Appendix

Unit Sales and Price Effects of Pre-announced Consumption Tax Reforms: Micro-level Evidence from European VAT

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Contents

A Data Analysis

A.1 Data Production

Gesellschaft für Konsumforschung (GfK) Retail and Technology GmbH generates the data in the following way: First, distribution channels are defined, which are relevant for a respective product group. Examples of distribution channels are hypermarkets, technical superstores, department stores, *etc*. An address database is established for all outlets in a given country belonging to a certain distribution channel with the goal of determining the universe of retailers. This is achieved through census data and special questionnaires to dealers/retailers. Once the universe is known in its structure, the sample is drawn through disproportional quota sampling, taking into account three key factors – region, distribution channel, and turnover class. The aim is to make sure that the data provides an equally good representation of developments for each product. GfK collects price and quantity data retailer by retailer. Incoming data from different sources referring to the same product is translated into one single definite GfK product code. Once checked, the basic data is extrapolated for each distribution channel. GfK's data collection, sampling and extrapolation methodology are described in detail in Fischer (2012), who uses similar data for washing machines from 1995-2005, at a four-monthly or bi-monthly frequency, to study price convergence in the countries of the European Monetary Union (EMU).

A.2 Data Transformation

Transformations applied to all estimation samples:

The complete untransformed data contains a total of 20,666,643 observations, some of which are removed. In particular, observations without an identifier (id) are dropped (10,242 obs.), observations for products for which all units/price variables are missing across all years, and observations within a product for which all units and prices in a given year are reported as zero (4,932 obs). A small number of units sold (13,512 obs.) and prices (1,336 obs.) have negative values, which are replaced with missing observations. The negative values likely arise due to returned items. Out of 20,666,643 observations for units sold, 8,341,832 are missing values, and 1,370,799 are zeros. For prices, 8,901,213 data points are missing and 861,537 are zeros. Usually zero/missing units sold are coupled with a zero/missing price.

Monthly percentage changes in prices calculated within product-country groups are restricted to no more than 200% increases and no less that 50% decreases by replacing prices with missing observations when the percentage change exceeds the specified range. This affects 272,175 observations (decreases), of which the vast majority, 255,084, are due to a percentage change exactly equal to -100%, which occurs when a positive price is followed by a price of zero. 17,091 changes are due to prices falling by more than 50% from one month to the next, while 3,808 prices are replaced with missing values because the increase is larger than 200%. This restriction applies to all descriptive statistics presented in Panels B and C of Table 1. All results are robust to an alternative transformation, which drops zero prices without imposing any other restriction on the percentage change. In this case, the mean of $\Delta \log(PRICE)$ is -0.005 (0.142) with a min. -11.15 and a max of 33.57. Further, results remain robust if zero prices are left in the data as they are. Both sets of results are available upon request.

Due to membership into the EMU, in all estimation samples, data for Slovakia is dropped before January 1st, 2009 (175,848 obs), for Slovenia – before January 1st, 2007 (65,520 obs.), and for Estonia all observations after December 2010 are excluded (94,641 obs.). Panel A of Table 1 reports descriptive statistics based on all available data for Slovenia, Slovakia, and Estonia.

For the purpose of providing descriptive statistics, prices in Table 1 are shown in Euro, calculated using monthly exchange rates sourced by Eurostat, but all log-changes used in the estimation and summarized in Table 1 are based on prices in national currencies.

Outliers in $\Delta \log(UNITS)$ are present as clearly shown by the min-max range of this variable in Panels B and C in Table 1. Such outliers arise as a result of two characteristics of the data. First, 543,832 units sold lie in an interval (0,1), with some values as small as 0.0000001, which typically occurs in the last year a model is in the panel. The log-transformation of such small values results in substantial log-changes in units. Our results are robust to the replacement of all such values with zero (results available upon request). In this case, the mean of $\Delta \log(UNITS)$ becomes -0.016 (0.878) with a minimum of -7.87 and a maximum of 8.89. The maximum value of 8.89 is for a product entering the German market with units sold of 1 in its first month and 7,276 in the second month. The minimum value is generated by a product that exits the market with sales of 1 unit in its last month, but 2,626 units in the preceding month. Apart from the (0,1) values, therefore, outliers in $\Delta \log(UNITS)$ arise naturally from the fluctuations in sales at the beginning and the end of products' life-cycles.

Transformations applied to estimation sample of Panel B of Table 1

In this estimation sample the data is restricted to models traded in at least two countries at the same time. This results in the loss of 9,644,145 observations. Refer to Table B.5 for some summary statistics of the full and the reduced sample. The restriction removes two thirds of all models in the data, but the remaining 29,683 products on average account for 53% of all units sold and generate 58% of the sales value within a year. Panel B of Table 1 provides summary statistics only for the observations that are actually used in the estimations in Tables 3 and 4. The remaining variables in Panel B are summarized based on the union of sales and price estimation samples.

Transformations applied to estimation sample of Panel C of Table 1

The estimates in Table B.12 are based on the estimation sample described in Panel C of Table 1. This is the sample that incorporates models traded in only one country in the estimation by collecting, within a product category, all models with an identical set of characteristics into one group (Table B.4). For example, all built-in, 2-door, freezer-top refrigerators with a no-frost system belong into one group. A number of models have a single or multiple unknown/non-available characteristics, which necessitated dropping these models from the data. In total, 39,481 models (2,207,532 obs.) were removed. 92% of the lost observations stem from two product categories – hoods and cooktops, which have numerous models with missing information on the shape of chimney and heating type characteristics (see Table B.4). We further had to ensure that models in the resulting products groups-date cells are traded in at least two countries, which resulted in the loss of 26,217 additional observations. Panel C of Table 1 provides summary statistics only for the observations that are actually used in the estimation in Table B.12.

Endogenous reforms and reforms announced less than a month before implementation

Seven reforms were announced less than one month before their implementation (see Table 2 and Figure 3). To identify observations affected by these reforms, we generated a variable $early$, which has a value of unity for all observations in countries undergoing such reforms six months before and six months after the respective implementation dates. All specifications excluding relevant models' observations around the seven reforms are estimated on the condition that $early = 0$. Endogenous reforms are identified in a similar fashion. We generated a variable $endog$, which is set to unity six months before and six months after the implementation dates of all endogenous reforms listed in Table 2. Specifications using exogenous reforms are run subject to $endog = 0$.

TABLE B.1 – LITERATURE ON SPENDING RESPONSES TO CONSUMPTION TAX RATE CHANGES

Paper	Policy Varation	Data	Identification	Findings
Crossley *et al.*(2014)	UK: 2008 VAT decrease by 2.5pp. temporary	Aggregate expenditure and retail sales per GDP	Diff-in-diff relative to 1) non-VAT goods 2) other OECD countries	Retail sales increase by 1%
Agarwal *et al.* (2016)	US: 2003 Nine sales tax holidays	Household daily transactions (Consumer Expenditure Survey) and credit card data	Diff-in-diff relative to household consumption on same date in states without sales tax holidays	Increased spending on apparel (41% and 56%) during holidays, without offsetting declines before and after
Cashin & Unayama (2016)	Japan: 1997 VAT increase	Household micro-level data on spending on durables, storables, non-storable non-durables; deflated; household characteristics (JFIES Survey)	Time-series	Intertemporal consumption shift by 0.21% before tax increase by 1pp., strong transitory effects on durables
Baker *et al.* (2020)	US: 2008-2014 ZIP code level sales tax rates	Nielsen Consumer Panel: household- and store-specific purchases	Diff-in-diff relative to households in states without sales tax change	1pp. increase exerts transitory effect of 1.19% and intertemporal consumption shift of 0.3%
Cashin (2018)	Japan: 1997 VAT increase	JFIES Survey as in Cashin & Unayama (2016); deflated	Structural model estimation	Intertemporal consumption shift by 0.13% before increase by 1pp., transitory effects.
D'Acunto *et al.* (2019)	Germany: 2007 VAT increase by 3pp.	Micro-level household data on inflation expectations, willingness to pay for consumption goods and household-specific characteristics (GfK MAXX Survey)	Diff-in-diff relative to households in other EU countries (not Germany)	10.3% higher durable consumption before increase

Notes: The table draws from a specific selection of papers that deal with VAT or retail sales taxes. We exclude studies that consider effects of targeted subsidies that aim to stimulate consumer spending and promote fuel efficiency (*e.g.*, Mian and Sufi, 2012, Green, Melzer, Parker and Rojas, 2020, Li, Linn and Spiller, 2013, and Hoekstra, Puller and West, 2017). The table does not aim to provide a general overview of findings , but focuses on selected empirical results.

TABLE B.2 – LITERATURE ON CONSUMPTION TAX PASS-THROUGH INTO PRICES

Paper	Policy Variation	Data	Identification	Findings
Poterba (1996)	US: 1925-1939 21 state sales tax changes; US: 1947-1977: 33 state and local sales tax changes	City-specific CPI index for clothing and personal care items	Diff-in-diff relative to national price changes for clothing and personal care	1925-1939: Incomplete forward shifting 1947-1977: Full-shifting
Besley & Rosen (1999)	US: 1982-1990 State and local taxes	City-specific CPI data disaggregated in 12 commodities	Intertemporal deviations from city-specific means	Over-shifting for 50% of commodities
Carbonnier (2007)	France: 1987 VAT decrease for cars; France: 1999 VAT decrease for household repair services	CPI disaggregated according to COICOP group	Double diff-in-diff relative to overall and energy-/rent-price indices	Under-shifting
Carare & Danninger (2008)	Germany: 2007 VAT increase	Harmonized CPI; disaggregated	Diff-in-diff relative to non-VAT-liable CPI items	Under-shifting; 24% pre-implementation pass-through
Viren (2009)	15 EU countries: 1970-2004 VAT increases	Harmonized CPI	Panel regression with fix.eff.	Under-shifting
Crossley *et al.*(2014)	UK: 2008 temporary VAT decrease	Harmonized CPI	Diff-in-diff relative to 1) non-VAT goods in the UK 2) prices in other OECD countries	Full-shifting, but early reversal
Benedek *et al.* (2019)	17 EU countries: 1999-2013; 65 changes incl. reduced rates	Harmonized CPI; disaggregated into 67 COICOP groups	Diff-in-diff relative to identical consumption categories in countries without tax changes	Full-shifting; 35% pre-reform pass-through for durables.

Notes: *Notes*: The table shows a selection of papers that deal with VAT or retail sales taxes. We exclude studies that consider the pass-through of reduced VAT rates in the context of household services (*e.g.*, Kosonen, 2015, Benzarti, Carloni, Harju, Kosonen, 2020). The table does not aim to provide a general overview of findings, but focuses on selected empirical results.

TABLE B.3 – DATA COVERAGE

Country	Coverage
AT, BE, CZ, DE, ES, FR, IT, NL, PL, PT, SE, UK	Jan. 2004 - Sept. 2013 for all categories of white goods.
DK	Jan. 2004 - Sept. 2013 WM, TD, CO, RG; Jan. 2007 - Sept. 2013 FRZ; Jan. 2008 - Sept. 2013 HB; HD are not covered.
EE, LV, LT	Jan. 2006 - Sept. 2013 for WM, CO, RG; Jan. 2008 - Sept. 2013 for HB, DW; HD,TD, FRZ are not covered.
GR	Jan. 2005 - Sept. 2013 for all product categories except TD, which is covered from Jan. 2007 - Sept. 2013.
FI	Jan. 2005 - Sept. 2013 for all product categories, except HD, which is not covered.
HU	Jan. 2004 - Sept. 2013 for all product categories except HD, which is covered from Oct. 2006 - Sept. 2013.
RO	Jan. 2009 - Sept. 2013 for all product categories except HD, which is covered from Jan. 2012 - Sept. 2013.
SI	Jan. 2005 - Sept. 2013 for all product categories except HD, which is covered from Jan. 2009 - Sept. 2013.
SK	Jan. 2006 - Sept. 2013 for all product categories.

Notes: CO: Cooker; DW: Dishwasher; FRZ: Freezer; HB: Hob/Cooktop; HD: Hood; RG: Refrigerator; TD: Tumble dryer; WM: Washing machine. AT: Austria (5.52); BE: Belgium (5.40); CZ: the Czech Republic (4.56); DE: Germany (10.01); DK: Denmark (2.88); EE: Estonia (1.27); ES: Spain (7.62); FI: Finland (2.67); FR: France (9.47); GR: Greece (2.99); HU: Hungary (3.24); IT: Italy (8.25); LV: Latvia (0.96); LT: Lithuania (1.73); NL: the Netherlands (5.48); PL: Poland (4.87); PT: Portugal (5.02); RO: Romania (1.10); SE: Sweden (3.84); SI: Slovenia (1.90); SK: Slovakia (2.80); UK: United Kingdom (8.43). Numbers in parentheses after country labels are the number of observations associated with the respective country as a percent from total observations in the data set.

TABLE B.4 – PRODUCT CHARACTERISTICS

Product Category	Characteristics
Cookers	Construction (built-in, under-, freestanding); type (cooker, oven); fuel (electric, gas, mixed).
Coolers/Refrigerators	No-frost system (yes/no); construction (built-in, under-, freestanding); type (1 door (dr) 81-90 cm, 1 dr.>90 cm, 1 dr. up to 80 cm, 2 drs. freezer bottom, 2 drs. freezer top, 3+ drs., side-by-side); brand*.
Dishwashers	Construction (built-in, under, freestanding); size (compact, full size, slimline, table top); integration (fully, partly, no).
Freezers	Construction (built-in, under, freestanding); type (upright, chest, box); height in cm (42-213 cm); brand*.
Hobs/Cooktops	Fuel (electric, gas, mixed); surface (ceramic/glass, sealed, gas on glass, mixed sealed+ceramic); heating type (halogen, induction, radiant).
Hoods	Hood type (canopy/cartridge, ceiling, chimney, integrated, standard, table/hob extra, telescopic); chimney (corner, island, wall, no chimney/deco); shape chimney (box, decorative, head-free, pyramid/trapeze, not applicable).
Tumble Driers	Type (condenser, ventilation); control type (electronic, timer); loading capacity in kg (1-10 kg).
Washing Machines	Type (front- or top-loading, wash-dry, other); spin speed (400-3100); loading capacity in kg (1-17 kg); brand*.

Notes: *Brand information is available for a subset of products in three categories, namely for 48% of refrigerators, 46% of freezers, and 44% of washing machines in the estimation sample of Panel B of Table 1. The characteristic sets used in the group-date fixed effects in Table B.12 are all possible combinations of the characteristics above per product category. In total, in the estimation sample of Panel C of Table 1, there are 686 groups of products with an identical set of characteristics. Refer to Section A.2 for details on how the groups are constructed.

Table B.5 – Full Sample: Descriptive Statistics By Product Category

	Mean	Std. Dev.	Min	Max
	Average № Products per Year			
Total, of which:	109,848	3,890	102,879	117,844
Cookers	21,582	503	20,477	22,134
Fridges	24,102	1,359	22,402	26,712
Dishwashers	11,185	1,318	8,745	13,305
Freezers	6,265	416	5,722	7,117
Cook tops	14,006	783	12,572	14,875
Hoods	14,918	1,733	10,810	17,148
Tumble dryers	3,195	196	2,966	3,531
Washing machines	14,877	708	13,855	16,019
Sold in at least 2 countries	29,683	6,466	10,095	36,540
	Average № of Units Sold per Year (Thousands)			
Total, of which:	62,408	5,079	47,083	65,712
Cookers	8,623	729	6,252	9,207
Fridges	14,069	1,101	10,708	15,020
Dishwashers	6,784	686	5,401	7,432
Freezers	3,836	381	2,631	4,113
Cook tops	5,920	464	4,691	6,342
Hoods	4,949	433	3,714	5,371
Tumble dryers	3,523	415	2,268	3,942
Washing machines	14,729	1,205	11,416	15,655
Sold in at least 2 countries	33,159	5,906	13,829	38,692
	Average Value of Sales per Year (Millions Euro)			
Total, of which:	25,987	2,193	19,447	27,883
Cookers	3,908	386	2,740	4,334
Fridges	6,313	538	4,765	6,859
Dishwashers	3,413	302	2,604	3,638
Freezers	1,349	118	976	1,440
Cook tops	2,178	189	1,720	2,337
Hoods	1,245	108	974	1,337
Tumble dryers	1,427	151	1,032	1,598
Washing machines	6,171	498	4,635	6,565
Sold in at least 2 countries	15,187	2,558	6,743	17,389
	Product Age			
Full sample:	30.5	23.2	1	117
Cookers	30.8	23.4	1	117
Fridges	28.9	21.8	1	117
Dishwashers	27.7	20.7	1	117
Freezers	28.6	22.0	1	117
Cook tops	34.5	25.5	1	117
Hoods	36.9	27.6	1	117
Tumble dryers	29.5	22.0	1	117
Washing machines	27.1	20.3	1	117
Sold in at least 2 countries	31.2	21.8	1	117

Notes: The descriptive statistics are based on the primary data in Panel A of Table 1. Product age shows the average number of months from the earliest date a product enters the market in any country and the latest date it exits the market in any country in the data.

TABLE B.6 – DESCRIPTIVE STATISTICS BY BRAND QUALITY

	Mean	Std. Dev.	Min	Max	
	Sub-sample with Brand Information				
№ Units Sold	67.10	194.68	0	19,062	1,481,867
Price (Euro)	572.74	392.36	0	11,392	1,458,501
Market Age (months)	25.38	16.43	2	117	1,481,867
Rank	546	567	1	5,364	1,481,867
	Top-level Brands				
№ Units Sold	60.53	177.56	0	8,815	685,218
Price (Euro)	754.38	468.91	0	11,392	672,332
Market Age (months)	25.51	16.53	2	117	685,218
Rank	620	600	1	5,364	685,218
	Medium-level Brands				
№ Units Sold	65.10	190.65	0	19,062	475,306
Price (Euro)	471.56	238.80	0	4,355	468,638
Market Age (months)	24.44	15.61	2	117	475,306
Rank	509	542	1	5,364	475,306
	Low-level Brands				
№ Units Sold	84.08	231.11	0	7,927	321,343
Price (Euro)	337.49	130.68	0	3,999	317,531
Market Age (months)	26.46	17.28	2	117	321,343
Rank	445	506	1	5,064	321,343

Notes: The table refers to the sub-sample of refrigerators, freezers and washing machines with brand information. Assignment into reliability/quality groups is based on mean brand prices, so that across the full product range of a brand over time, the mean price of top level brands lies within an interval $[500, +\infty)$, and for medium-level brands–in the interval $(500, 390]$. Given this selection, the list of top brands includes 32 brands. 24 brands are classified as medium-level. The list of lower-level brands is composed of 76 brands.

TABLE B.7 – NUMBER OF IDENTIFYING REFORMS BY ORDER OF LEADS

Lead	№ Identifying countries	№ Identifying reforms
$\Delta\tau_d$	17	33
$\mathsf{E}\left[\mathsf{L}^{-1}\Delta\tau_d\right]$	16	29
$\mathsf{E}\left[\mathsf{L}^{-2}\Delta\tau_d\right]$	15	26
$\mathsf{E}\left[\mathsf{L}^{-3}\Delta\tau_d\right]$	12	20
$\mathsf{E}\left[\mathsf{L}^{-4}\Delta\tau_d\right]$	11	17
$\mathsf{E}\left[\mathsf{L}^{-5}\Delta\tau_d\right]$	9	12
$\mathsf{E}\left[\mathsf{L}^{-6}\Delta\tau_d\right]$	7	10
$\mathsf{E}\left[\mathsf{L}^{-7}\Delta\tau_d\right]$	6	8
$\mathsf{E}\left[\mathsf{L}^{-8}\Delta\tau_d\right]$	6	8
$\mathsf{E}\left[\mathsf{L}^{-9}\Delta\tau_d\right]$	6	8
$\mathsf{E}\left[\mathsf{L}^{-10}\Delta\tau_d\right]$	5	6
$\mathsf{E}\left[\mathsf{L}^{-11}\Delta\tau_d\right]$	3	3
$\mathsf{E}\left[\mathsf{L}^{-12}\Delta\tau_d\right]$	2	2
$\mathsf{E}\left[\mathsf{L}^{-13}\Delta\tau_d\right]$	2	2
$\mathsf{E}\left[\mathsf{L}^{-14}\Delta\tau_d\right]$	2	2

Notes: The table shows the varying number of VAT reforms and countries captured by higher-order leads of the change in the tax rate, $\Delta\tau_d$. Due to data limitations for Latvia such as market size and narrower time and category coverage, we take the earliest announcement in the data to be that of the German VAT increase in 2007, which was announced 14 months prior to implementation. For this reason, no more than 14 leads are considered.

Table B.8 – Basic Estimates Of Unit Sales Effects: Alternative S.E. Clustering

	(1)	(2)	(3)	(4)
$\mathsf{F}\Delta\tau_d$	2.615	2.444	2.426	2.421
Heteroscedasticity Robust	(0.195) [0.000]	(0.205) [0.000]	(0.205) [0.000]	(0.216) [0.000]
Cluster Country	(0.608) [0.000]	(0.446) [0.000]	(0.453) [0.000]	(0.516) [0.000]
Cluster Country Wild Bootstrap	- [0.007]	- [0.004]	- [0.007]	- [0.011]
Cluster Country ∩ Category	(0.366) [0.000]	(0.314) [0.000]	(0.315) [0.000]	(0.340) [0.000]
Cluster Country & Product	(0.511) [0.000]	(0.381) [0.000]	(0.387) [0.000]	(0.439) [0.000]
$\Delta\tau_d$	-3.817	-4.338	-4.350	-4.412
Heteroscedasticity Robust	(0.212) [0.000]	(0.217) [0.000]	(0.217) [0.000]	(0.228) [0.000]
Cluster Country	(1.377) [0.011]	(0.711) [0.000]	(0.707) [0.000]	(0.697) [0.000]
Cluster Country Wild Bootstrap	- [0.058]	- [0.001]	- [0.001]	- [0.001]
Cluster Country ∩ Category	(0.648) [0.000]	(0.415) [0.000]	(0.415) [0.000]	(0.436) [0.000]
Cluster Country & Product	(1.139) [0.003]	(0.596) [0.000]	(0.593) [0.000]	(0.585) [0.000]
$\mathsf{L}\Delta\tau_d$	-2.146	-1.700	-1.717	-1.754
Heteroscedasticity Robust	(0.205) [0.000]	(0.214) [0.000]	(0.214) [0.000]	(0.226) [0.000]
Cluster Country	(0.836) [0.018]	(0.423) [0.001]	(0.436) [0.001]	(0.471) [0.001]
Cluster Country Wild Bootstrap	- [0.084]	- [0.007]	- [0.012]	- [0.011]
Cluster Country ∩ Category	(0.433) [0.000]	(0.289) [0.000]	(0.291) [0.000]	(0.313) [0.000]
Cluster Country & Product	(0.696) [0.006]	(0.366) [0.000]	(0.375) [0.000]	(0.406) [0.000]
Cumulative Effect	-3.349	-3.594	-3.640	-3.744
Heteroscedasticity Robust	(0.357) [0.000]	(0.370) [0.000]	(0.369) [0.000]	(0.415) [0.000]
Cluster Country	(0.826) [0.001]	(0.417) [0.000]	(0.425) [0.000]	(0.587) [0.000]
Cluster Country Wild Bootstrap	- [0.003]	- [0.000]	- [0.000]	- [0.000]
Cluster Country ∩ Category	(0.544) [0.000]	(0.453) [0.000]	(0.454) [0.000]	(0.571) [0.000]
Cluster Country & Product	(0.695) [0.000]	(0.375) [0.000]	(0.381) [0.000]	(0.516) [0.000]
Month-country effects	No	Yes	Yes	Yes
Year-country effects	No	No	No	Yes
N	4,126,760	4,126,760	4,126,760	4,126,760
Product-date effects	1,331,154	1,331,154	1,331,154	1,331,154
Products	72,056	72,056	72,056	72,056

Notes: The table repeats the basic estimation of unit sales effects in Table 3, but reports heteroscedasticity robust standard errors, standard errors clustered by country and by the intersection of country and product category (country ∩ category.). Standard errors are in parentheses, and p-values in squared brackets. We report two sets of p-values when clustering over country: From a standard fixed-effects estimation with 22 country clusters, and from the wild bootstrap post-estimation procedure developed in Roodman *et.al.* (2018) using 999 bootstrap replications. For convenience, the table also shows standard errors at our default level of clustering over country and product.

TABLE B.9 – EXOGENOUS TAX RATE CHANGES: ONE-WAY COUNTRY CLUSTERING

Dependent variable	$\Delta\log(PRICE)$				$\Delta\log(UNITS)$			
Reforms	All		n ≥ 1	n>3	All		n ≥ 1	n>3
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$L^{-3}\Delta\tau_d$	-0.011				-0.207			
	(0.066)				(0.845)			
$L^{-2}\Delta\tau_d$	0.234				0.786			
	(0.104)				(1.096)			
$L^{-1}\Delta\tau_d$	0.014				2.480			
	(0.045)				(1.058)			
$E\left[L^{-3}\Delta\tau_d\right]$		0.002	0.001	-0.009		-0.235	-0.252	-0.219
		(0.063)	(0.064)	(0.067)		(0.864)	(0.866)	(0.873)
$E\left[L^{-2}\Delta\tau_d\right]$		0.230	0.230	0.273		0.364	0.343	0.395
		(0.105)	(0.104)	(0.111)		(1.149)	(1.143)	(1.208)
$E\left[L^{-1}\Delta\tau_d\right]$		0.041	0.045	0.065		2.485	2.469	2.244
		(0.047)	(0.048)	(0.054)		(1.072)	(1.069)	(1.095)
$\Delta\tau_d$	0.170	0.170	0.166	0.130	-4.563	-4.563	-4.806	-4.684
	(0.135)	(0.135)	(0.139)	(0.149)	(1.242)	(1.242)	(1.211)	(1.382)
$L\Delta\tau_d$	0.362	0.362	0.359	0.379	-1.491	-1.488	-1.079	-1.352
	(0.091)	(0.091)	(0.095)	(0.103)	(0.912)	(0.912)	(0.825)	(1.059)
$L^{2}\Delta\tau_d$	-0.017	-0.017	-0.013	-0.008	-0.153	-0.149	-0.256	0.912
	(0.102)	(0.102)	(0.105)	(0.121)	(1.078)	(1.078)	(1.116)	(0.779)
$L^{3}\Delta\tau_d$	0.073	0.073	0.078	0.109	1.222	1.222	1.211	0.543
	(0.077)	(0.076)	(0.082)	(0.089)	(0.687)	(0.688)	(0.649)	(0.559)
	Cumulative Effects							
Total	0.824	0.861	0.867	0.938	-1.927	-2.364	-2.369	-2.162
	(0.289)	(0.292)	(0.301)	(0.346)	(1.072)	(0.906)	(0.978)	(1.135)
Pre-reform	0.237	0.273	0.277	0.328	3.059	2.613	2.560	2.420
	(0.155)	(0.154)	(0.155)	(0.168)	(0.746)	(0.670)	(0.680)	(0.659)
Post-reform	0.587	0.588	0.590	0.610	-4.986	-4.977	-4.929	-4.581
	(0.171)	(0.171)	(0.178)	(0.201)	(0.783)	(0.785)	(0.883)	(0.951)
Pass-through F(1)	0.37	0.23	0.20	0.03				
P-value	0.55	0.64	0.66	0.86				
N	3,633,800	3,633,800	3,589,517	3,557,472	3,724,135	3,724,135	3,676,199	3,643,045
Product-date effects	1,200,757	1,200,757	1,189,120	1,181,310	1,228,615	1,228,615	1,215,792	1,207,765
Products	69,614	69,614	69,277	68,956	70,455	70,455	70,118	69,790

Notes: Regression results are based on data for 22 EU countries. The dependent variable in columns (1) to (4) is the change in the logarithm of price, $\Delta\log(PRICE)$, and in columns (5) to (8) it is the change in the logarithm of unit sales, $\Delta\log(UNITS)$. Observations up to two quarters before and after reforms classified as endogenous (see Table 2) are removed from the estimation. Estimates in columns (3) and (7) are based on a reduced sample, in which observations in countries with reforms announced less than a month before implementation, are removed around the respective reform date. The monthly change in the standard VAT rate is denoted by $\Delta\tau_d$. Note that $E\left[L^{-j}\Delta\tau_d\right] = L^{-j}\Delta\tau_d$ for all reforms that were announced $n > j$ periods ahead, and $E\left[L^{-j}\Delta\tau_d\right] = 0$ for reforms announced $n \leq j$. All specifications include a full set of product-date, country and country-month specific fixed effects. The monthly unemployment rate, $Unempl$, and the number of months a product appears in the data in a specific country, $M.age$, as well as $M.age^2$ are controlled for but not reported. Standard errors in parentheses are robust in all specifications and clustered by country.

Table B.10 – Price Effects: Increasing Number of Countries in Product-Date Cells

	(1) $k_i \geq 3$	(2) $k_i \geq 4$	(3) $k_i \geq 5$	(4) $k_i \geq 6$	(5) $k_i \geq 7$	(6) $k_i \geq 8$
$\mathsf{E}\left[\mathsf{L}^{-3}\Delta\tau_d\right]$	0.241	0.234	0.240	0.234	0.237	0.250
	(0.045)	(0.044)	(0.042)	(0.037)	(0.042)	(0.047)
$\mathsf{E}\left[\mathsf{L}^{-2}\Delta\tau_d\right]$	0.046	0.045	0.046	0.059	0.069	0.080
	(0.048)	(0.052)	(0.058)	(0.064)	(0.069)	(0.069)
$\mathsf{E}\left[\mathsf{L}^{-1}\Delta\tau_d\right]$	0.130	0.113	0.111	0.085	0.082	0.089
	(0.040)	(0.040)	(0.045)	(0.045)	(0.052)	(0.056)
$\Delta\tau_d$	0.165	0.184	0.197	0.222	0.263	0.260
	(0.047)	(0.046)	(0.050)	(0.050)	(0.052)	(0.060)
$\mathsf{L}^{1}\Delta\tau_d$	0.438	0.443	0.445	0.421	0.412	0.390
	(0.045)	(0.047)	(0.049)	(0.053)	(0.053)	(0.050)
$\mathsf{L}^{2}\Delta\tau_d$	-0.120	-0.111	-0.088	-0.079	-0.050	-0.039
	(0.099)	(0.107)	(0.114)	(0.110)	(0.117)	(0.122)
$\mathsf{L}^{3}\Delta\tau_d$	0.100	0.115	0.106	0.104	0.083	0.089
	(0.033)	(0.033)	(0.034)	(0.037)	(0.040)	(0.043)
			Cumulative Effects			
Total pass-through	1.000	1.023	1.057	1.045	1.096	1.119
	(0.102)	(0.098)	(0.107)	(0.107)	(0.126)	(0.140)
Pre-reform	0.416	0.392	0.398	0.378	0.387	0.420
	(0.083)	(0.082)	(0.083)	(0.083)	(0.093)	(0.103)
Post-reform	0.584	0.631	0.660	0.667	0.708	0.700
	(0.070)	(0.078)	(0.087)	(0.088)	(0.093)	(0.098)
Pass-through F(1)	0.00	0.05	0.29	0.18	0.57	0.73
P-value	0.99	0.82	0.60	0.68	0.46	0.40
N	3,190,647	2,562,875	2,077,874	1,671,171	1,337,786	1,057,569
Product-date effects	912,854	648,451	470,798	341,567	248,364	179,899
Products	42,066	26,809	18,366	12,943	9,274	6,690

Notes: Regression results in columns (1) to (6) are based on data for 22 EU countries. The dependent variable is the change in the logarithm of price, $\Delta\log(PRICE)$. Reforms' announcement information is fully incorporated. Observations in countries with reforms announced less than a month before implementation are removed around the respective reform date. The sample is gradually restricted to products sold contemporaneously in at least 3 up to at least 8 countries, where k_i is number of countries in which model i is sold. The monthly change in the standard VAT rate is denoted by $\Delta\tau_d$. Note that $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = \mathsf{L}^{-j}\Delta\tau_d$ for all reforms that were announced $n > j$ periods ahead, and $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = 0$ for reforms announced $n \leq j$. All specifications include a full set of product-date (id), country and country-month specific fixed effects. The monthly unemployment rate, $Unempl$, and the number of months a product appears in the data in a specific country, $M.age$, as well as $M.age^2$ are controlled for but not reported. Standard errors in parentheses are robust in all specifications and clustered by country and product.

Table B.11 – Unit Sales Effects: Increasing Number of Countries in Product-Date Cells

	(1)	(2)	(3)	(4)	(5)	(6)
	$k_i \geq 3$	$k_i \geq 4$	$k_i \geq 5$	$k_i \geq 6$	$k_i \geq 7$	$k_i \geq 8$
$\mathsf{E}\left[\mathsf{L}^{-3}\Delta\tau_d\right]$	-0.922	-1.112	-1.145	-1.106	-1.233	-0.957
	(0.531)	(0.518)	(0.588)	(0.632)	(0.669)	(0.648)
$\mathsf{E}\left[\mathsf{L}^{-2}\Delta\tau_d\right]$	-0.689	-0.644	-0.768	-0.775	-1.008	-1.034
	(0.440)	(0.478)	(0.551)	(0.588)	(0.537)	(0.495)
$\mathsf{E}\left[\mathsf{L}^{-1}\Delta\tau_d\right]$	2.794	2.924	2.967	3.081	3.382	3.508
	(0.341)	(0.361)	(0.395)	(0.440)	(0.558)	(0.626)
$\Delta\tau_d$	-4.635	-4.799	-4.789	-4.723	-4.674	-4.394
	(0.573)	(0.590)	(0.596)	(0.562)	(0.582)	(0.643)
$\mathsf{L}^1\Delta\tau_d$	-1.655	-1.924	-2.143	-2.306	-2.287	-2.216
	(0.350)	(0.291)	(0.287)	(0.273)	(0.262)	(0.314)
$\mathsf{L}^2\Delta\tau_d$	-0.419	-0.365	-0.284	-0.169	-0.383	-0.193
	(0.379)	(0.400)	(0.419)	(0.468)	(0.470)	(0.489)
$\mathsf{L}^3\Delta\tau_d$	1.172	0.989	0.850	0.917	0.842	0.712
	(0.347)	(0.324)	(0.373)	(0.440)	(0.469)	(0.505)
	Cumulative Effects					
Total	-4.353	-4.931	-5.311	-5.080	-5.362	-4.573
	(0.744)	(0.661)	(0.780)	(0.865)	(0.831)	(0.845)
Pre-reform	1.183	1.168	1.055	1.200	1.141	1.518
	(0.686)	(0.666)	(0.719)	(0.701)	(0.606)	(0.595)
Post-reform	-5.536	-6.099	-6.366	-6.281	-6.503	-6.091
	(0.510)	(0.516)	(0.554)	(0.600)	(0.702)	(0.772)
N	3,255,452	2,611,985	2,115,467	1,700,080	1,359,930	1,074,686
Product-date effects	927,440	656,984	475,835	344,538	250,059	180,918
Products	42,298	26,897	18,400	12,963	9,281	6,693

Notes: Regression results in columns (1) to (6) are based on data for 22 EU countries. The dependent variable is the change in the logarithm of unit sales, $\Delta\log(UNITS)$. Reforms' announcement information is fully incorporated. Observations in countries with reforms announced less than a month before implementation are removed around the respective reform date. The sample is gradually restricted to products sold contemporaneously in at least 3 up to at least 8 countries, where k_i is number of countries in which model i is sold. The monthly change in the standard VAT rate is denoted by $\Delta\tau_d$. Note that $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = \mathsf{L}^{-j}\Delta\tau_d$ for all reforms that were announced $n > j$ periods ahead, and $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = 0$ for reforms announced $n \leq j$. All specifications include a full set of product-date, country and country-month specific fixed effects. The monthly unemployment rate, $Unempl$, and the number of months a products appears in the data in a specific country, $M.age$, as well as $M.age^2$ are controlled for but not reported. Standard errors in parentheses are robust in all specifications and clustered by country and product.

Table B.12 – Unit Sales Effects: Including Single-Country Products

Reforms	All		All		n≥ 1	
	(1)	(2)	(3)	(4)	(5)	(6)
$\mathsf{L}^{-3}\Delta\tau_d$		-0.357				
		(0.519)				
$\mathsf{L}^{-2}\Delta\tau_d$		-0.346				
		(0.455)				
$\mathsf{L}^{-1}\Delta\tau_d$	1.897	1.874				
	(0.562)	(0.563)				
$\mathsf{E}\left[\mathsf{L}^{-3}\Delta\tau_d\right]$				-0.311		-0.402
				(0.525)		(0.545)
$\mathsf{E}\left[\mathsf{L}^{-2}\Delta\tau_d\right]$				-0.536		-0.641
				(0.464)		(0.453)
$\mathsf{E}\left[\mathsf{L}^{-1}\Delta\tau_d\right]$			2.014	1.987	2.050	2.043
			(0.610)	(0.609)	(0.636)	(0.634)
$\Delta\tau_d$	-3.426	-3.433	-3.428	-3.436	-3.941	-3.957
	(1.144)	(1.147)	(1.142)	(1.146)	(1.139)	(1.144)
$\mathsf{L}^{1}\Delta\tau_d$	-1.775	-1.759	-1.773	-1.764	-1.379	-1.372
	(0.572)	(0.564)	(0.574)	(0.572)	(0.534)	(0.535)
$\mathsf{L}^{2}\Delta\tau_d$		-0.774		-0.770		-0.995
		(0.297)		(0.294)		(0.285)
$\mathsf{L}^{3}\Delta\tau_d$		1.116		1.115		1.324
		(0.334)		(0.332)		(0.322)
			Cumulative Effects			
Total	-3.304	-3.678	-3.187	-3.715	-3.270	-3.999
	(0.455)	(0.917)	(0.397)	(0.956)	(0.381)	(0.768)
Pre-reform	1.897	1.172	2.014	1.140	2.050	1.000
	(0.562)	(0.858)	(0.610)	(0.869)	(0.636)	(0.825)
Post-reform	-5.201	-4.849	-5.201	-4.855	-5.320	-5.000
	(0.831)	(0.863)	(0.828)	(0.863)	(0.849)	(0.819)
N	7,784,370	7,784,370	7,784,370	7,784,370	7,579,291	7,579,291
Group-date effects	44,457	44,457	44,457	44,457	44,062	44,062
Products	236,743	236,743	236,743	236,743	234,265	234,265

Notes: Regressions are based on data for 22 EU countries. The dependent variable is the change in the logarithm of unit sales, $\Delta\log(UNITS)$. Estimates in columns (5) to (6) are based on a reduced sample, in which observations in countries with reforms announced less than a month before implementation, are removed around the respective reform date. The monthly change in the standard VAT rate is denoted by $\Delta\tau_d$. Note that $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = \mathsf{L}^{-j}\Delta\tau_d$ for all reforms that were announced $n > j$ periods ahead, and $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = 0$ for reforms announced $n \leq j$. All specifications include a full set of country-, country-month specific and group-date-specific fixed effects, where the groups are based on all possible combinations of the characteristics per product category as shown in Table B.4. For more details on the formation of the groups, refer to Section A.2 in the Appendix. Group-date cells, which contain a single country, are dropped from the estimation. The monthly unemployment rate, $Unempl$, and the number of months a product appears in the data in a specific country, $M.age$, as well as $M.age^2$ are controlled for but not reported. Standard errors in parentheses are robust in all specifications and clustered by country and group.

Table B.13 – Differential Unit Sales and Price Effects for Top-Selling Products

Forward terms	$\mathsf{L}^{-i}\Delta\tau_d$	$\mathsf{E}\left[\mathsf{L}^{-i}\Delta\tau_d\right]$		
Reforms	All	All	n≥ 1	n>3
	(1)	(2)	(3)	(4)
		Price effects $R50$		
Total	0.592	0.349	0.217	0.230
	(0.251)	(0.169)	(0.140)	(0.159)
Pre-reform	0.375	0.132	0.130	0.144
	(0.137)	(0.073)	(0.074)	(0.093)
Post-reform	0.217	0.217	0.086	0.086
	(0.140)	(0.140)	(0.099)	(0.095)
		Price effects $R100$		
Total	0.611	0.342	0.215	0.279
	(0.233)	(0.128)	(0.111)	(0.111)
Pre-reform	0.412	0.143	0.123	0.144
	(0.156)	(0.061)	(0.064)	(0.067)
Post-reform	0.199	0.199	0.092	0.135
	(0.106)	(0.106)	(0.079)	(0.075)
N	4,032,497	4,032,497	3,916,710	3,747,026
Product-date effects	1,302,880	1,302,880	1,275,887	1,227,984
Products	71,223	71,223	70,663	69,586
		Sales effects $R50$		
Total	-1.059	-0.835	-0.083	-0.879
	(1.293)	(1.269)	(1.024)	(1.388)
Pre-reform	-0.306	-0.081	-0.013	-0.657
	(0.787)	(0.718)	(0.734)	(0.725)
Post-reform	-0.753	-0.754	-0.070	-0.222
	(0.902)	(0.905)	(0.767)	(0.973)
		Sales effects $R100$		
Total	-0.679	-0.559	-0.558	-1.482
	(0.920)	(0.846)	(0.830)	(0.987)
Pre-reform	-0.461	-0.337	-0.521	-0.891
	(0.701)	(0.655)	(0.664)	(0.761)
Post-reform	-0.218	-0.222	-0.037	-0.592
	(0.665)	(0.666)	(0.662)	(0.692)
N	4,126,760	4,126,760	4,006,045	3,834,261
Product-date effects	1,331,154	1,331,154	1,302,736	1,254,536
Products	72,056	72,056	71,492	70,413

Notes: The table shows regressions for unit sales and prices following eq. (4.1) and eq.(4.2), with a full set of interaction terms for $\Delta\tau_d$ with indicators $R50$ ($R100$). The latter denote dummy variables equal to one if a product reaches a top 50 (top 100) rank within its respective category at some point in its life-cycle. The table reports the cumulative sum of pre-reform and post-reform coefficients as well as the total effect only for the interaction terms. In other words, it focuses solely on the differential effect for top-sellers and other goods. The monthly change in the standard VAT rate is denoted by $\Delta\tau_d$. Note that $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = \mathsf{L}^{-j}\Delta\tau_d$ for all reforms that were announced $n > j$ periods ahead, and $\mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right] = 0$ for reforms announced $n \leq j$. All specifications include a full set of product-date, country and country-month specific fixed effects. The monthly unemployment rate, $Unempl$, and the number of months a products appears in the data in a specific country, $M.age$, as well as $M.age^2$ are controlled for but not reported. Standard errors in parentheses are robust in all specifications and clustered by country and product.

TABLE B.14 – PERMANENT RESPONSE DIFFERENCES

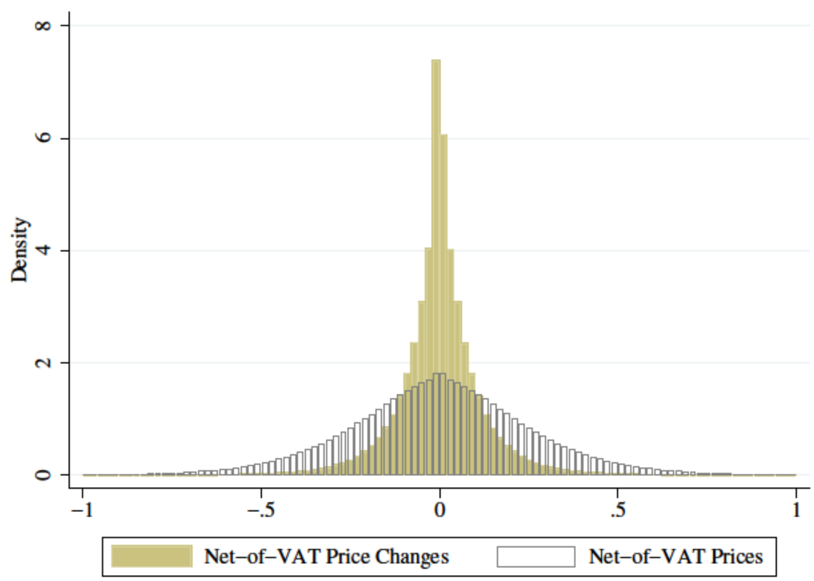
	Exogenous (1)	Exogenous & n≥ 1 (2)	Exogenous & n>3 (3)
		Panel A: Product Categories	
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{RG}}$	0.218	0.284	-0.124
	(1.301)	(1.290)	(1.459)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{WM}}$	-1.995	-2.314	-2.864
	(1.910)	(1.868)	(1.844)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{CO}}$	-3.765	-4.210	-3.048
	(1.765)	(1.691)	(1.688)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{FRZ}}$	1.869	0.972	1.666
	(2.618)	(2.553)	(2.444)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{DW}}$	-7.099	-6.429	-3.169
	(4.329)	(4.290)	(3.158)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{TD}}$	-3.516	-3.431	-3.827
	(2.057)	(2.190)	(2.465)
F-test: Different permanent effects	1.55	1.53	1.02
P-value	0.18	0.19	0.41
N	3,046,468	3,008,885	2,981,514
Product-date effects	996,031	986,525	980,035
Products	57,807	57,587	57,352
		Panel B: Brand Quality Groups	
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{Top}}$	-0.875	-0.669	-0.618
	(1.826)	(1.853)	(1.910)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{Mid}}$	-2.560	-2.831	-1.366
	(2.925)	(2.850)	(2.948)
$\sum_{j=1}^{7} \mathsf{E}\left[\mathsf{L}^{-j}\Delta\tau_d\right]^{\text{Low}}$	2.392	1.448	-1.110
	(2.896)	(2.912)	(3.144)
F-test: Different permanent effects	0.77	0.55	0.03
P-value	0.46	0.58	0.97
N	1,355,903	1,341,798	1,329,973
Product-date effects	370,796	368,774	367,491
Products	16,448	16,431	16,390

Notes: Regression results are based on data for 22 EU countries. The dependent variable in columns (1) to (3) is the change in the logarithm of unit sales, $\Delta \log(UNITS)$. Panel A reports results from regressions where all tax effects are interacted with product category dummies. Standard errors are clustered at the intersection of country and product category and at product level. Panel B reports results from regressions where all tax effects are interacted with brand quality group dummies. Standard errors are clustered at the intersection of country and brand and at product level Both specifications allow seasonal patterns to differ between product categories/brand quality groups. The F-statistics refer to tests of the equality of permanent effects across product categories/brand quality groups.

FIGURE C.1 – UNIT SALES RESPONSE: 12 MONTHS AFTER IMPLEMENTATION

Notes: The figure depicts the time path of unit sales 12 months after a VAT tax rate change and is, in all other respects, identical to Figure 4.

FIGURE C.2 – DISTRIBUTION OF PRICE (CHANGE) DIFFERENCES



Notes: The histograms plot all price (price change) differentials in log points generated within product-date cells. For a product sold in k countries in a given month-year d with k non-missing price observations, the total number of possible relative price combinations are $k!/2!(k-2)!$. Note that since prices are inclusive of VAT, we first remove the VAT component, and translate all prices into Euro before calculating relative prices. The histogram excludes log point deviations in relative prices or price changes greater (smaller) or equal to 1 (-1), which constitute 1.3% of all observations.

D The Cases of Germany and Spain

The above analysis assumes that consumers are well aware of a forthcoming tax increase/decrease. This part of the appendix focuses in more detail on Germany and Spain to check this assumption using data on the press coverage of tax reforms. It also explores whether sales and price effects of tax rate changes are visible in the raw data.

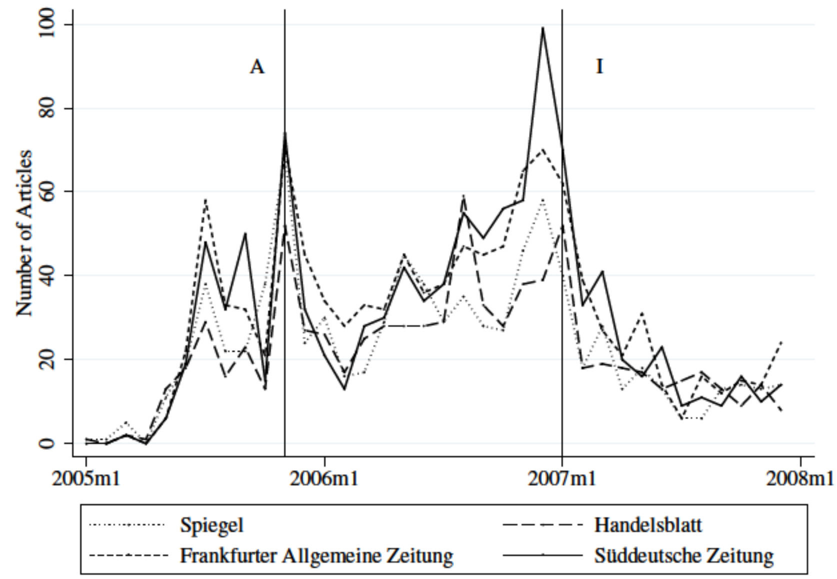
The German VAT increase of 3pp. in 2007 is discussed in detail by D'Acunto *et al.* (2019) and Carare and Danninger (2008). As a reform not tackling current or projected economic conditions, it meets the exogeneity criteria of Romer and Romer (2010).[1] In contrast, the VAT increases in Spain in 2010 (by 2pp.) and 2012 (by 3pp.) took place in a more difficult macroeconomic environment and were clearly motivated by fiscal predicaments in the aftermath of the 2008 financial crisis. Consequently, Gunter *et al.* (2017) classify both Spanish reforms as endogenous given their GDP-driven and pro-cyclical nature. The German reform and the first Spanish reform were announced well in advance – 14 months and 10 months, respectively, whereas the implementation lag for the second Spanish VAT increase was only a month and a half.

Figure D.1 graphs the number of articles in the German media discussing the VAT increase, based on four major non-tabloid newspapers in the country. The announcement and implementation dates for the tax reform are marked with reference lines. Two clear spikes in the number of articles are observed, one at the announcement date and one in the month before the implementation, even though the reform was being discussed continuously throughout 2006. Similarly to Germany, Figure D.2 depicts the number of articles discussing the Spanish reforms based on three main newspapers, with the second reform receiving almost double the coverage, which is not surprising given its short announcement and political context.

Figure D.3 shows annual growth rates of sales and prices in Germany and Spain relative to the same month of the previous year. Panel A depicts a strong growth in sales, especially in the last two to three months before the implementation of the VAT increase in Germany, and a substantial

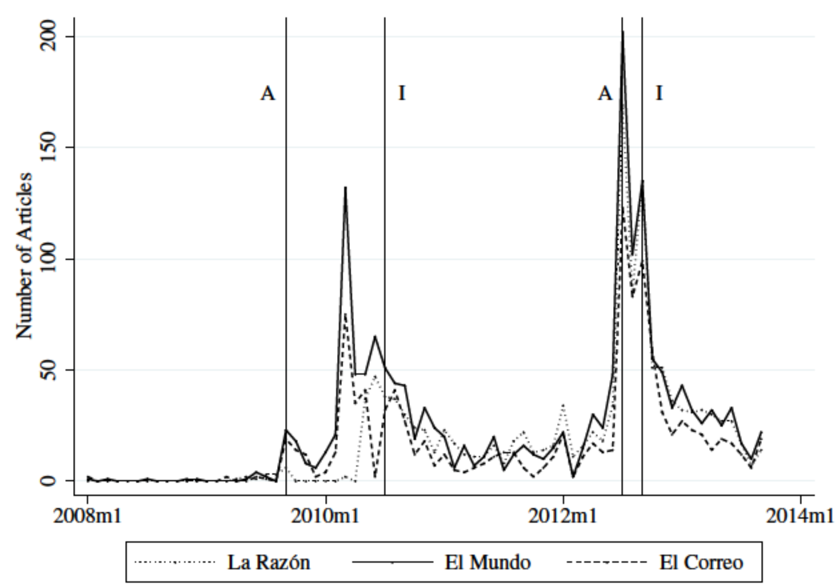
[1] Based on Romer and Romer's (2010) classification, tax changes serving long-run objectives, or those addressing past economic conditions such as tax increases dealing with an inherited budget deficit, are treated as exogenous.

FIGURE D.1 – GERMANY: NEWSPAPER ARTICLES ADDRESSING REFORM, 2005-2007



Notes: The figure depicts the number of articles in four major German newspapers, which mention "VAT rise" either in the title, or the main text from January 2005 until December 2007. The search keyword is "VAT rise" ("Mehrwertsteuererhöhung"). Germany increased the standard VAT rate from 16 to 19% on 1.1.2007, with the tax increase officially announced in November 2005. Authors' calculations using the online archives of Der Spiegel, Handelsblatt, Frankfurter Allgemeine Zeitung and Süddeutsche Zeitung.

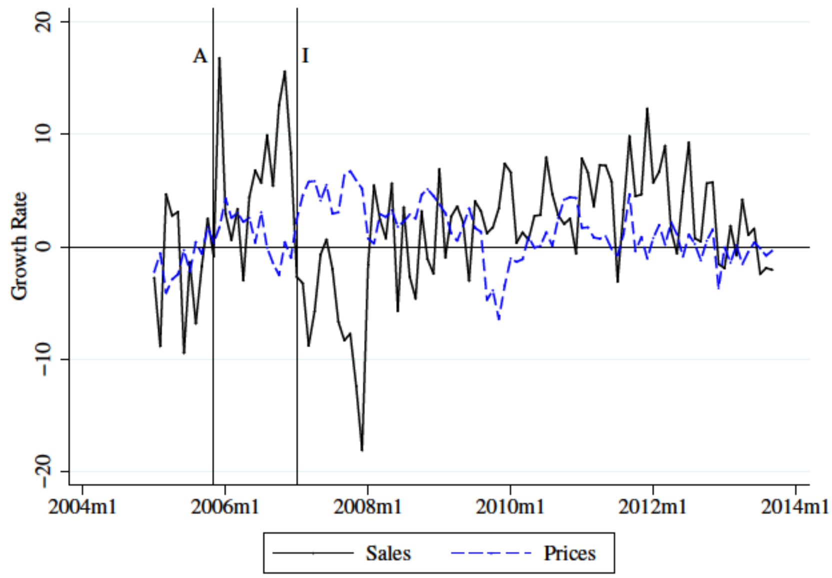
FIGURE D.2 – SPAIN: NEWSPAPER ARTICLES ADDRESSING REFORMS, 2008-2013



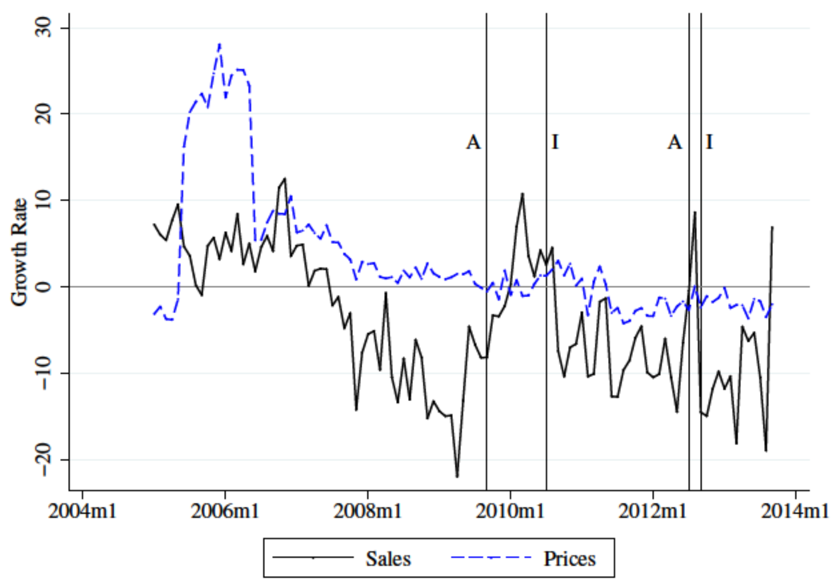
Notes: The figure shows the number of articles in three major Spanish newspapers, which mention "VAT rise" either in the title, or the main text from January 2008 until September 2013. The search keyword is "VAT rise" ("subida de IVA"). Spain increased the standard VAT rate twice in the depicted period: from 16 to 18% on 1.7.2010, with the tax increase officially announced in September 2009, and from 18 to 21% on 1.9.2012, announced on 11.7.2012. Authors' calculations using the online archives of La Razon, El Mundo, and El Correo.

FIGURE D.3 – GROWTH RATE OF UNIT SALES AND PRICES

A. GERMANY



B. SPAIN



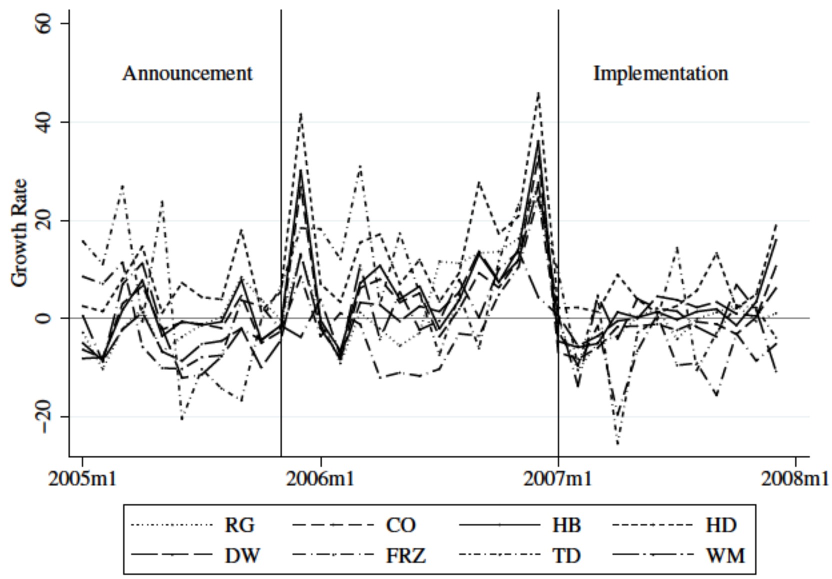
Notes: The figure depicts the annual growth rate of sales and prices in Germany and Spain relative to the same month of the previous year, starting from January 2004 and ending in September 2013. Germany increased the standard VAT rate from 16 to 19% on 1.1.2007, with the tax increase officially announced in November 2005. Spain increased the standard VAT rate twice in the depicted period: from 16 to 18% on 1.7.2010, with the tax increase officially announced in September 2009, and from 18 to 21% on 1.9.2012, announced on 11.7.2012.

drop afterwards. The period after implementation is characterized by substantially higher prices. This pattern is consistent with the theoretical predictions for sales and with full and instantaneous price pass-through.

The growth rate of unit sales jumps also in December 2005, one month after announcement. Disaggregating by categories of products (see Fig. D.4), we found that this response is driven by cooktops, hoods, and cookers, which are often sold as part of a kitchen unit. Closer inspection revealed that this effect is entirely driven by sales of Kitchen and Furniture specialising stores. A possible explanation is that those durables may have substantial delivery lags, which would induce consumers to buy early in order to ensure that the lower VAT rate applies. The dashed black line in Figure D.5 depicts the growth rate without cooktops, hoods and cookers. The announcement response then falls by half. Finally, the figure also shows growth rate of sales in neighbouring Austria, a closely integrated market to the German economy. Austria did not change its standard VAT rate and the sales growth rate does not deviate much around zero.

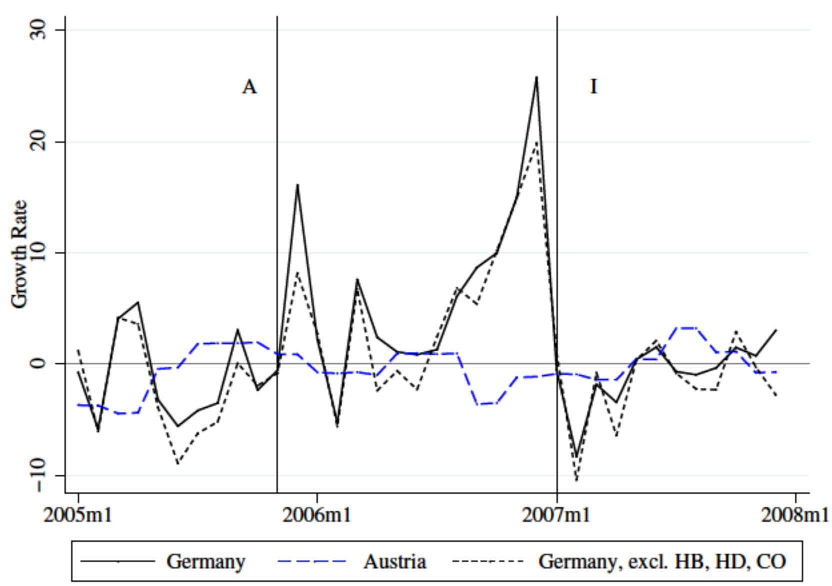
As shown in Panel B of Figure D.3, the market for white goods in Spain shrank considerably from 2007 to 2012. Against this negative trend, the two VAT reforms are associated with temporary pre-reform peaks in sales. In contrast to the German case, after the first reform, sales seem not to recover. With regard to price effects, a price increase is visible after the first reform, but a year after the reform prices are falling again. The second VAT increase is also not clearly reverting the negative price trend.

Figure D.4 – Germany: Growth Rate Of White Goods' Unit Sales By Product Category, 2005-2007



Note: The figure depicts the growth rate of the number of units sold in month *m* in years 2005, 2006, and 2007 relative to the average sales in 2004 and 2008 for the same month *m* for eight categories of durable goods: refrigerators (RG), cookers (CO), hobs/cooktops (HB), hoods (HD), dishwashers (DW), freezers (FRZ), tumble driers (TD) and washing machines (WM). The aggregate growth rate is depicted in two different ways in Figures D.3 and D.5. Germany increased the standard VAT rate from 16 to 19% on 1.1.2007, with the tax increase officially announced in November 2005.

Figure D.5 – Germany: Growth Rate Of Unit Sales



Notes: The figure depicts the growth rate of the total number of units sold in Germany. The solid line shows the growth rate in month *m* in years 2005, 2006, and 2007 relative to the average sales in 2004 and 2008 in the same month *m*. For example, sales in Dec. 2005 were 16% higher relative to the average sales in Dec. 2004 and Dec. 2008. The black dashed line depicts the same growth rate excluding HB, HD, and CO. The dashed line is the growth rate of units sold in Austria, where no VAT rate change occurred.

E Theoretical Appendix

E.1 Demand for Consumer Durables with a Pre-announced Tax Rate Change

This appendix provides a brief analysis of the demand for durable goods by a household facing a pre-announced change in a general consumption tax. The following section characterizes the houshold's optimization problem. Subsequently, section E.3 derives Euler equations, *i.e.* the optimal time path of consumption of durable and non-durable goods. Section E.4 discusses predictions for the effects of a tax rate change.

E.2 Household Optimization Problem

The household derives utility from the consumption of durable and non-durable goods. The intra-period utility function is

$$u_s = \left[(1-b)^{\frac{1}{\epsilon}} x_s^{\frac{\epsilon-1}{\epsilon}} + b^{\frac{1}{\epsilon}} k_s^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}},$$

where x_s is current consumption of non-durable goods and k_s indicates the consumption of services from the stock of consumer durables in the same period. ϵ denotes the elasticity of substitution.

Since the analysis deals with pre-announced changes in the tax rate, the consumer's choice is analyzed in a setting of certainty. The present value of the instantaneous utility in all periods is

$$\sum_{s=1}^{\infty} \beta^{s-t} \frac{\sigma}{\sigma-1} u_s^{1-\frac{1}{\sigma}},$$

where $\beta < 1$ is a discount factor reflecting the household's time preference, and σ is the intertemporal elasticity of substitution. In the specific case of $\sigma = \epsilon$, the utility function becomes additively separable in durable and non-durable goods consumption.

The stock of consumer durables evolves according to

$$k_s - k_{s-1} = i_s - \delta k_{s-1}.$$

where δ is the rate of depreciation. Writing $d = 1 - \delta$, we can solve for gross investment

$$i_s = k_s - k_{s-1} d. \tag{E.1}$$

Following standard practice, we assume a convex adjustment cost, formally

$$\frac{c}{2} \left(k_s - k_{s-1}\right)^2 .$$

For simplicity, the adjustment cost is determined by net investment. Hence, it is zero if the stock of durables is constant.[2] Normalizing the pre-tax price of non-durables to unity and setting the pre-tax, or producer price of the durable good to q_s, consumer prices for durable and non-durable goods are

$$p_s = (1 + \tau_s)\, q_s \text{ and } (1 + \tau_s)\,,$$

respectively.

The evolution of (financial) wealth is determined by total income, which consists of labor income w_s, and interest income, net of current purchases of non-durable consumption goods, current investment in durable goods and adjustment costs:

$$a_{s+1} - a_s = w_s + r a_s - (1 + \tau_s)\, x_s - (1 + \tau_s)\, q_s \left(k_s - k_{s-1} d\right) - \frac{c}{2} \left(k_s - k_{s-1}\right)^2 , \tag{E.2}$$

where a_s is the stock of wealth at the beginning of period s, and r is the interest rate.

Eliminating i_s by plugging (E.1) into (E.2), for each period $s \in [1, 2, \ldots]$, the household chooses consumption of non-durables x_s and of durables k_s to maximize expected discounted utility subject

[2]The results below can be generalized to hold also if the adjustment cost is related to gross investment $(k_s - dk_{s-1})$ as in Shapiro (1986).

to constraint (E.2).[3]

E.3 Euler Equations for Consumption

In period t, the optimal consumption structure obeys

$$\frac{k_t}{x_t} = \frac{b}{1-b}\left(Q_t + C_t\right)^{-\epsilon}. \tag{E.3}$$

Q_t denotes the user cost of the service flow of the durable good (Ogaki and Reinhard, 1998). C_t denotes the marginal adjustment cost. If $\epsilon > 0$, equation (E.3) states that a reduction in the user cost and a decline in the adjustment cost are associated with a substitution of non-durable with durable goods. The user cost is defined as

$$Q_t = \left[1 - \rho d\left(\frac{p_{t+1}}{p_t}\right)\right] q_t,$$

where $\rho = \frac{1}{1+r}$. Note that the user cost depends on the change in the consumer price in the next period $\frac{p_{t+1}}{p_t} = \frac{1+\tau_{t+1}}{1+\tau_t}\frac{q_{t+1}}{q_t}$. The user cost declines in period t if the consumer price increases in $t+1$. Assuming that the producer prices is fixed, $q_{t+1} = q_t$, and the user cost changes only with the tax rate. Note that the effect of the tax change on the user cost is larger if the depreciation rate is small.

The marginal adjustment cost is

$$C_t = \frac{c}{1+\tau_t}\left[\left(k_t - k_{t-1}\right) - \beta\left(k_{t+1} - k_t\right)\right].$$

In order to derive implications for the demand for durable goods, we first consider the time path of consumption of non-durables.

[3] The Lagrangian for the intertemporal optimization problem is

$$\mathcal{L} = \sum_{s=1}^{\infty}\left\{\beta^{s-1}\frac{\sigma}{\sigma-1}u_s^{\frac{\sigma-1}{\sigma}} + \lambda_{s+1}\beta^{s-1}\left[(1+r)\,a_s + w_s - (1+\tau_s)\,x_s - (1+\tau_s)\,q_s\left(k_s - k_{s-1}d\right) - \frac{c}{2}\left(k_s - k_{s-1}\right)^2 - a_{s+1}\right]\right\},$$

where λ_{s+1} is the Lagrange multiplier in current value terms.

With the simplifying assumption that $\beta(1+r) = 1$, the Euler equation for consumption of non-durables in period $t+1$ is

$$x_{t+1} = x_t \left(\frac{1+\tau_{t+1}}{1+\tau_t} \right)^{-\sigma} \left(\frac{1 + \frac{b}{1-b}(Q_{t+1} + C_{t+1})^{1-\epsilon}}{1 + \frac{b}{1-b}(Q_t + C_t)^{1-\epsilon}} \right)^{\frac{\sigma-\epsilon}{\epsilon-1}} . \tag{E.4}$$

Inserting from equation (E.3), we can use (E.4) to derive the corresponding Euler equation for the capital stock

$$k_{t+1} = k_t \left(\frac{1+\tau_{t+1}}{1+\tau_t} \right)^{-\sigma} \left(\frac{1 + \frac{b}{1-b}(Q_{t+1} + C_{t+1})^{1-\epsilon}}{1 + \frac{b}{1-b}(Q_t + C_t)^{1-\epsilon}} \right)^{\frac{\sigma-\epsilon}{\epsilon-1}} \left(\frac{Q_{t+1} + C_{t+1}}{Q_t + C_t} \right)^{-\epsilon} . \tag{E.5}$$

Equations (E.4) and (E.5) provide the optimal pattern of consumption of non-durable and durable goods. In the following section we discuss the empirical implications of a pre-announced change in the tax rate.

E.4 Effects of a Tax Rate Change

Equations (E.4) and (E.5) indicate that there are direct and indirect effects of the tax rate on the time path of consumption of non-durable and durable goods.

Turning first to non-durables, equation (E.4) suggests that there are two direct effects of taxes on the optimal path of consumption. First, there is a direct effect associated with intertemporal substitution. If the tax rate changes, say it increases in period $t+1$, the first term in parentheses shows that the consumption of non-durables after the tax rate increase is small relative to consumption before the increase. The strength of this effect is determined by the elasticity of intertemporal substitution.

A second direct effect is associated with the user cost of durables. With a tax increase in period $t+1$ relative to period t, the user cost of durables declines temporarily $Q_t < Q_{t+1}$. If the two types of consumption goods are substitutes, *i.e.* $\epsilon > 0$, this provides an incentive to substitute the consumption of non-durable goods with durable goods. As noted by Cashin and Unayama (2016), the implications for the time path of consumption of non-durables depend on whether the elasticity of intratemporal substitution is large or small relative to the elasticity of intertemporal substitution. With a small ϵ, such that $\epsilon < \sigma$ and $\epsilon < 1$, the last term in parentheses in equation (E.4) further contributes to a high level of consumption before and a low level after the tax rate increase. If the elasticity of intratemporal substitution is relatively large, $\epsilon > \sigma$ and $\epsilon < 1$, the intratemporal substitution of non-durable with durable goods works against a high level of consumption in period t and a low level in $t + 1$. In the case of separable utility $\sigma = \epsilon$, the time path of consumption of non-durables would only be affected by intertemporal substitution effects.

Besides direct effects, the pattern of consumption of non-durables around a tax rate change would also depend on indirect effects. With given producer prices, these are caused by changes in the marginal adjustment cost, which is a function of the consumption of durables.

Equation (E.5) shows that the two determinants of the time path of non-durable consumption also affect the time path of the consumption of durables. In fact, the first term in parentheses is identical to equation (E.4) indicating that both types of consumption are subject to the same permanent intertemporal substitution effect.

While the temporary decline in the user cost, caused by an increase in the tax rate, also affects both types of consumption goods, the effect on durables differs from the effect on non-durables due to the last term in parentheses in equation (E.5). Interestingly, the changes in the user cost matter for the time path of durables, even if the utility function is separable in consumption of durable and non-durable goods $\sigma = \epsilon$. With full price pass-through, the predictions are straightforward. If the tax rate increases in period $t + 1$, the user cost of durables declines temporarily in period t and reverts to its steady state level in period $t + 1$, so that, $Q_t < Q_{t+1}$. This contributes to a high level of the consumption of durables in period t relative to period $t + 1$.[4] As above, indirect effects for durables are caused by the marginal adjustment cost.

Although the actual time paths of consumption depend on the specific parameter values, the

[4]Note that with $\epsilon, \sigma > 0$, the partial derivatives of k_{t+1} are unambiguous: $\frac{\partial k_{t+1}}{\partial Q_{t+1}} < 0, \frac{\partial k_{t+1}}{\partial Q_t} > 0$, regardless of whether $\epsilon > \sigma$ or $\epsilon < \sigma$.

difference equations (E.4) and (E.5) suggest that we can distinguish temporary and permanent effects of tax rate changes. The temporary effects are associated with changes in the user cost and the marginal adjustment cost and are shaped by preference parameters. However, the permanent effects are determined solely by intertemporal substitution. This property of the optimal time path of consumption has been exploited by Cashin and Unayama (2016) to identify the elasticity of intertemporal substitution using non-storable non-durables.

To show this property, we consider a tax rate increase by $\Delta\tau$ announced by the government in period 0 to take place in period $t+1$. In the periods before $t+1$, the tax rate is equal to τ, and in all periods after the implementation, the tax rate is $\tau + \Delta\tau$. In this setting, given full pass-through, we can separate two time periods in which the user cost is constant: The period after implementation, $j = t+1, t+2, ...$, and the period before implementation except period t, $j = 1, 2..., t-1$. In both periods, the precise pattern of consumption depends on initial values and on the marginal adjustment cost.

Given stability of the Euler equations, if the time spans are sufficiently long, in each period, the levels of consumption will approach stationary levels. In the period after implementation, provided that the tax policy is unchanged, there is a time period $t+p$ with $p > 1$ such that $k_{t+p} - k_{t+p-1} \approx 0$. But also after the announcement and prior to the implementation, when adjustment to the initial policy innovation has already taken place, a stationary state is reached by $t-q$ with $q > 1$ such that $k_{t-q} - k_{t-q-1} \approx 0$. This requires that either adjustment costs are small, or that the implementation lag with length $1, ...t+1$ is large. Hence, for a given adjustment cost function, the implementation lag has to be sufficiently long.

These observations enable us to predict the difference in consumption levels before and after the tax increase. From equation (E.4), forward and backward substitution provides

$$x_{t+p} \quad = \quad x_{t-q} \left(\frac{1+\tau_{t+p}}{1+\tau_{t-q}} \right)^{-\sigma} \left(\frac{1 + \frac{b}{1-b} \left(Q_{t+p} + C_{t+p} \right)^{1-\epsilon}}{1 + \frac{b}{1-b} \left(Q_{t-q} + C_{t-q} \right)^{1-\epsilon}} \right)^{\frac{\sigma-\epsilon}{\epsilon-1}} . \tag{E.4}$$

With full price pass-through, the user cost in $t+p$ and $t-q$ is equal to its steady-state level,

$Q_{t+p} = Q_{t-q} = Q$. Moreover, if p is sufficiently large, changes in the optimal stock of durables around $t+p$ are small ($k_{t+p} - k_{t+p-1} \approx 0$, $k_{t+p+1} - k_{t+p} \approx 0$). Hence, the marginal adjustment cost C_{t+p} is approximately zero. Similarly, if q is large, changes in the optimal stock of durables around period $t-q$ are small ($k_{t-q} - k_{t-q-1} \approx 0$, $k_{t-q+1} - k_{t-q} \approx 0$) and the marginal adjustment cost C_{t-q} is approximately zero. Consequently, $\frac{Q_{t+q}+C_{t+q}}{Q_{t-p}+C_{t-p}} \approx 1$. Hence,

$$\frac{x_{t+p}}{x_{t-q}} \approx \left(\frac{1+\tau+\Delta\tau}{1+\tau}\right)^{-\sigma}. \tag{E.5}$$

By applying the same reasoning to the Euler equation for the consumption of durables, it is straightforward to show that

$$\frac{k_{t+p}}{k_{t-q}} = \left(\frac{1+\tau+\Delta\tau}{1+\tau}\right)^{-\sigma}. \tag{E.6}$$

This indicates that the relative difference in the levels of consumption of non-durables as well as of durables in periods p and q is determined by σ and the tax rate change.

While the permanent effects of a tax rate change on consumption levels are the same for both types of consumer goods, in contrast to non-durables, with durable goods it is important to distinguish between household consumption and investment. Also the empirical analysis in this paper is concerned with household unit purchases rather than consumption. In terms of the theoretical discussion, this suggests deriving empirical predictions on the investment in durables rather than on the stock of durables. Based on the definition of investment, the log of investment in period s can be approximated by

$$\log i_s = \log\delta + \log k_{s-1} + \frac{1}{\delta} d\log k_s.$$

First differencing yields an expression for changes in investment

$$d\log i_s = \frac{1}{\delta}\left[d\log k_s - d\log k_{s-1}\right] + d\log k_{s-1}.$$

Summing all investment changes around a tax rate change in a time interval from $t-q$ to $t+p$ we get:

$$\sum_{s=t-q}^{t+p} d\log i_s = \frac{1}{\delta}\sum_{s=t-q}^{t+p} [d\log k_s - d\log k_{s-1}] + \sum_{s=t-q}^{t+p} d\log k_{s-1}.$$

If the stock of durables is approximately constant at the beginning and end of the time interval, $d\log k_{t+p} \approx \log k_{t-q-1} \approx 0$, and $\sum_{s=t-q}^{t+p} d\log k_s \approx \sum_{s=t-q}^{t+p} d\log k_{s-1}$. Noting that the sum of net-investment in all periods corresponds to the total change in the stock of durables,we obtain

$$\sum_{s=t+p}^{t-q} d\log i_s \approx \log\frac{k_{t+p}}{k_{t-p}}.$$

This indicates that the sum of changes in investment is approximately equal to the total change in the stock of durables. Recall from equation (E.6) that the total change in the stock of durables is determined by the tax rate change and the elasticity of intertemporal substitution

$$-\sigma = \frac{\sum_{s=t-q}^{t+p} d\log i_s}{\Delta\tau}.$$

Thus, we can infer the elasticity of intertemporal substitution by summing the investment changes and using the information about the magnitude of the tax rate change.

F References only used in the Appendix

Fischer, C., 2012. Price convergence in the EMU? Evidence from micro data. *European Economic Review* 56(4), 757–776.

Roodman, D., MacKinnon, J., Nielsen, M., Webb, M., 2019. Fast and wild: Bootstrap inference in Stata using boottest. *The Stata Journal* 19(1): 4-60.