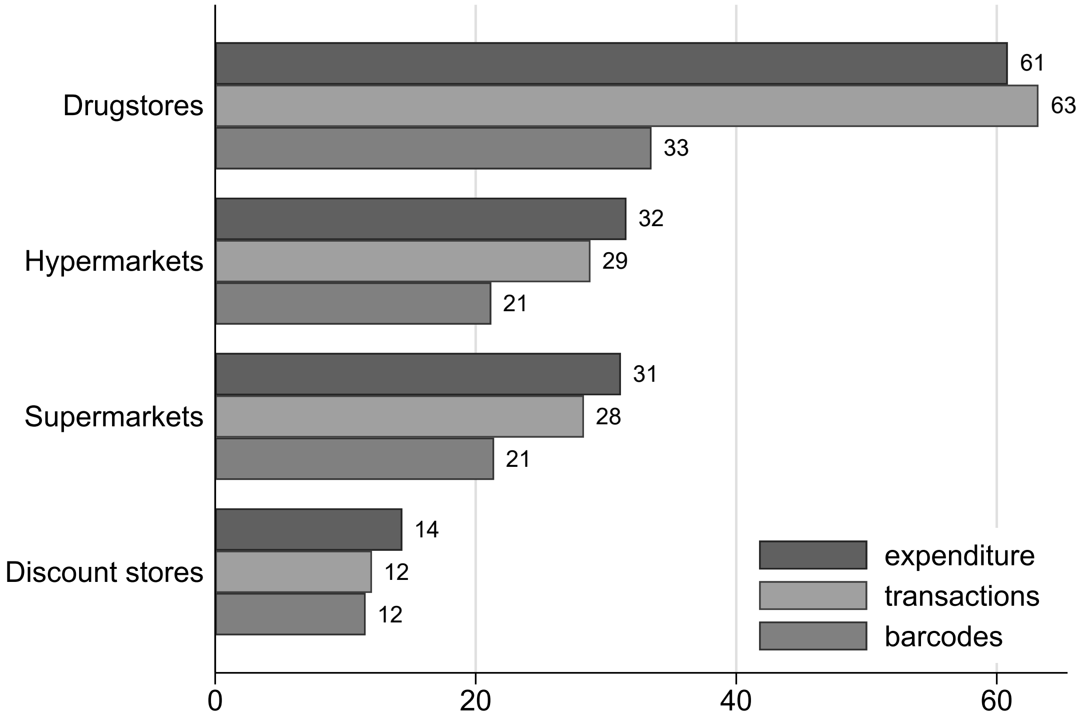
Note: Sample period 2008–2018. 19 regions per country within a 60 km band. Only products with a barcode. The column 'zero price difference' refers to the share of price differences of a given barcode at the mode in percent (0). The first four groups are restricted to at least two observations at zero. The columns 'barcodes' refers to the total count of unique barcodes within a group, 'transaction' refers to the total count of transactions in barcodes within the respective group, 'expenditure' refers to the total sum of expenditure in barcodes in the respective group in euro, the next column is the share of the latter two in euro, and the last column is the number of transactions per barcode.

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 border 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 15 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 higher 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.

Table 15: Border effects (15 region pairs)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Basket correlation		Common	Absolute price		Absolute price	
	COICOP 4	COICOP 5	barcode share	difference		change difference	
Constant	0.98***	0.97***	0.40***	5.74***	7.22***	12.16***	12.28***
(Germany)	(0.006)	(0.006)	(0.006)	(0.38)	(0.34)	(1.19)	(0.75)
Austria	0.01*	0.01	0.08***	3.00***	2.12***	-0.59	1.80
	(0.008)	(0.008)	(0.008)	(0.53)	(0.43)	(2.02)	(1.02)
Border	-0.06***	-0.17***	-0.34***	16.23***	14.71***	5.53***	4.31***
	(0.006)	(0.001)	(0.007)	(1.04)	(0.59)	(1.51)	(0.79)
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)	(0.01)	(0.01)
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)	(0.02)	(0.01)
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)	(0.02)	(0.01)
Frequency	year	year	year	week	month	month	bi-month
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) the sum of constant, avg. coefficient of retailer controls and avg. coefficient of month controls. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

B.3 Controlling for distance

Table 16 replicates Table 2, now including the distance between regions as control variable in the regression.

Table 16: 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***	7.78***	11.08***
(Germany)	(0.004)	(0.003)	(0.001)	(0.40)	(1.16)
Austria	0.05***	0.04***	0.08***	2.82***	2.25
	(0.005)	(0.004)	(0.001)	(0.52)	(2.01)
Border	-0.03***	-0.10***	-0.14***	15.16***	4.57***
	(0.004)	(0.004)	(0.001)	(0.70)	(1.41)
Common trend	0.004***	0.004***	0.001***	0.00	0.01
(Germany)	(0.001)	(0.001)	(<0.001)	(0.008)	(0.012)
Austria trend	-0.003***	-0.003***	-0.005***	0.01	0.04
	(0.001)	(0.001)	(<0.001)	(0.006)	(0.027)
Border trend	-0.003***	-0.006***	-0.001***	0.01	-0.01
	(0.001)	(0.001)	(<0.001)	(0.008)	(0.018)
Distance	0.004***	0.002	-0.004***	0.4***	0.2
	(0.002)	(0.001)	(0.001)	(0.1)	(0.2)
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

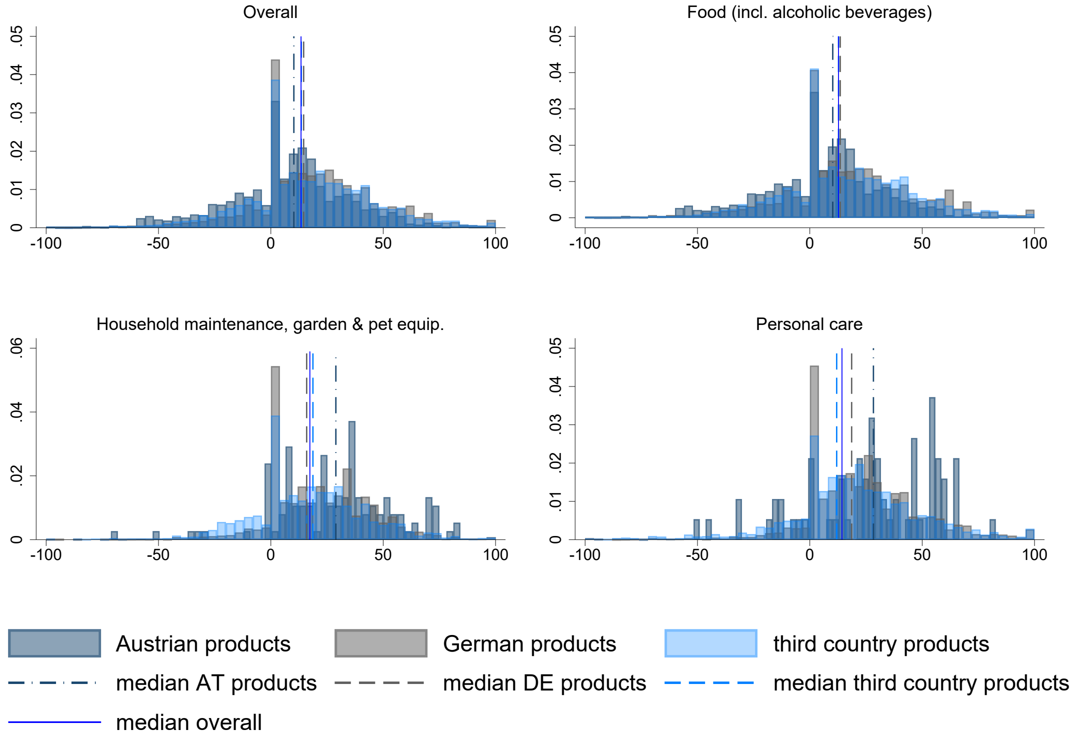
Note: Sample period 2008–2018. 703 region pairs. Standard errors in parentheses (columns 4 and 5: robust, barcode-clustered standard errors). Estimation by ordinary least squares. Bi-month and retailer controls in columns 4 and 5 not reported. Dependent variables: (1/2) pairwise correlation of COICOP4/COICOP5 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 at bi-monthly frequency. Germany effect in (1)-(3) is the constant, in (4) and (5) the sum of constant, avg. coefficient of retailer controls and avg. coefficient of month controls. "Distance" refers to the distance between two regions of a region pair in 100 kilometers. Asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

The results shows that whereas several quantities vary with distance, the magnitude of the distance effect within the sample region is negligible. The estimates of the border effect remain largely unchanged, and the maximum distance effect within the sample region is one order of magnitude (or more) smaller than the border effect.

B.4 Price differences by product origin

In this appendix 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.

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 Relation between region characteristics and prices

In the paper we establish that the 19 regions in each country are very similar. But as they are obviously not identical, we explore in this appendix to what extent differences in regional characteristics can explain price differences both within each country and across the border. To do so, we study the price level differences between and within Austria and Germany directly, i.e. Y_{irjt} are now non-absolute differences. Cross-border region pairs subtract the German from the Austrian value. (Within-country region pairs are randomly ordered.) The regression specification is

$$Y_{irjt} = \underbrace{\beta_0 + \beta_1 \mathbb{1}^{AT}(j) + \beta_3 \mathbb{1}^{B}(j)}_{\text{border/country effects}} + \underbrace{X_j \times \mathbb{1}^{R}(j)}_{\Delta \text{ explanatory variables}} + \underbrace{\gamma_1 t \times \mathbb{1}^{R}(j)}_{\text{border/country trends}} + \underbrace{\lambda_r}_{\text{retailer controls}} + \underbrace{\theta_{m(t)}}_{\text{month controls}} + \epsilon_{irjt}, \tag{5}$$

where the explanatory variables $X_j \times \mathbb{1}^R(j)$ are the (non-absolute) difference in average (logarithmic) regional household income (in percent), in 2008-2018 income growth (in percent), in the age of the household head (in years) and in the distance to the border (in kilometers) for each of the 703 region pairs.

Table 17: PRICE LEVEL AND REGIONAL CHARACTERISTICS

explanatory variable	cross-country	within Germany	within Austria
Region effect	15.20***	0.58	-0.29
Δ avg. income	-0.02	-0.04***	0.07***
Δ avg. income growth	-0.02**	-0.01*	-0.06***
Δ avg. age	0.35***	0.08	0.00
Δ distance to border	0.06***	0.00	0.03***

Note: The table shows country and border coefficients of the OLS estimation of Equation (5). Period 2008–2018. Dependent variable: (non-absolute) within-retailer y-o-y price difference at a bimonthly frequency. Explanatory variables: (non-absolute) difference in average (logarithmic) regional household income (in percent), income growth (in percent), age (years) of household head and distance to the border (km) for each of the 703 region pairs, as well as time trends and retailer and month controls, which are not reported. In case of cross-border pairs it is the Austrian minus the German price. 333,327 observations. Adjusted R^2 = 0.11. Barcode-clustered standard errors not reported, asterisks indicate the level of significance, (*) at the 10%, (**) at the 5%, and (***) at the 1% level.

The results in Table 17 confirm the significantly higher price level in Austria (15%) already discussed in the main text. This is large compared to the income difference and even compared to the GDP per capita difference. For a Spanish apparel manufacturer selling via the internet, for example, Simonovska (2015) estimates that countries with twice the income per capita pay on average 18% higher prices – among very different and very distant countries. The income difference between the Austrian and Bavarian border region studied here is much smaller. As shown in the third column of Table 1, Austrian GDP per capita in the border region is on average only about 30% higher than on the German side. A back-of-the-envelope calculation based on these numbers gives a five percentage point price difference as upper bound to what might be explained by the average income difference. That is, income alone cannot explain the border effect.

The income between the regions within each country differs even less. We find that these small income variations do not explain economically meaningful price differences between regions of the same country. Likewise, besides the country-income effect, regional income does not capture cross-border regional price variation, i.e. nothing in addition to what is already captured by the border effect. This obtains because retailers practice more or less uniform pricing on each side of the border.

Instead, the average age has some explanatory power, with regions that are older on average facing (slightly) higher prices.[41]

B.6 Border effect along household and product characteristics

Table 18 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 the monthly net income in euro of all members of the household from all sources of income. 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. Because the raw income ranges of the bottom and top groups are given as half-open intervals, we approximate the income of these groups with a best-guess income median consistent with the overall shape of the country's income distribution.

Table 19 suggests a marginally larger border effect in the purchases of older shoppers.

Tables 20 and 21 show the most permanent border effect within personal care items.

B.7 More granular regions (price difference regression)

Table 22 repeats the persistence analysis, distinguishing 19 instead of three regions per country.

[41] This stands in contrast to Aguiar and Hurst (2007), who find that older U.S. households realize lower prices as they spend more time on comparing prices. Elderly households and retirees in Austria and Germany might differ from those in the USA, as they are not necessarily poorer than the rest of the population in terms of disposable income.

Table 18: Age and income groups in Austria and Germany

		Bracket	Age (of household head, in years) Obs.	Mean	Min	Max
AT	1	$\leq p25$	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

		Bracket	Income (of household, in euro) 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 19: 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.

Table 20: 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 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 (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.

Table 22: 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 23: 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 24: 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.

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Teresa Messner
Oesterreichische Nationalbank, Vienna, Austria; email: teresa.messner@oenb.at

Fabio Rumler
Oesterreichische Nationalbank, Vienna, Austria; email: fabio.rumler@oenb.at

Georg Strasser (corresponding author)
European Central Bank, Frankfurt am Main, Germany; email: georg.strasser@ecb.europa.eu

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