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EXCHANGE RATES AND PRICES:  
EVIDENCE FROM THE 2015 SWISS FRANC APPRECIATION

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**ABSTRACT**

We dissect the impact of a large and sudden exchange rate appreciation on Swiss border import prices, retail prices, and consumer expenditures on domestic and imported non-durable goods, following the removal of the EUR/CHF floor in January 2015. Cross-sectional variation in border price changes by currency of invoicing carries over to consumer prices and allocations, impacting retail prices of imports and competing domestic goods, as well as import expenditures. We provide measures of the sensitivity of retail import prices to border prices and the sensitivity of import shares to relative prices, which is higher when using retail prices than border prices.

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# 1 Introduction

In this paper we study how prices and consumer expenditures respond to exchange rate movements based on the large and sudden appreciation of the Swiss franc (CHF) on January 15, 2015. Using data on prices and invoicing currency at the border, as well as Nielsen “homescan” data on retail prices and purchases by Swiss households, we present a range of facts that shed light on the sources of incomplete exchange rate pass-through and the role of nominal rigidities in price adjustment, the extent of expenditure switching by households, and the allocative implications of invoicing currency in international trade. We also provide estimates of the sensitivities of retail prices to border prices and import shares to relative prices, which are important elasticities in open economy models.

The Swiss experience provides a unique setting to study the consequences of a large policy-driven change in the nominal exchange rate. On September 6, 2011, after a sharp appreciation of the Swiss franc, the Swiss National Bank (SNB) introduced a minimum exchange rate of 1.20 CHF per EUR. In late 2014 and early 2015, foreign developments such as anticipation of a large-scale quantitative easing program in the euro area raised the perceived cost of sustaining this policy (see e.g. SNB, 2015; Amador et al., 2020), prompting the SNB to unexpectedly abandon the minimum exchange rate on January 15, 2015.<sup>1</sup>

The subsequent appreciation episode is unique in a number of ways.<sup>2</sup> First, it followed a period of remarkable exchange rate stability, with the EUR/CHF exchange rate fluctuating in the range of 1.2–1.22 in the last six months before January 15, 2015. It is hence unlikely that the price dynamics we examine reflect adjustment lags due to prior exchange rate movements. Second, the exchange rate movement was large in magnitude relative to standard short-term exchange rate fluctuations in advanced economies, which have been a main focus of the literature.<sup>3</sup> EUR/CHF appreciated by more than 20% on the day of the policy change, 14.0% by the end of March relative to January 14, 14.7% by the end of June, and 10.6% by the

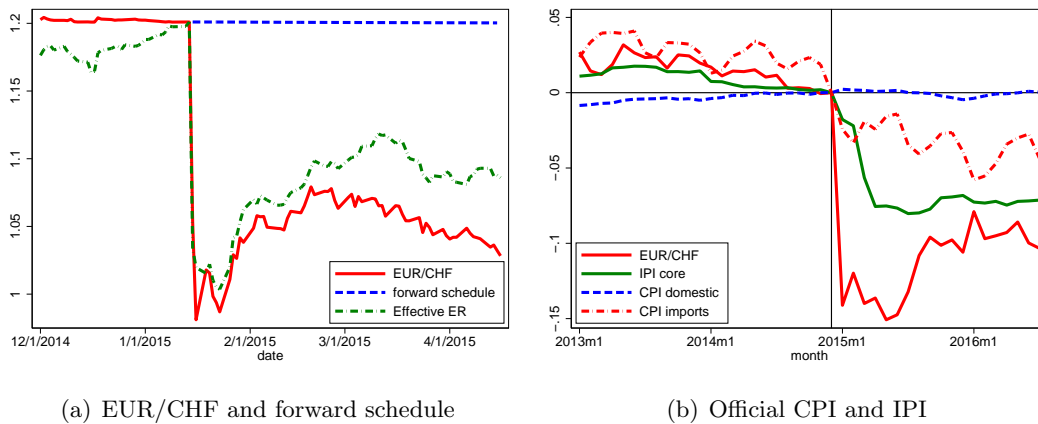
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<sup>1</sup>The SNB had reiterated its commitment to the minimum exchange rate throughout late 2014, arguing as late as December 1 that it “remains the key instrument for ensuring appropriate monetary conditions” (see Jordan, 2014). Of 22 economists surveyed between January 9 and 14, 2015, none expected the SNB to get rid of its minimum rate during the course of 2015 (see Bloomberg, 2015). Forward rates the day before the appreciation show that investors expected a flat profile of the exchange rate, as illustrated in Panel (a) in Figure 1. Jermann (2017) argues that option prices before January 15 revealed a low probability of abandoning the exchange rate floor.

<sup>2</sup>A number of related papers also examine this episode. Bonadio et al. (2019) document the response of unit values at the border, Efung et al. (2016) examine the effects on the valuations of publicly listed Swiss firms, and Kaufmann and Renkin (2017, 2019) study the price and employment response of Swiss manufacturing firms and the response of export prices.

<sup>3</sup>There are many papers that resort to large devaluations in developing countries; see, for example, Burstein et al. (2005), Alessandria et al. (2010), Cravino and Levchenko (2017), and Gopinath and Neiman (2014). However, these episodes tend to be accompanied by other major macroeconomic developments that can confound the effects of exchange rate movements. Cavallo et al. (2015) use micro data on prices to show how a large monetary shock in a non-crisis context – Latvia’s euro area accession – impacts international relative prices.

**Figure 1:** *The 2015 CHF appreciation*



*Notes:* Panel (a) shows daily nominal EUR/CHF exchange rates and effective CHF nominal exchange rates (Switzerland’s 59 main trading partners) between December 1, 2014 and April 30, 2015, and forward exchange rates on January 14, 2015 (overnight 1 week, 1, 2, and 3 months). Panel (b) shows monthly EUR/CHF nominal exchange rate, core import price index, and consumer price index for imports and for domestic goods and services, all relative to December 2014. Sources: Bank for International Settlements (2016), Swiss National Bank (2016), Datastream (2015).

end of December 2015 (see panel (a) in Figure 1).<sup>4</sup> The CPI-based bilateral real exchange rate followed a similar path to the EUR/CHF nominal exchange rate, as shown in Figure A.1 in the online appendix (referred to as appendix from here on). The real appreciation was prolonged, with the EUR/CHF real exchange rate returning to its December 2014 level only by the end of 2017. Third, the appreciation occurred against the backdrop of a stable Swiss economy — Table A.1 in the appendix shows that Swiss economic aggregates were remarkably stable in 2012-2016 — and reflected a policy response to foreign events.<sup>5</sup>

Following the 2015 CHF appreciation, there was a large decline in average import prices — more so at the border than at the consumer level — and a muted response in average prices of Swiss-produced goods (which we refer to interchangeably as domestic goods), as shown in panel (b) in Figure 1 using aggregate price indices from the SNB and the Swiss Federation Statistical Office (SFSO). To examine in more detail the response of these prices, as well as consumer expenditures, we combine several micro-level data sources, described in Section 2. Information on border prices and invoicing currency is from the good-level survey underlying the calculation of the official Swiss import price index. The transaction-level information on non-durable retail prices and expenditures is from the Swiss Nielsen homescan data, which we

<sup>4</sup>The Swiss franc appreciated less markedly against other currencies such as the yen or the pound sterling, as is evidenced by the effective exchange rate index shown in panel (a) in Figure 1.

<sup>5</sup>The price movements we focus on are unlikely to be the lagged result of safe-haven capital inflows while the minimum rate was in place. Foreign safe-haven demand for CHF was largely channelled through branches of foreign banks and invested in sight deposit accounts at the SNB (see e.g. Auer, 2015). Moreover, the CHF real exchange rate did not appreciate much in that period, and when it did in 2015, the growth rate of real GDP and real consumption fell slightly relative to 2014 (see Table A.1 in the appendix).

augment with data on the origin of the purchased goods. We exploit variation across product categories in currency of invoicing to trace the role of invoicing from border prices to retail prices and, further, to expenditure allocations.

We start our analysis in Section 3 by documenting the response of border prices in the aftermath of the appreciation and how this response varies across goods by invoicing currency. The decline in border prices was much larger for EUR-invoiced goods than for CHF-invoiced goods, even conditioning on non-zero price changes, consistent with findings in Gopinath et al. (2010) for border prices in the United States. However, estimated differences in conditional price changes attenuate over time and become statistically insignificant about one year after the CHF appreciation. These patterns are qualitatively consistent with models of endogenous invoicing (e.g. Gopinath et al., 2010). We perform simple accounting exercises to quantify the impact on border prices of hypothetical changes in the currency of invoicing from CHF to EUR and changes in the degree of nominal price stickiness. We conclude from these exercises that over short horizons (during which border price stickiness in the currency of invoicing is quantitatively relevant), counterfactual shifts in the currency of invoicing have larger effects on border prices than do counterfactual shifts in the degree of nominal price stickiness.

In Section 4 we examine the response of retail prices. After documenting in the homescan data a decline in the retail price of imports relative to Swiss-produced goods, we provide evidence that variation across goods in invoicing currency at the border has a sizable impact on retail price changes faced by consumers. According to our estimates, in the first two quarters after the appreciation, retail import prices in product categories that are (hypothetically) fully invoiced in foreign currency fell by roughly 7 percentage points more than in product categories (hypothetically) fully invoiced in CHF. While previous evidence on the role of invoicing currency is based on import and export price changes at the border (see e.g. Gopinath et al., 2010; Fitzgerald and Haller, 2014; Gopinath, 2016), our results establish that differences in border price changes associated with the currency of invoicing carry over to consumer prices.<sup>6</sup>

We estimate the sensitivity of import prices at the retail level with respect to changes in border prices, leveraging heterogeneity in border price changes induced by variation in pre-appreciation EUR invoicing shares. These estimates imply that, after two quarters, a 1 percentage point larger reduction in import prices at the border resulted in a roughly 0.55 percentage point larger price reduction for imported products at the retail level.<sup>7</sup>

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<sup>6</sup>The invoicing currency and response of border and consumer prices to exchange rate movements is an important ingredient of optimal exchange rate policy (see e.g. Engel, 2003; Devereux and Engel, 2007; Egorov and Mukhin, 2020).

<sup>7</sup>Berger et al. (2012) use the micro price data underlying the official US import and consumer price indices of the US Bureau of Labor Statistics to match individual identical items at the border and retail levels, estimating the evolution of good-specific distribution shares. For related work studying pass-through at different layers of the distribution chain, see e.g. Nakamura and Zerom (2010) and Goldberg and Hellerstein (2013).

Even though the response of retail prices of Swiss-produced goods was on average very muted, we show that prices fell more in border product categories invoiced in EUR relative to those in CHF, conditioning on the expenditure share of competing imported goods in the same product category. Relatedly, prices of domestically produced goods fell by more in product categories with larger declines in retail prices of imported goods conditioning on import shares. We argue that, under a certain exclusion restriction, these observations point to the presence of pricing complementarities that imply that domestic producers react to changes in prices of competing imported retail products.<sup>8</sup>

We further examine the response of the extensive margin of adjustment of retail prices. We show that the average decline in retail import prices in 2015 was partly accounted for by an increase in the fraction of nominal price changes, which can in turn be decomposed into a large increase in the frequency of price reductions and a smaller decline in the fraction of price increases. We provide aggregate time series evidence as well as cross-product evidence exploiting variations in invoicing currency and in the magnitude of changes of border prices. Specifically, the increase in the frequency of price reductions was larger for imported products with a larger share of EUR invoicing and with larger price reductions at the border. That is, differences in border price changes associated with the currency of invoicing carry over to consumer prices not only for average changes but also for the extensive margin of price adjustment.<sup>9</sup>

Finally, in Section 5 we examine the extent of consumer expenditure switching in response to the appreciation. On average during the year following the appreciation, expenditure shares of imported goods rose by roughly 4% (or by 1 percentage point, from 0.26 to 0.27). Import shares rose substantially even at short horizons after the appreciation. Leveraging cross-sectional variation along the invoicing dimension, we show that expenditure shares on imported goods increased by more in product categories in which imports are invoiced in EUR than in those categories invoiced in CHF. Hence, differences in invoicing currency at the border matter also for consumer allocations.<sup>10</sup> To estimate the sensitivity of import expenditure shares with respect to changes in relative prices, we instrument import price

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<sup>8</sup>These results complement evidence of strategic complementarities in Gopinath and Itskhoki (2011), Auer and Schoenle (2016), and Amiti et al. (2019), using retail price data and in the context of a well-identified exchange rate shock. Relatedly, Cavallo et al. (2020) and Flaaen et al. (2020) show that US domestic producers increased retail prices in response to the recent increase in US tariffs on competing Chinese imports.

<sup>9</sup>For related work documenting the role of the extensive margin of price adjustment in response to large aggregate shocks, see e.g. Gagnon (2009) in the context of Mexico's 1994 devaluation, Karadi and Reiff (2019) in the context of VAT changes in Hungary, and Gopinath et al. (2012) in the context of the trade collapse during the 2008 Great Recession.

<sup>10</sup>Differences in currency of invoicing at the border also carry over to allocations in the export side. In the context of the CHF appreciation, Auer et al. (2019) show that export growth in 2015 was larger in industries with higher EUR invoicing of export border prices. Cravino (2017) uses data on Chilean exports to estimate the differential response of exports to exchange rate shocks according to the invoicing currency of the transaction. Amiti et al. (2018) study the differential response of Belgian exports across heterogeneous firms within sectors.

changes across product categories using EUR invoicing shares at the border. Estimated price elasticities of import shares are close to 1 based on border-level measures of import prices, and much higher (ranging between 2 and 5) based on retail-level measures of import prices, but also less tightly estimated given large idiosyncratic movements in consumer prices. The large gap in estimated elasticities based on the measure of import prices is partly explained by lower exchange rate pass-through into retail prices compared with border prices.<sup>11</sup>

## 2 Data description

In this section we provide an overview of the border and retail data that we use in our analysis. We provide additional details in Appendix B. In the replication package we provide contact information to obtain the proprietary data.

### 2.1 Import prices at the border

We base the analysis of border prices on the microdata used by the SFSO to calculate the Swiss Import Price Index (Swiss Federal Statistical Office, 2016). The data are a survey-based panel of Swiss import prices similar to the US import price data studied in Gopinath and Rigobon (2008). The survey asks firms<sup>12</sup> to quote the price and invoicing currency of the goods accounting for the firm’s highest volume of imports.<sup>13</sup> Since most consumer goods are surveyed on a quarterly basis, we focus on this time horizon. Surveys are carried out by the SFSO in the first two weeks of each quarter. In the exposition, we refer to the last pre-appreciation quarterly observations (first two weeks of January 2015) as 14Q4, and to the first post-appreciation quarterly observations (first two weeks of April 2015) as 15Q1. Since we observe weights by product categories only starting in December 2015 (after a major resampling of products), our baseline border price regressions are unweighted. For regressions that use the subset of categories matched to the retail data, we weight according to consumer expenditures.

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<sup>11</sup>Our estimates based on retail prices are on the high range of elasticity estimates in the literature based on time-series variation and using border prices to measure import prices (see e.g. Feenstra et al., 2018, and references therein).

<sup>12</sup>The SFSO data contain an importing firm identifier, which we use in sensitivity analysis of border price pass-through. However, since we do not observe firm characteristics of Swiss importers or foreign exporters, we do not study the fundamentals that drive heterogeneous invoicing patterns as in e.g. Devereux et al. (2017) and Amiti et al. (2018).

<sup>13</sup>For each good invoiced in foreign currency, we have information on the price expressed in foreign currency and the price expressed in CHF. Given that for some observations there are large disparities between exchange rates implied by these two prices and official exchange rates (that are likely due to errors by contractors performing the conversion), we perform robustness exercises in which we convert foreign currency prices into CHF using official exchange rates.

**Table 1:** *Border data summary statistics*

	Number of observations	% CHF-invoiced	% EUR-invoiced	% USD-invoiced
2013	14,666	68.5	28.7	2.4
2014	14,789	65.8	31.3	2.4
2015	17,381	56.1	38.1	4.7
2016	17,976	51.5	42.0	5.2

*Notes:* This table shows the number of observations and the share of observations invoiced in CHF, EUR, and USD for various years in the non-commodity border price sample.

Table 1 displays, for the sample of non-commodity goods (commodities include agricultural products, coal, petroleum, metals, electricity and gas), the number of border price observations and the share of observations by currency of invoicing per year between 2013 and 2016. The share of observations invoiced in either CHF or EUR is close to 95% over the whole period, with CHF accounting for the highest share but falling over time.<sup>14</sup> USD invoicing is quite limited (the US accounted for 7% of Swiss goods imports in 2015).<sup>15</sup> In our baseline regressions, we exclude goods invoiced in foreign currency other than EUR because other currencies fluctuated vis-à-vis CHF and EUR before January 15, 2015.

The SFSO assigns imported goods to industries based on the industry of the importing firm using a classification similar to the 4-digit North American Industry Classification System (NAICS) code in the US. Our sample of non-commodity products covers 188 such product categories, of which 43 are consumer good categories that can be matched to retail categories as described below. For our analysis tracing currency of invoicing at the border to retail prices and expenditures, we calculate a pre-appreciation measure of invoicing intensity by border product category. We define the EUR invoicing share by product category as the fraction of border prices invoiced in EUR (relative to those invoiced in CHF or EUR) across all four quarters in 2014. In Table B.5 in the appendix we report the list of matched border product categories and retail product categories, as well as the EUR invoicing share of each category.

Given our prior that EUR invoicing shares by category are less tightly inferred for categories with a low number of border price observations, we exclude from our baseline analysis 6 (out of 43) border product categories for which we observe 7 or fewer border prices per quarter

<sup>14</sup>The rise over time in the share of EUR-invoiced goods is largely due to entry of new goods into the sample that are invoiced in EUR. For continuing products, the fraction that switches invoicing currency between quarters is very low, on average roughly 0.5% per quarter in 2015 (see Figure B.1 in the appendix).

<sup>15</sup>As reported in Table B.1 in the appendix, invoicing shares are very similar if we weight border product categories using NAICS two-digit weights in December 2015, which is the first period the SFSO reports weights. We note that Bonadio et al. (2019) and Federal Customs Administration (2015) report invoicing shares for imports based on more comprehensive customs data, allowing transactions to be weighted by import volume. In Federal Customs Administration (2015), import invoicing shares in 2014 are 31.6% for CHF, 54.9% for EUR, and 10.6% for USD.



on average in 2014.<sup>16</sup> Across the baseline sample of 37 border categories, the EUR invoicing share in 2014 varies between 0 and 0.74, with a median of 0.13 and a mean of 0.25.

## 2.2 Retail prices and expenditures

The analysis of retail prices and expenditures is based on Nielsen homescan data covering a demographically and regionally representative sample of around 3,000 households in Switzerland in the period January 2012 to June 2016 (Nielsen Switzerland, 2016). Participating households record purchases in supermarkets and drugstores, scanning goods such as food, non-food grocery items, health and beauty aids, and selected general merchandise. Individual products are classified into one of 256 product classes (which are narrower than border product categories) such as apple juice, shampoo, and toilet paper.<sup>17</sup>

In the raw data, an observation is a transaction including the household identifier, barcode (European Article Number, or EAN) of the product purchased, quantity purchased, price paid (net of good-specific discounts due to e.g. coupons), date of the shopping trip, and the name of the retailer. In the three months after the CHF appreciation, we observe on average 85 transactions per household. The data include 17 distinct retail stores. Since we do not observe the location of the retailer in a transaction, we assign it to one of 23 regions where the household lives (for more details, see appendix). We exclude purchases made in other countries via cross-border shopping.

We augment these data with information on the country of production of individual goods. Whereas EAN codes provide information on the country in which a product has been registered, in many instances this is not the country in which the product has actually been produced. However, that information is disclosed in the label of each product. We collect label information from codecheck.info, a Swiss health information portal with a large database of products sold in supermarkets, drug stores, and pharmacies (Codecheck, 2016). Coverage is not complete and notably excludes goods that are only occasionally sold in grocery stores, such as toys, clothing, or household electronics. We drop observations for which we do not

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<sup>16</sup>The 6 categories we drop account for roughly 12% of retail expenditures on imported goods in 2014. In the sensitivity analysis, we consider a more restrictive sample that drops 9 categories with 8 or fewer observations per quarter, and a less restrictive sample that drops 2 categories with 4 or fewer observations per quarter. We also discuss which results are robust to keeping all border categories, including those with only 2 observations per quarter.

<sup>17</sup>In the Appendix we describe additional adjustments we make to the data, such as dropping newspapers, magazines, and non pre-packaged fresh fruits and vegetables products, and dropping transactions with errors in the entered price.

**Table 2: Nielsen data summary statistics**

Summary Statistics Nielsen Samples			
	Non-balanced	Balanced yearly	Balanced monthly
No. of Imported Goods	4,545	2,682	937
No. of EU Imported Goods	4,134	2,362	794
No. of Domestic Goods	3,865	3,748	2,189
Expenditure share imports 2014	27	26	23
Expenditure share EU imports 2014	23	22	19
No. Product classes	233	217	172
No. Product classes (imports)	215	188	132
No. of Transactions - Imports	803,273	762,331	598,423
No. of Transactions - Domestic	2,396,208	2,390,273	2,106,375

*Notes:* The ‘non-balanced’ sample consists of EAN goods with information on country of origin (imports or domestic) that can be matched to border product categories with more than 7 border prices per quarter in 2014 (which we use in the baseline regressions). The ‘balanced yearly’ sample is a subsample of the first one that only includes goods observed each year between 2013 and 2015. The ‘balanced monthly’ sample is a subsample of the first one that only includes goods observed every month from mid-2013 to mid-2016. *No. of Imported Goods* and *Expenditure share imports* are, respectively, the number of imported goods and the expenditure share of imported goods in total expenditures in 2014. We report separately imports from the EU. *No. product classes* and *No. product classes imports* are the number of unique Nielsen product classes with positive expenditures on imports or domestic goods, and only on imports, respectively. *No. of transactions – imports* and *No. of transactions – domestic* are the number of underlying transactions at the household level over imports and domestic goods, respectively.

observe the country of origin.<sup>18</sup>

Table 2 provides basic summary statistics of the Nielsen data, for three different samples. The first sample (non-balanced) consists of goods with information on country of origin (imports or domestic) that can be matched to border product categories with more than seven border price observations per quarter in 2014. The second sample (balanced yearly) is a subsample of the first one that only includes goods observed each year between 2013 and 2015. The third sample (balanced monthly) is a subsample of the first one that only includes goods observed in each of the 18 months before and after the appreciation. We use the first and second samples in our analysis of expenditure allocations. We use the third sample in our analysis of retail prices. For each sample we provide the number of unique imported and domestic products, product classes, transactions, and import shares in 2014. The share of expenditures on imports relative to expenditures on all goods for which we observe country of

<sup>18</sup>We accessed codecheck.info between October 2015 and March 2016, searching for all goods in the Nielsen data. We also cross-checked the results from codecheck.info with information on websites of the various retailers. To get a sense of coverage, there are 5,444 unique goods in the Nielsen dataset that are observed in each of the 18 months before and after the appreciation. We found 3,481 of these goods on the web, accounting for 72% of all expenditures in this balanced sample of goods in 2014.

origin is 27% in the non-balanced sample (and 23% in the monthly balanced sample).<sup>19</sup> The import share is 23% in the non-balanced sample if we restrict the sample to goods imported from the European Union (EU). In our baseline results we include all imports because we do not observe the country of origin of imports in the border price data.

### 3 Exchange rate pass-through to border prices

In this section we report the impact of the 2015 CHF appreciation on border prices, first at the level of individual goods and then at the level of product categories. We then document the extent of price flexibility and exchange rate pass-through by currency of invoicing, conditioning and not conditioning on nominal price changes. Finally, we perform simple accounting exercises to quantify the impact on border prices of counterfactual shifts in invoicing from CHF to EUR and changes in the degree of nominal price stickiness.

#### 3.1 Changes in average border prices by currency of invoicing

We first document the differential response of average changes in border prices by currency of invoicing after the CHF appreciation. We denote by  $p_{it}^{bor}$  the log of the border price (in CHF) of imported good  $i$  in quarter  $t$ . Keeping in mind our date convention, we refer to the period prior to the CHF appreciation as 14Q4. We consider panel regressions of the form

$$p_{it}^{bor} = \sum_{s \neq 14Q4} \beta_s \times \mathbb{I}_{s=t} \times EURinv_i + \alpha_t + \lambda_i + \varepsilon_{it}, \quad (1)$$

over the period  $t = 13Q1, \dots, 16Q2$ , where  $\mathbb{I}_{s=t}$  is the time period indicator function,  $EURinv_i = 1$  ( $= 0$ ) if product  $i$  is invoiced in EUR (CHF) in quarter 14Q4,  $\alpha_t$  is a time fixed effect, and  $\lambda_i$  is a product fixed effect.<sup>20</sup> Observations are equally weighted since we do not observe import values per product. Standard errors are clustered at the level of border product categories.

Panel (a) of Figure 2 displays estimates of  $\alpha_t$  and  $\alpha_t + \beta_t$  between 2013 and 2016, representing average cumulative changes, relative to 14Q4, in CHF-invoiced and EUR-invoiced border prices, respectively. CHF- and EUR-invoiced goods display similar price dynamics before

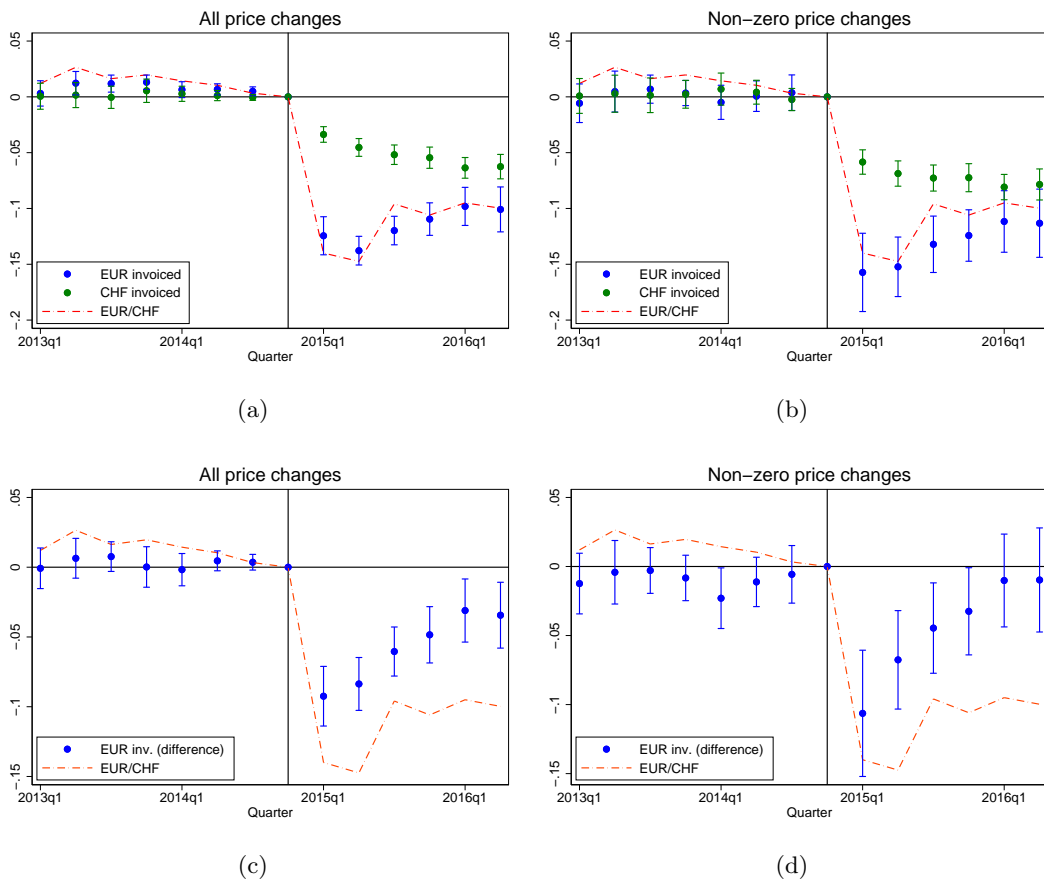
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<sup>19</sup>For comparison purposes, the share of imports in total consumption reported in SFSO (2014) is 26.7% in 2014. Since services are mostly locally sourced, this means that the import share in our sample is lower than in overall consumption of goods.

<sup>20</sup>We consider a balanced panel of products with price data every quarter in the two-year period 13Q4-15Q3. We do not include 15Q4 in the balanced panel because the SFSO conducted a major re-sampling of products in December 2015. Moreover, for every quarter we exclude a small number of observations for which the currency of invoicing differs from 14Q4.

January 2015, a period of stability of the EUR/CHF exchange rate. In contrast, EUR-invoiced prices fall significantly relative to CHF-invoiced prices in the post-appreciation period. As summarized in the top rows of Table 3, the EUR appreciated by 14.0% in the first three months and by 14.7% in the first six months after December 2014. EUR-invoiced border prices fell by 12.4% and 13.8% in the first and second quarters, respectively (implying exchange rate pass-through rates of 89% and 94%, respectively). CHF-invoiced border prices fell by 3.4% and 4.5%, respectively, during the same time (implying pass-through rates of 24% and 31%, respectively).

**Figure 2:** *Border price changes by invoicing currency*



*Notes:* This figure presents the EUR/CHF exchange rate and border price changes compared with 14Q4 based on estimates of equation (1). Panels (a) and (b) display average price changes by currency of invoicing, either all price changes (a) or non-zero price changes (b). Panels (c) and (d) show the difference in the average price change of EUR-invoiced goods and CHF-invoiced goods including time  $\times$  category fixed effects, either all price changes or non-zero price changes. Whiskers indicate the bounds of a 95% confidence interval, calculated clustering at the level of border product category.

Average differences in price changes by currency of invoicing (i.e.  $\beta_t$ ) fall over time from roughly 9% in 15Q1 to 5.5% in 15Q4, explained in part by a gradual decline in CHF-invoiced prices and in part by overshooting of the EUR/CHF and EUR-invoiced prices. Estimates of

**Table 3:** *Border and retail price changes and implied pass-through rates*

	Changes				Rates			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1) EUR/CHF	-14.0	-14.7	-9.6	-10.6				
2) All EUR inv.	-12.4	-13.8	-12.0	-11.0	88.9	93.5	124.9	103.4
3) Non-zero price changes	-15.7	-15.2	-13.2	-12.4	112.4	103.3	137.7	117.3
4) All CHF inv.	-3.4	-4.5	-5.2	-5.5	24.1	30.7	54.1	51.5
5) Non-zero price changes	-5.8	-6.9	-7.3	-7.2	41.7	46.6	75.8	68.4
6) Retail imports	-1.3	-2.9	-2.7	-3.9	9.3	19.4	28.6	36.6
7) Retail domest.	-0.3	-0.7	-0.4	-0.8	2.2	4.6	4.2	7.5

*Notes:* The left panel displays changes in CHF/EUR in each quarter of 2015 relative to 14Q4 (row 1) and average changes in various prices: EUR-invoiced border prices (row 2) and the subset with a non-zero price change (row 3), CHF-invoiced border prices (row 4) and the subset with a non-zero price change (row 5), and retail price changes of imported and domestic goods from the Nielsen data (rows 6 and 7) described in section 4. The right panel reports exchange rate pass-through % rates, calculated as ratios to row 1.

$\beta_t$  are similar if we include time fixed effects or time  $\times$  category fixed effects, as shown in panel (c) of Figure 2. Table C.2 in Appendix C.1 reports estimates and standard errors of  $\beta_t$  for each quarter after 14Q4, as well as the average effect in the first three quarters of 2015 calculated by imposing a single  $\beta$  over this time period. In Appendix C.1 we report a wide range of sensitivity analysis.

### 3.2 Invoicing and price changes across product categories

We next show that the differential response of border prices by invoicing currency that we document above helps explain part of the variation in average border price changes across product categories. We exploit this relationship when we match individual retail goods to product categories at the border.

We estimate

$$p_{gt}^{bor} - p_{g14Q4}^{bor} = \alpha_t + \beta_t \times EURshare_g + \varepsilon_{gt}, \quad (2)$$

where  $p_{gt}^{bor}$  denotes the simple average of border prices in border category  $g$  at time  $t$  (including prices in all invoicing currencies),  $EURShare_g$  denotes the fraction of border prices in category  $g$  invoiced in EUR across all quarters of 2014, and  $\alpha_t$  is a time fixed effect.

Table 4 reports estimates of  $\beta_t$  between 15Q1 and 16Q2 for different sets of product categories and weighting schemes. We consider the baseline dataset of non-commodity categories and the restricted set of consumer good categories that we match to our Nielsen data and that hence can be used in our retail price and expenditure analysis below. For the sample of Nielsen categories, we consider unweighted and weighted estimates (using 2014 consumer expenditures by category). In Appendix C.2 we report additional sensitivity analysis.

**Table 4:** *Border price changes and EUR invoicing intensity across border product categories*

	noncommodity	Nielsen unw.	Nielsen weighted
2015Q1	-0.067 [0.019]	-0.060 [0.038]	-0.110 [0.029]
2015Q2	-0.080 [0.018]	-0.076 [0.030]	-0.135 [0.033]
2015Q3	-0.053 [0.022]	-0.066 [0.027]	-0.107 [0.036]
2015Q4	-0.031 [0.025]	-0.037 [0.024]	-0.042 [0.026]
2016Q1	-0.016 [0.028]	-0.015 [0.029]	-0.008 [0.029]
2016Q2	-0.011 [0.028]	-0.018 [0.030]	-0.023 [0.030]
Observations	888	220	220
Adjusted $R^2$	0.22	0.27	0.48
Avg effect 15 Q1-Q3	-0.066 [0.011]	-0.067 [0.018]	-0.117 [0.019]
Observations	544	128	128
Adjusted $R^2$	0.34	0.39	0.62
Border categories	150	32	32

*Notes:* This table displays estimates of  $\beta_t$  in equation (2) between 15Q1 and 16Q2 for different sets of product categories and weighting schemes. The first column uses all non-commodity product categories, while the second and third columns use the baseline sample of border categories in our retail price analysis. The first and second columns show results from unweighted regressions, whereas the third column weights according to Nielsen consumer expenditures in 2014. The upper panel shows estimates of  $\beta_t$  between 15Q1 and 16Q2. The bottom panel shows the average effect (imposing a common  $\beta_t$ ) in 15Q1, 15Q2, and 15Q3. Estimates of (2) by quarter in 15Q1, 15Q2, and 15Q3 imply  $R^2$  of 0.35, 0.4, and 0.29, respectively. Standard errors clustered by border category are shown in brackets.

Estimates of  $\beta_t$  are negative and highly significant in the first three quarters of 2015 (except in Q1 of the unweighted Nielsen border sample), indicating that border prices fall more, on average, in product categories with more EUR invoicing. Estimates of  $\beta_t$  in the first three quarters are largest in the weighted Nielsen sample, in spite of the low number of categories. The weighted Nielsen-based estimates imply that a category that is fully invoiced in EUR experiences in the first three quarters of 2015 a decline in border prices that is between 11% and 13.5% larger relative to a category that is fully invoiced in CHF. These differences are slightly larger than those based on individual product prices (that combine within and between category variation) reported in Table C.4 of the appendix. Variation across product categories in 2014 invoicing shares explains (in terms of  $R^2$ ) between 29% and

40% of cumulative changes in border prices across Nielsen categories in each of the first three quarters of 2015. This relationship is much weaker starting in 15Q4, when the border price sample size declines due to product re-sampling by the SFSO.

Regression (2) constitutes the basis of the first stage in the 2SLS regressions we consider below. The results above anticipate that the first stage is strong in the first three quarters of 2015.

### 3.3 Price stickiness and border price changes

We begin by measuring the quarterly frequency of price changes and showing that for CHF-invoiced goods it increases substantially after the CHF appreciation. We then show that differences in border price changes by currency of invoicing persist when we condition on nominal price changes in the invoicing currency.

The top panel of Figure 3 displays, by invoicing currency, the fraction of products for which the price (in its currency of invoicing) in any quarter differs from the price in Q4 of the previous year.<sup>21</sup> For CHF-invoiced products, the fraction of products with a price change in 2014 (relative to Q4 of 2013) is roughly 41% in Q1 and 52% in Q2. These measures are similar in 2013. EUR-invoiced prices change less frequently.<sup>22</sup>

In 2015, after the CHF appreciation, there is a marked increase in the fraction of price changes for CHF-invoiced goods, even though prices are still far from fully flexible. The fraction of price changes (relative to Q4 of the previous year) rises from 41% in 14Q1 to 58% in 15Q1, from 52% in 14Q2 to 66% 15Q2, from 57% in 14Q3 to 71% in 15Q3, and from 61% in 14Q4 to 75% in 15Q4.<sup>23</sup> The bottom panel of Figure 3 shows that the increase in the fraction of price changes for CHF-invoiced goods is achieved through a large and long-lasting (i.e. not driven by temporary sales) increase in the fraction of price reductions and a small decline in the fraction of price increases (the latter is shown in Figure C.1 in the appendix). For EUR-invoiced products, the fraction of products with a price change or a price decrease does not change much in 2015.

We next return to regression (1), conditioning on non-zero price changes as in Gopinath

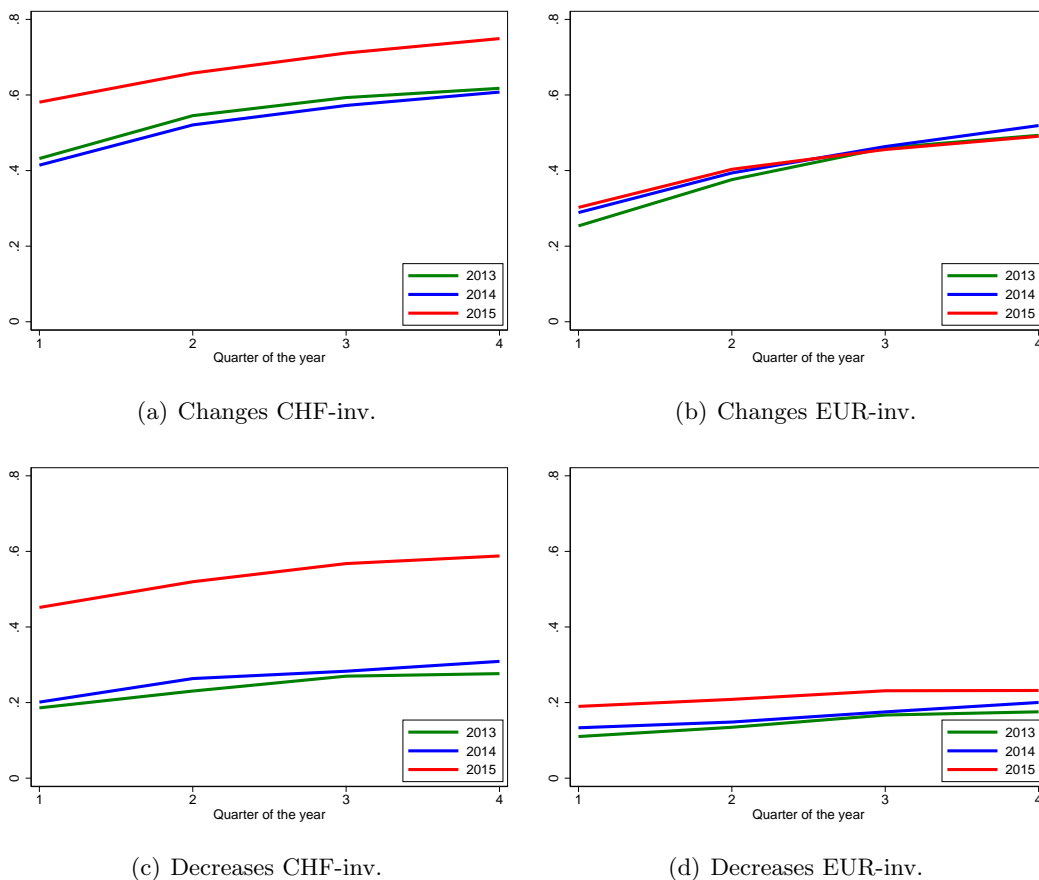
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<sup>21</sup>We exclude observations with price imputations due to product replacements, as well as observations in which the currency of invoicing differs from Q4 in the previous year.

<sup>22</sup>The average fraction of price changes from one quarter to another when pooling all quarters between 2013 and 2015 is roughly 35% for CHF-invoiced goods and 25% for non-CHF invoiced goods. To put these numbers in perspective, the average monthly frequency of border price changes for differentiated imported and exported goods in the US reported in Table IV of Gopinath and Rigobon (2008) is roughly 0.15, implying a quarterly frequency of  $1 - 0.85^3 = 0.39$  (assuming that the probability of a price change is independent across months).

<sup>23</sup>In Table C.10 in the appendix we additionally show that the degree of price flexibility is a characteristic that varies persistently across goods. For any given horizon, products for which price changed in 2013 (2014) are more likely to display a price change in 2014 (2015). The likelihood of a price change rises in 2015 irrespective of whether the price changed in previous years.

**Figure 3:** *Fraction of border price changes by currency of invoicing*



*Notes:* Panels (a) and (b) display for each quarterly horizon the fraction of products with changes in the price compared with Q4 of the previous year, for years 2013, 2014, and 2015, for CHF-invoiced goods (panel a) and EUR-invoiced goods (panel b). Panels (c) and (d) display, in a similar format, the fraction of price declines compared with Q4 of the previous year.

et al. (2010). Panel (b) of Figure 2 displays average cumulative price changes by currency of invoicing. CHF-invoiced prices in 2015 fall relative to 14Q4, by 5.8% in Q1, 6.9% in Q2, and 7.2% in Q3 and Q4 (exchange rate pass-through rates of 42% and 47% in Q1 and Q2, respectively, and roughly 70% in Q3 and Q4). Note the gradual decline in CHF-invoiced reset prices in spite of EUR/CHF overshooting. In contrast, EUR-invoiced prices (expressed in CHF) fall by slightly more than the EUR/CHF exchange rate (note, however, that standard errors are much larger due to smaller sample size).

Estimated differences in non-zero price changes by currency of invoicing (i.e.  $\beta_t$ ) fall over time from 10% in Q1 to 5% in Q4. Allowing for time  $\times$  category fixed effects, estimates of  $\beta_t$  (displayed in panel (c) of Figure 2 and in Table C.2) are as large initially but attenuate more rapidly over time and become insignificant in 2016. In sensitivity analysis in Appendix C, we show that, for certain sample choices, estimates of  $\beta_t$  become insignificant as early as



Q3 of 2015.

In Appendix C.1, we show that independently of invoicing, prices of commodities (excluded from our baseline analysis) change much more frequently than those of non-commodities. Moreover, differences in price changes by invoicing currency (including time  $\times$  category fixed effects) are small and mostly insignificant. These results are consistent with the view that currency of invoicing is quantitatively relevant for price changes only for products with sticky prices in their currency of invoicing.

The fact that pass-through rates conditional on price changes are significantly smaller for CHF-invoiced products than for EUR-invoiced products, but only in the earlier quarters after the CHF appreciation, is qualitatively consistent with models of endogenous invoicing as in Gopinath et al. (2010). Specifically, in those models the choice of invoicing currency is determined by a discounted sum of future desired pass-through conditional on non-price adjustment. Hence, currency choice puts a higher weight on conditional pass-through rates in earlier periods after the exchange rate shock, which is precisely when estimated differences in conditional pass-through rates between invoicing currencies are larger in our data.<sup>24</sup>

### 3.4 Accounting-based counterfactuals

What would have been the average change in border prices had these been fully invoiced in CHF or in EUR? How do counterfactual changes in invoicing currency compare with counterfactual changes in the degree of price stickiness? We answer these questions by performing simple accounting exercises.

The average change in CHF-invoiced border prices in quarter  $t$  relative to 14Q4 is  $p_{Ct}^{bor} = f_{Ct} \times s_{Ct}$ , where  $f_{Ct}$  denotes the fraction of CHF-invoiced prices that change between 14Q4 and  $t$ , and  $s_{Ct}$  denotes the average size of these non-zero price changes (reset prices). The average change in EUR-invoiced border prices (expressed in CHF) is  $p_{Et}^{bor} = f_{Et} \times s_{Et} + (1 - f_{Et}) \times e_t$ , where  $f_{Et}$  denotes the fraction of EUR-invoiced prices that change (in EUR) between 14Q4 and  $t$ ,  $s_{Et}$  denotes the average size of these non-zero price changes (expressed in CHF), and  $e_t$  denotes the EUR/CHF change in this time period. The average change in border prices including both invoicing currencies (roughly 2/3 CHF and 1/3 EUR) is  $p_t^{bor} = 2/3 \times p_{Ct}^{bor} + 1/3 \times p_{Et}^{bor}$ . Row 1 of Table 5 reports  $p_{Ct}^{bor}$ ,  $p_{Et}^{bor}$ , and  $p_t^{bor}$  for the first and

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<sup>24</sup>We leave for future research whether an endogenous currency choice model is quantitatively consistent with the profile of pass-through rates and the increase in the fraction of non-zero price changes we document for this large and unanticipated exchange rate shock.

last quarters of 2015 (quarters 2 and 3 are reported in Table C.12 in Appendix C.4).<sup>25</sup>

Rows 2 and 3 consider counterfactual degrees of price stickiness given actual average reset price changes by currency of invoicing. Specifically, row 2 (“All sticky”) sets  $f_{Ct} = f_{Et} = 0$ , so that  $p_{Ct}^{bor} = 0$  and  $p_{Et}^{bor} = e_t$ . Row 3 (“All flex”) sets  $f_{Ct} = f_{Et} = 1$  and actual  $s_{Ct}$  and  $s_{Et}$ , so that  $p_{Ct}^{bor} = s_{Ct}$  and  $p_{Et}^{bor} = s_{Et}$ . In the “All flex” scenario we are assuming that, for products with unchanged price in 2015 (due to e.g. menu costs, information costs, or inattention) the price would change, if given the opportunity to do so, as much as observed reset prices in the data.<sup>26</sup> We do not take into account equilibrium changes in reset prices in each counterfactual scenario, as could be the case in the presence of pricing complementarities across price setters.

In 15Q1, the average decline in border prices is -4.7% under “All sticky” and -9.1% under “All flex”. This implies that a counterfactual shift from “All sticky” to “All flex” would result in a 4.5 percentage point (pp) larger reduction in border prices in 15Q1 (row 4). To understand these results, note that if  $s_{Ct} = 0$  and  $s_{Et} = e_t$ , a shift from “All sticky” to “All flex” would have no impact on average border price changes. In practice, reset prices fall by much less (but not zero) for CHF-invoiced than for EUR-invoiced goods, so changes in the degree of price flexibility have a limited impact on border price changes. The difference between CHF and EUR price changes, which is 14% under “All sticky”, is as large as 9.9% under “All flex”.

Rows 5 and 6 consider counterfactual invoicing choices. We assume that the degree of price stickiness is a characteristic of the invoicing currency, while the size of non-zero price changes (expressed in CHF) is a characteristic of the product and not of the invoicing currency, as in models in which invoicing currency choice on a product is shaped by its conditional pass-through rate. Specifically, in row 5 (“All CHF”) we assume that EUR-invoiced goods are counterfactually invoiced in CHF, so that for these goods  $p_{Et}^{bor} = f_{Ct} \times s_{Et}$ . In row 6 (“All EUR”) we assume that all CHF-invoiced goods are counterfactually invoiced in EUR, so that  $p_{Ct}^{bor} = f_{Et} \times s_{Ct} + (1 - f_{Et}) \times e_t$ . Note that if prices were fully flexible, then these counterfactual shifts in currency of invoicing would have no impact on average border price changes.

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<sup>25</sup>The average change in EUR-invoiced prices,  $p_{Et}^{bor}$ , reported in Table 5 differs from that in Table 3 (by roughly 2.1 percentage points in 15Q1). This is due to sample differences (in our sticky price calculations we drop observations with price imputations arising from product replacement) and because we impose that for EUR-invoiced goods with zero price changes the change in price (expressed in CHF) is equal to the change in the EUR/CHF,  $e_t$ , which is not always the case in the raw data due to errors in exchange rate conversion. In Appendix C.4 we show that results do not vary much when using prices that are converted into CHF based on the official quarterly EUR/CHF rate. We also report sensitivity to using a smaller CHF invoicing share when calculating  $p_t^{bor}$ .

<sup>26</sup>In the appendix we provide suggestive evidence that the size of price changes in 2015 is independent of the degree of price flexibility in previous years. Specifically, in Table C.11 we show that the size of price changes in 2015 does not vary systematically across products with the likelihood of a price change in previous years (a measure of the product’s price flexibility).

**Table 5:** *Counterfactual changes in border prices*

	15Q1			15Q4		
	CHF	EUR	2\3 CHF +1\3 EUR	CHF	EUR	2\3 CHF +1\3 EUR
1) Actual	-3.4	-14.5	-7.1	-5.4	-11.5	-7.4
2) All sticky	0.0	-14.0	-4.7	0.0	-10.6	-3.5
3) All flexible	-5.8	-15.7	-9.1	-7.2	-12.4	-9.0
4) All flex - all sticky			-4.5			-5.4
5) All CHF	-3.4	-9.1	-5.3	-5.4	-9.3	-6.7
6) All EUR	-11.5	-14.5	-12.5	-8.9	-11.5	-9.8
7) All EUR - all CHF			-7.2			-3.1

*Notes:* See main text for a description of each counterfactual. Quarters 2 and 3 are reported in the Appendix.

Evaluated at the degree of price flexibility in the data, the average decline in border prices in 15Q1 is -5.3% under “All CHF” and -12.5% under “All EUR”. This implies that a counterfactual shift from “All CHF” to “All EUR” would result in a 7.2 pp larger reduction in border prices in 15Q1 (Row 7).<sup>27</sup>

Comparing rows 4 and 7, we observe that a shift in invoicing from “All CHF” to “All EUR” (given the observed degree of price stickiness) has a bigger impact on average border price changes than a shift from “All sticky” to “All flex” (given the observed fraction of goods by invoicing currency). This is also the case in 15Q2, as shown in Table C.12 in Appendix C.4. In contrast, in 15Q4 (as well as in 15Q3) a shift in invoicing has a smaller impact on average border prices than a shift in price flexibility. Currency of invoicing of border prices matters less over time because at longer time horizons border prices are more flexible and the EUR/CHF appreciation is smaller.

## 4 Retail price response

In this section we examine the response of Nielsen-based retail prices to the CHF appreciation. After reporting average changes in retail prices of imports and Swiss-produced goods, we examine how these changes vary in the cross-section by invoicing currency at the border and import penetration. We then estimate the sensitivity of retail import prices to border prices, and the sensitivity of Swiss-produced retail prices to import retail prices. Finally, we document changes in the extensive margin of price adjustment, first on average for imports

<sup>27</sup>If we assume that both the fraction and size of non-zero price changes is a characteristic of the currency choice and not of the product (in contrast to models of endogenous invoicing currency), then,  $p_{Et}^{bor} = p_{Ct}^{bor}$  under “All CHF” and  $p_{Ct}^{bor} = p_{Et}^{bor}$  under “All EUR”. The impact of a shift from “All CHF” to “All EUR” is 11.1 pp in 15Q1, which is even larger than 7.2 pp under our baseline assumptions.

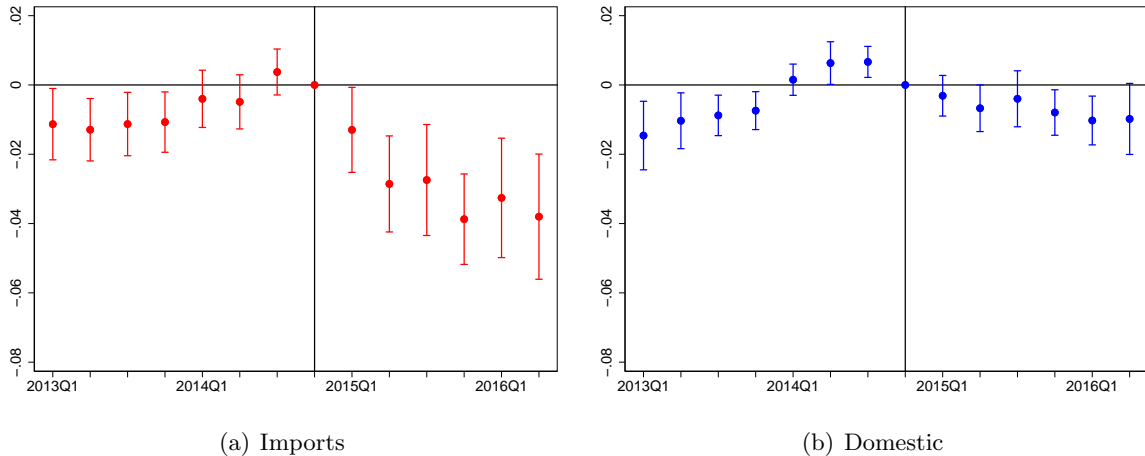
and Swiss-produced goods, and then across goods that vary in their currency of invoicing at the border.

We denote by  $P_{irst}^{ret}$  the retail price of product  $i$  (EAN) in region  $r$ , retailer  $s$ , and month  $t$ , averaged across households, weeks, and stores in triplet  $rst$ . We then average  $P_{irst}^{ret}$  across regions and retailers in month  $t$  to obtain a measure of the retail price of product  $i$  in month  $t$ ,  $P_{it}^{ret}$ . To smooth out idiosyncratic product-level shocks or temporary price discounts, we construct quarterly log prices as a simple average of monthly log prices. We base our analysis on a balanced sample of goods sold in at least one store and retailer every month in the three-year period between June 2013 and May 2016.<sup>28</sup>

#### 4.1 Average price changes for imports and Swiss-produced goods

Consistent with the official consumer price inflation estimates displayed in Figure 1, retail import prices in the Nielsen data fell in 2015 relative to Swiss-produced goods.

**Figure 4:** *Average retail price changes*



*Notes:* This figure displays time fixed effects (or cumulative average price changes) relative to 14Q4 of imports in panel (a) and Swiss-produced goods in panel (b), weighting goods by 2014 expenditures. Whiskers indicate the bounds of a 95% confidence interval, calculated clustering at the level of retail product class.

Figure 4 displays time fixed effects of log retail prices,  $p_{it}^{ret}$ , by quarter relative to 14Q4 (October 15, 2014 - January 14, 2015) for all imports and Swiss-produced goods, weighting individual goods by expenditures in 2014. There are no strong pre-trends in prices in the period 2013-14. Starting in 15Q1, there is a marked decrease in retail import prices while the

<sup>28</sup>In Appendix D.2, we report robustness of our invoicing on retail price regressions to calculating  $P_{irst}^{ret}$  by aggregating prices within  $rst$  using median or mode instead of average, and to calculating  $P_{it}^{ret}$  by aggregating prices  $P_{irst}^{ret}$  across regions and stores using median instead of average. We also report estimates using monthly rather than quarterly prices. Finally, we consider longer and shorter balanced samples.

response of Swiss-produced goods is more muted. As summarized in the bottom two rows of Table 3, the cumulative decline in retail import prices is 1.3% in 15Q1 and 3.8% in Q4. The implied exchange rate pass-through rate rises from 9% in 15Q1 to 36% at the end of the year. Swiss-produced retail prices fell by less than 1% cumulative in 2015 (i.e. the implied pass-through rate is less than 10%).<sup>29</sup>

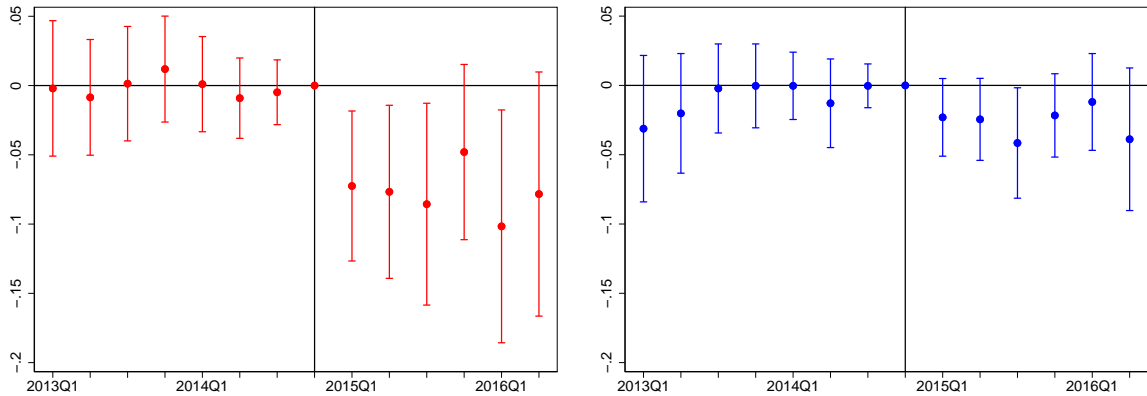
## 4.2 Currency of invoicing, border prices, and retail import prices

We document the differential response of retail prices according to the EUR invoicing share of the corresponding border product category. To do so, we consider panel regressions of the form

$$p_{it}^{ret} = \sum_{s \neq 14Q4} \beta_s \times \mathbb{I}_{s=t} \times EURShare_{g(i)} + \alpha_t + \lambda_i + \varepsilon_{it} \quad (3)$$

over the period  $t = 13Q1, \dots, 16Q2$ , where  $g(i)$  denotes the border category associated with retail product  $i$ ,  $EURShare_{g(i)}$  denotes the fraction of border prices in category  $g(i)$  invoiced in EUR across all quarters in 2014,  $\alpha_t$  is a time fixed effect, and  $\lambda_i$  is a product fixed effect. In all cross-sectional regressions using retail price data, observations are weighted by expenditures in 2014 and standard errors are clustered at the level of retail product classes.<sup>30</sup>

**Figure 5:** *Invoicing and retail prices*



*Notes:* This figure reports estimates of  $\beta_t$  from equation (3), for all imports (left panel) and Swiss-produced goods (right panel). The dependent variable is good log retail price by quarter. Independent variables include time dummies, time dummies interacted by EUR invoicing intensity in 2014 of the corresponding border category, and EAN fixed effects. Whiskers indicate the bounds of a 95% confidence interval, calculated clustering at the level of retail product class.

<sup>29</sup>Figure D.1 in the appendix shows similar (but more volatile) patterns based on monthly prices relative to December 2014. Figure D.2 in the appendix shows that import prices from the EU fell slightly more than prices of all imports.

<sup>30</sup>We cluster by retail product class because it is the level of variation of regressors in many of the regressions below. In the appendix we report for the main results specifications that cluster standard errors at the level of border product categories.

Figure 5 displays estimates of  $\beta_t$  for imported goods (left column) and Swiss-produced goods (right column). Table D.1 in the appendix reports estimates and standard errors by quarter, as well as the average effect (imposing a common  $\beta$ ) in the first three quarters of 2015. For both imports and domestic goods, there are no significant pre-trends in the period 2013-14. For domestic goods, estimates of  $\beta_t$  in 2015-16 are negative but small and statistically insignificant. For imported goods, estimates of  $\beta_t$  are negative and much larger than for domestic goods, significant at the 1% level in 15Q1, at the 5% level in 15Q2, 15Q3, and 16Q1, and at the 10% level in 16Q2. For 15Q4, the estimate is negative but less tightly estimated. These estimates imply that retail prices decline by roughly 7.3 percentage points more in 15Q1 for goods belonging to border product categories that are (hypothetically) fully invoiced in EUR compared with goods in product categories (hypothetically) fully invoiced in CHF currencies. The estimated average effect in the period 15Q1-15Q3 is 7.8 pp. In Appendix D.2 we report extensive sensitivity analysis.

We next leverage cross-product variation in price changes and in invoicing currencies at the border to measure the sensitivity of retail prices of imported goods to changes in border prices in the corresponding border product category. Specifically, for every quarter in 2015 we consider the regression

$$p_{it}^{ret} - p_{i14Q4}^{ret} = \alpha_t + \beta_t \times \left( p_{g(i)t}^{bor} - p_{g(i)14Q4}^{bor} \right) + \varepsilon_{it}, \quad (4)$$

over imported goods  $i$ , where  $p_{g(i)t}^{bor}$  denotes the simple average of border prices at time  $t$  in the border category associated with retail product  $i$ ,  $g(i)$ , and  $\beta_t$  is the average sensitivity of retail prices to border prices across goods at time  $t$ . The rate of pass-through from border prices to retail prices,  $\beta_t$ , reflects a combination of changes in the cost of distribution services and changes in retail markups.

Given the concern that other drivers of retail prices in 2015 (such as category-specific demand shocks) may be correlated with border prices, we instrument border price changes in 2015 by the fraction of EUR-invoiced products in border category  $g(i)$  in 2014,  $EURShare_{g(i)}$ . This instrument is valid if EUR invoicing shares by product category in 2014 are uncorrelated with other category-specific drivers of retail price changes in 2015 including (i) shocks to product demand or retail costs, and (ii) good-specific sensitivity of retail prices to border prices. Note that this restriction does not require that EUR invoicing shares in 2014 are uncorrelated with border price exchange rate pass-through in 2015 — in fact, our instrument builds on this correlation.<sup>31</sup>

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<sup>31</sup>Wooldridge (1997) provides a detailed discussion of 2SLS in models with random coefficients (in our setting, variation in  $\beta_t$  across goods:  $\beta_{g(i)t} = \beta_t + v_{g(i)t}$ ). In addition to the standard exclusion restriction, consistency of 2SLS requires that  $v_{g(i)t}$  is conditionally mean independent with respect to  $EURShare_{g(i)}$ , and that the covariance between  $v_{g(i)t}$  and  $(p_{g(i)t}^{bor} - p_{g(i)14Q4}^{bor})$  is conditionally independent with respect to  $EURShare_{g(i)}$  (but this covariance need not be zero).

While we believe that this instrument somewhat alleviates endogeneity concerns, we cannot a priori rule out violations of the exclusion restriction. For example, one could build a model featuring variation in additive retail distribution costs across product categories in which, as in Corsetti and Dedola (2005), the level of retail distribution costs shapes border to retail price pass-through as well as desired exchange rate to border price pass-through. In this case, the exclusion restriction would be violated if the choice of invoicing between EUR and CHF in 2014 was endogenously determined by desired exchange rate pass-through, since product categories with higher retail distribution costs would feature lower border to retail price pass-through and more CHF invoicing.<sup>32</sup>

Table 6 reports OLS and 2SLS estimates of (4) for each quarter in 2015. Based on OLS, retail import prices fall by roughly 0.53 pp more in product categories with a 1 pp larger decline in border prices in 15Q1, and by 0.47 pp more in 15Q2. In the third and fourth quarters, the estimates are around 0.35, but less tightly estimated. The positive co-movement between border and retail import prices suggested by these OLS estimates is a feature of the data not only after January 2015 and, more importantly, does not establish a causal impact of border to retail import prices.<sup>33</sup>

**Table 6:** *Sensitivity of retail import prices to border prices*

	1Q		2Q		3Q		4Q	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta p_{g(i)t}^{bor}$	0.527 [0.182]	0.609 [0.197]	0.472 [0.169]	0.568 [0.214]	0.355 [0.235]	0.951 [0.378]	0.374 [0.242]	1.741 [1.094]
Observations	937	937	937	937	937	937	937	937
F first stage		82.5		78.6		22.1		2.5
Estimation	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS

*Notes:* This table reports estimates of  $\beta_t$  from equation (4). The dependent variable is the cumulative change in the retail price of imported goods relative to 14Q4,  $\Delta p_{it}^{ret} = p_{it}^{ret} - p_{i14Q4}^{ret}$ . Under OLS, the independent variable is the change in the border price of the corresponding border category over the same time window,  $\Delta p_{g(i)t}^{bor}$ . Under 2SLS, the border price change is instrumented with EUR invoicing intensity in 2014 of the corresponding border category. Standard errors are clustered at the level of retail product class.

The first stage of the 2SLS is significant in the first three quarters of 2015 (see F-statistic reported in the bottom row), as revealed also by estimates of equation (2) displayed in Table 4. The estimated 2SLS estimates of  $\beta_t$  are 0.61 in 15Q1 and 0.57 in 15Q2 with standard errors of roughly 0.2. The point estimate in 15Q3 is 0.95 (with a standard error of 0.3) and the

<sup>32</sup>If distribution cost inputs and imported goods are combined in a Cobb-Douglas fashion (rather than additive), then the level of retail distribution costs shapes border to retail pass-through but not exchange rate to border price pass-through. So, in this case the exclusion restriction would not be violated.

<sup>33</sup>Estimating the OLS relationship between changes in border and retail import prices in each quarter of 2013 and 2014 (a period of EUR/CHF stability) relative to the fourth quarter of 2014 results in three quarters (out of a total of 7) with positive and significant coefficients. Moreover, all 2SLS estimates are close to zero and not statistically significant.

estimate in 15Q4 is insignificant.<sup>34</sup> In Appendix D.3 we report a range of sensitivity analysis.

### 4.3 Invoicing, import penetration, and retail prices of domestic goods

Whereas there is at most a weak relationship between changes in prices of Swiss-produced goods and the EUR invoicing share (see Figure 5 above), we next show that this relationship is stronger once we condition on the expenditure share of competing imported goods in the same product category. We argue that, under certain exclusion restrictions and in combination with estimates of co-movement between Swiss-produced and import retail prices, these results point to the presence of pricing complementarities between domestic and imported retail products (i.e. domestic producers react to changes in price of competing imported retail products).

We consider panel regressions of the form

$$p_{it}^{ret} = \sum_{s \neq 14Q4} \mathbb{I}_{s=t} \times ImpShare_{g(i)} \times (\gamma_s + \beta_s \times EURShare_{g(i)}) + \alpha_t + \lambda_i + \varepsilon_{it}, \quad (5)$$

for imported goods and domestic goods separately, where  $ImpShare_{g(i)}$  denotes the import expenditure share in retail category  $g(i)$  calculated over 2014. We include in the regression the interaction between import shares and EUR invoicing share because we expect a higher sensitivity of domestic prices to import prices in product categories with a large participation of imported products, as in the model of variable markups we consider in Appendix D.6.

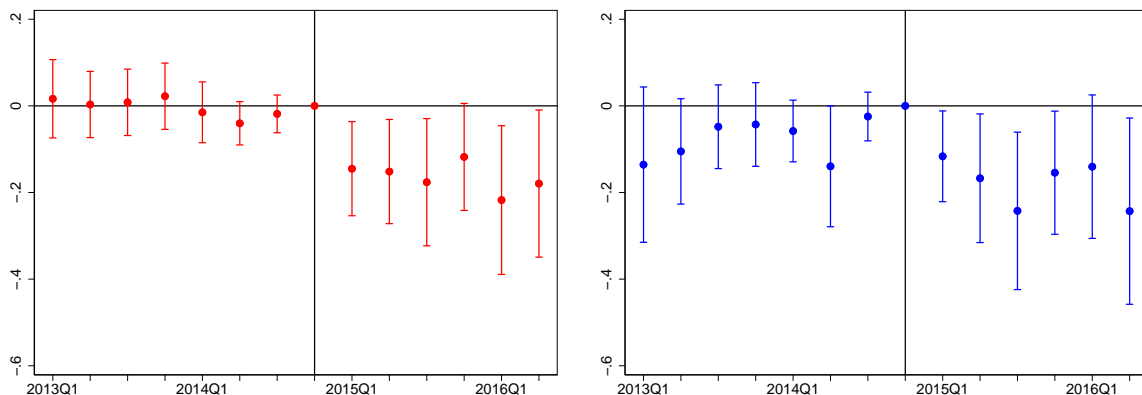
Figure 6 presents estimates of  $\beta_t$  for imported goods (left panel) and Swiss-produced goods (right panel). Table D.17 in the appendix reports estimates and standard errors by quarter, as well as the average effect in the first three quarters of 2015. While estimates of  $\beta_t$  in 2013-14 are largely insignificant, they are negative and significant in 2015 not only for imports but also for Swiss-produced goods. Evaluated at the median import share of 23% across product categories, our point estimates imply that retail prices of domestically produced goods decline in 15Q1 (Q2 and Q3) relative to 14Q4 by 2.7 pp (3.8 and 5.6) more for goods in border product categories that are (hypothetically) fully invoiced in EUR compared with goods in product categories fully invoiced in CHF. In Appendix D.4 we report sensitivity analysis.

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<sup>34</sup>2SLS estimates throughout the cross-sectional regressions can be higher or lower than OLS estimates. On the one hand, measurement error in prices and invoicing shares can lead to attenuation bias, while on the other hand endogeneity can lead to upward biases in OLS estimates.



**Figure 6:** *Invoicing, import penetration, and retail prices*



*Notes:* This figure reports estimates of  $\beta_t$  from equation (5), for imports (left panel) and Swiss-produced goods (right panel). The dependent variable is log retail price by quarter. Independent variables include time dummies, time dummies interacted with import expenditure shares in 2014 of the corresponding product class, time dummies interacted with the product of import expenditures by product class and EUR invoicing intensity by border category in 2014, and EAN fixed effects. Whiskers indicate the bounds of a 95% confidence interval, calculated clustering at the level of border product category.

Motivated by these results, we aim to estimate the sensitivity of retail prices of Swiss-produced goods to changes in retail prices of imported goods in the same retail product category. For every quarter in 2015, we consider a regression of the form

$$p_{it}^{ret} - p_{i14Q4}^{ret} = \alpha_t + \beta_t \times ImpShare_{g(i)} \times \left( p_{g(i)t}^{retimp} - p_{g(i)14Q4}^{retimp} \right) + \varepsilon_{it}, \quad (6)$$

over Swiss-produced goods  $i$ , where  $p_{g(i)t}^{retimp}$  denotes average retail price of imports in product class  $g(i)$  (weighted by 2014 expenditures). The coefficient  $\beta_t$  captures the average sensitivity of retail prices of Swiss-produced goods to changes in retail prices of imported goods in the corresponding product category at time  $t$ .

OLS estimates of  $\beta_t$ , shown in Table 7, are positive in every quarter of 2015 with varying statistical significance, implying that prices of domestically produced goods fall by more in product categories with larger price reductions of retail prices of imported goods. This is not necessarily evidence of strategic complementarities in pricing between domestic and competing foreign products since domestic and import prices within a product category could also co-move due to correlated changes in demand or production costs.<sup>35</sup>

In the absence of direct measures of domestic marginal costs that we can use as a control,

<sup>35</sup>Since products in our sample consist mostly of non-durable final consumer goods such as shampoo, cheese, and mineral water, it is unlikely that domestically produced goods within a product category make intensive intermediate input use of imported goods in the same product category. However, domestically produced and imported goods within a product category may employ common inputs in production that induce a correlation in cost changes, as in Amiti et al. (2019).

**Table 7:** *Sensitivity of domestic retail prices to import retail prices*

	1Q		2Q		3Q		4Q	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$ImpShare_{g(i)} \times \Delta p_{g(i)t}^{retimp}$	1.240 [0.372]	0.939 [0.489]	0.937 [0.315]	1.250 [0.518]	0.668 [0.438]	1.518 [0.553]	0.739 [0.336]	1.119 [0.533]
Observations	1972	1972	1972	1972	1972	1972	1972	1972
F first stage		23.0		38.4		35.4		25.6
Estimation	OLS	2SLS	OLS	2SLS	OLS	2SLS	OLS	2SLS

*Notes:* This table reports estimates of  $\beta_t$  from equation (6). The dependent variable is the cumulative change in the retail price of Swiss-produced goods relative to 14Q4,  $\Delta p_{it}^{ret} = p_{it}^{ret} - p_{i14Q4}^{ret}$ . Under OLS, the independent variable is the product of import expenditure share in 2014 and the change in retail import prices over the same time horizon for the corresponding product class,  $ImpShare_{g(i)} \times \Delta p_{g(i)t}^{retimp}$ . Under 2SLS, the import share-interacted change in retail import prices is instrumented by the import share-interacted EUR invoicing intensity in 2014 of the corresponding border category. Standard errors are clustered at the level of retail product class.

we address the endogeneity concern by instrumenting  $ImpShare_{g(i)} \times \left( p_{g(i)t}^{retimp} - p_{g(i)14Q4}^{retimp} \right)$  by  $ImpShare_{g(i)} \times EURshare_{g(i)}$ , where these shares are calculated in 2014. The exclusion restriction, following the same logic as in the discussion after equation (4), is that the product of import share and EUR invoicing share by product category in 2014 is uncorrelated with other category-specific drivers of domestic retail price changes in 2015 including (i) shifts in product demand or in production costs, and (ii) good-specific sensitivity of domestic retail prices to import retail prices. This restriction does not require that EUR invoicing in 2014 is uncorrelated with border price exchange-rate pass-through in 2015.

Once again, we cannot a priori rule out violations of the exclusion restriction. However, the weaker relationship between EUR invoicing shares and domestic retail price changes in 2015, unless we interact it by import share of final goods in the corresponding category, casts some doubt on the hypothesis that Swiss-produced goods in EUR-invoiced categories use more imported inputs, which would violate the exclusion restriction.<sup>36</sup> Similarly, suppose that the exclusion restriction was violated because the sensitivity of domestic retail prices to import retail prices is higher in product categories with higher border price pass-through, which also shapes the choice of invoicing between EUR and CHF in 2014. Then we would expect a stronger relationship between EUR invoicing shares and domestic retail price changes in 2015, even without conditioning on import shares.

2SLS estimates of  $\beta_t$ , reported in Table 7, are positive with significance varying by quarter

<sup>36</sup>Figure D.5 in Appendix D.6 shows that there is very little Swiss value added contained in imports from the euro area, both for the aggregate of manufacturing industries and for the food, beverage, and tobacco industries (which are more closely related to the set of final consumption goods examined in this paper). These low shares speak against the possibility that marginal costs (and prices) of Swiss producers and foreign exporters are correlated due to local and foreign firms using identical Swiss inputs. Unfortunately, we do not have a good measure of the Swiss share of imported intermediate inputs by industry.

(10% in Q1, 5% in Q2 and Q4, and 1% in Q3). Based on Q2 and Q3 estimates, the decline in domestic prices is roughly 0.3 pp larger in product categories with the median import share and 1 pp larger decline in retail import prices. In Appendix D.5 we report a range of sensitivity analysis.

#### 4.4 Invoicing and the extensive margin of retail prices

We next examine how the degree of retail price stickiness responded to the CHF appreciation. The decline in retail import prices in 2015 is partly accounted for by a large increase in the fraction of nominal price changes, which can itself be decomposed into an increase in the frequency of negative price changes and a decrease in the frequency of positive price changes. We first provide aggregate time series and then examine the cross-sectional relationship with currency of invoicing at the border.

We do not construct a measure of price flexibility at the level of individual goods and stores because, at such a disaggregated level, our scanner data are very sparse over time. Instead, we aggregate prices for each good  $i$ , region  $r$ , retailer  $s$ , and month  $t$  according to the modal price across households, weeks, and stores within the quadruplet  $irst$ . We then calculate, for each good  $i$ , year  $y = 13, 14, 15$ , and monthly horizon  $h = 1, \dots, 12$ , the fraction of region-retailer tuples for which the modal price in month  $h$  of year  $y$  differs from the modal price in December of the previous year. We denote this fraction by  $f_{iyh}$ . We further decompose the fraction of price changes into the fraction of increases (+) and decreases (-):  $f_{iyh} = f_{iyh}^+ + f_{iyh}^-$ .<sup>37</sup>

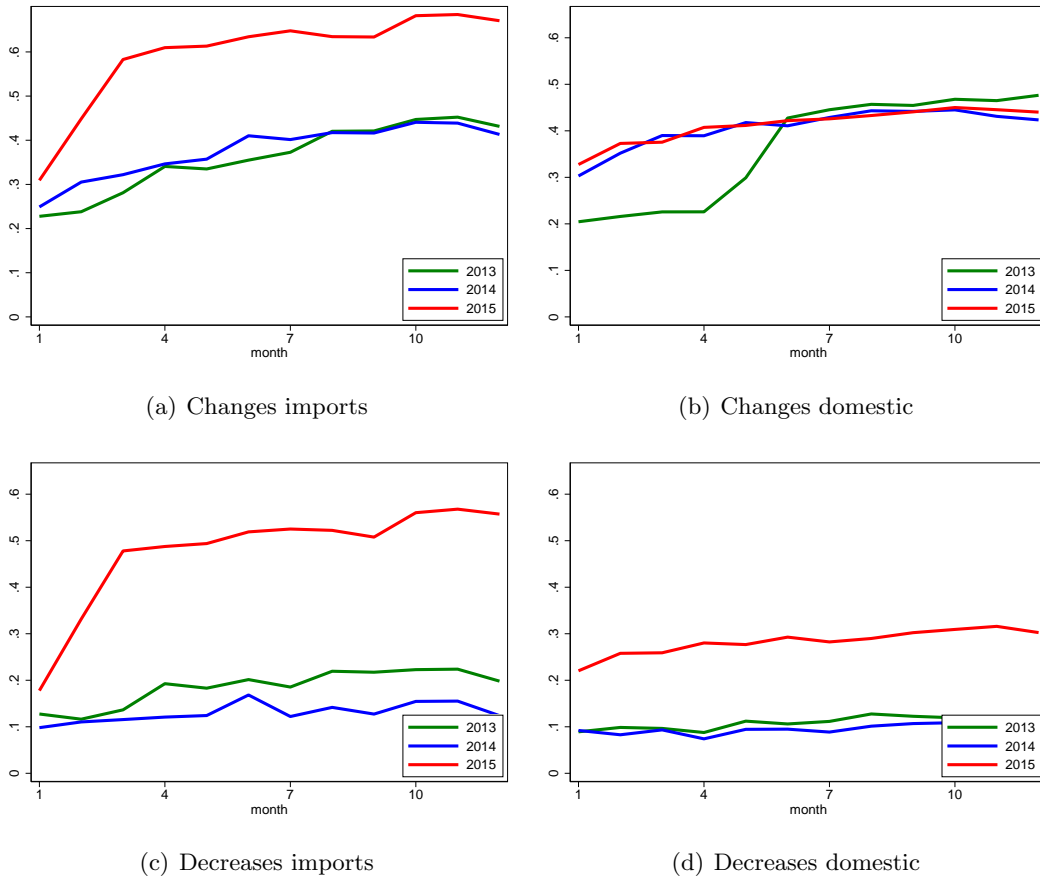
The top row in Figure 7 displays the fraction of modal price changes  $f_{iyh}$  averaged across goods (weighting goods by expenditures in 2014) for imports (left panel) and Swiss-produced goods (right panel). For every monthly horizon in 2013 and 2014, the degree of price flexibility is similar for imported goods and for Swiss-produced goods. The fraction of price changes is roughly 20% at the one-month horizon in 2013 and in 2014. That is, modal prices change in roughly 20% of region/retailer pairs between December 2013 and January 2014 (and between December 2012 and January 2013). This fraction rises to roughly 40% at 12-horizons in 2013

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<sup>37</sup>More formally, let  $p_{irshy}$  denote the log of the modal price across households, weeks, and stores within region  $r$ , retailer  $s$ , month  $h$ , year  $y$ , and let  $p_{iyh}$  be the average of  $p_{irshy}$  over  $r, s$  pairs. Changes in log prices between December of year  $y-1$  and month  $h$  of year  $y$  are  $p_{iyh} - p_{iy-1,12} = f_{iyh} \times s_{iyh}$  where  $f_{iyh}$  is the fraction of  $r, s$  observations with non-zero price changes in this time period, and  $s_{iyh}$  is the average size of non-zero price changes. Note that, in the presence of temporary price changes,  $f_{iyh}$  does not need to increase monotonically over time. We can further decompose changes in prices as  $p_{iyh} - p_{iy-1,12} = f_{iyh}^+ \times s_{iyh}^+ - f_{iyh}^- \times s_{iyh}^-$ , where  $f_{iyh}^+$  ( $f_{iyh}^-$ ) denotes the fraction of observations with a price increase (decrease) between month  $t$  and December of the previous year, and  $s_{iyh}^+$  ( $s_{iyh}^-$ ) denotes the average size of these price increases (decreases).

and 2014.<sup>38</sup>

**Figure 7:** *Fraction of price changes compared with December of previous year*



*Notes:* Panels (a) and (b) display the weighted average fraction of changes in modal prices relative to December of the previous year,  $f_{iyh}$ , for 1-12 month horizons. Panels (c) and (d) show the same statistic for price decreases,  $f_{iyh}^-$ . Panels (a) and (c) consider imported goods and panels (b) and (d) consider Swiss-produced goods.

In 2015, at every monthly horizon, the average fraction of modal price changes for imported goods rises significantly compared with 2013 and 2014. At the one-month horizon, the average  $f_{iyh}$  for imports rises from 20% in 2013-14 to 30% in 2015. At the 12-month horizon, it rises from 40% to 60%. In contrast, there is little change in the fraction of price changes by time horizon for Swiss-produced goods.

The increase in the fraction of price changes for imported goods following the January 2015

<sup>38</sup>Figure E.2 in Appendix E.1 displays the monthly fraction of price changes from one month to the other between 2013 and 2016. The fraction of price changes per month is on average roughly 0.2. Nakamura and Steinsson (2008) report that the average monthly fraction of price changes (inclusive of sales) in the US CPI is roughly 0.25 for all goods and for processed food goods, and 0.21 for household furnishings. The fraction of price changes is roughly half as large when sales are excluded, as is the case in our retail price data when we exclude temporary price reductions.

appreciation is almost completely driven by price reductions. The bottom row in Figure 7 shows that the average  $f_{iyh}^-$  rises from roughly 10% in 2013 and 2014 to roughly 40% in 2015 at either the one-, the two-, or the three-month horizon. The fraction of price decreases at longer horizons is also much higher in 2015 than in 2013 or 2014. This suggests that the 2015 price reductions were not short-lived sales. Figure E.1 in the appendix shows that there was only a small decline in the fraction of price increases for imported goods.<sup>39</sup>

The evolution of retail price stickiness varies systematically across imported goods by currency of invoicing and price changes at the border. The impact of the appreciation on the extensive margin and especially on the fraction of price reductions was more pronounced in border product categories with higher EUR invoicing shares. For a given monthly horizon  $h$ , we consider panel regressions of the form

$$f_{iyh}^+ \text{ or } f_{iyh}^- = \sum_{y'=13,15} \beta_{y'h} \times \mathbb{I}_{y'=y} \times EURShare_{g(i)} + \alpha_{yh} + \lambda_{ih} + \varepsilon_{iyh}. \quad (7)$$

The dependent variable is either the fraction of price increases or the fraction of price decreases by product.  $\alpha_{yh}$  and  $\lambda_{ih}$  denote year and product fixed effects, respectively, that can vary by monthly horizon  $h$ .

Table 8 reports estimates of  $\beta_{13h}$  and  $\beta_{15h}$  for price decreases (-) and increases (+), separately for imports and Swiss-produced goods. We consider monthly horizons  $h = 1, 2, 3$ , since these horizons experience the largest changes in aggregate fractions of price changes. We report results for  $h = 4, 5, 6$ , as well as other sensitivity analysis in Appendix E.2.

Consider our estimates for 2015. For price reductions, estimates of  $\beta_{15h}$  are positive and significant at the 1% level in each of the horizons we consider. At the three-month horizon (between December and March), the fraction of price reductions is 57.4 percentage points higher in 2015 (compared with the same three-month horizon in 2014) for goods in product categories with border prices that are (hypothetically) fully EUR-invoiced compared with product categories fully invoiced in CHF. For price increases, estimates of  $\beta_{15h}$  are negative and significant at the 1% or 5% levels, depending on the monthly horizon. That is, the fraction of price increases fell by more in 2015 (compared with 2014) for imported goods in

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<sup>39</sup>In Appendix E.1, we document that, accompanying the increase in the fraction of price reductions of imported goods, there was a significant decline in the absolute size of retail price reductions for imported goods in early 2015. We then show in Appendix E.4 that a simple Ss pricing can generate this seemingly puzzling negative co-movement between the change in the frequency of price adjustment and the change in the absolute size of price changes of imported goods. Specifically, in response to a decline in the CHF-denominated cost of imported goods, the absolute size of price reductions falls if new price changes (i.e. those that would not have occurred in the absence of the shock) are sufficiently small relative to the size of typical price reductions, which depends on the assumed distribution of idiosyncratic shocks.

**Table 8:** *Invoicing currency and the extensive margin of retail price changes*

	Decreases			Increases		
	(1) 1m	(2) 2m	(3) 3m	(4) 1m	(5) 2m	(6) 3m
<i>Panel (a). Imported goods</i>						
<i>EURShare</i> × I13	-0.031 [0.068]	0.048 [0.058]	-0.004 [0.098]	-0.105 [0.078]	-0.119 [0.112]	-0.291 [0.121]
<i>EURShare</i> × I15	0.284 [0.095]	0.651 [0.169]	0.574 [0.181]	-0.267 [0.106]	-0.279 [0.126]	-0.363 [0.109]
Observations	2537	2508	2506	2537	2508	2506
Unique products	884	881	877	884	881	877
Adjusted $R^2$	0.11	0.19	0.24	0.19	0.18	0.21
<i>Panel (b). Domestic goods</i>						
<i>EURShare</i> × I13	0.063 [0.057]	-0.065 [0.029]	-0.021 [0.036]	-0.031 [0.179]	-0.112 [0.202]	-0.272 [0.228]
<i>EURShare</i> × I15	0.356 [0.278]	0.284 [0.292]	0.318 [0.298]	-0.255 [0.218]	-0.308 [0.260]	-0.472 [0.290]
Observations	6223	6145	6121	6223	6145	6121
Unique products	2138	2125	2113	2138	2125	2113
Adjusted $R^2$	0.12	0.12	0.14	0.17	0.15	0.20

*Notes:* This table displays estimates of  $\beta_{13h}$  and  $\beta_{15h}$  in equation (7). Panel (a) reports estimates for imported goods, while (b) reports those for Swiss-produced goods. Columns (1)-(3) report estimates for price decreases. Columns (4)-(6) report estimates for price increases. Standard errors are clustered at the level of retail product class.

product categories with more EUR invoicing.<sup>40</sup>

For Swiss-produced goods, in contrast, estimates of  $\beta_{15h}$  are not significantly different from zero for either the fraction of price decreases or the fraction of price increases. Similarly, our estimates for 2013 are small and largely insignificant, suggesting that there are no pre-trends in the relationship between the fraction of price increases or decreases and currency of invoicing of border prices between 2013 and 2014.

We further show, in Appendix E.3, that the extensive margin of retail price adjustment for imported goods is strongly associated with changes in border prices in the corresponding

<sup>40</sup>Point estimates for price increases are lower in absolute terms than those for price decreases. For example, at the three-month horizon,  $\beta_{15h} = 0.57$  for price decreases whereas  $\beta_{15h} = -0.36$  for price increases. This is consistent with the fact, shown in Figure 7, that the overall fraction of price changes rose in 2015. In Table E.2 in the appendix we report estimates of equation (7) based on the overall fraction of price changes,  $f_{iyh} = f_{iyh}^+ + f_{iyh}^-$ , as the dependent variable. Estimates of  $\beta_{15h}$  are positive, which is consistent with the fact that point estimates are higher in absolute terms for the fraction of price decreases than for the fraction of price increases, but only statistically significantly different from zero at the two-month horizon.

product category. Under both OLS and 2SLS (instrumenting border price changes by 2014 EUR invoicing shares in the corresponding border category), we show that categories with a larger border price reduction in 2015 display significantly more price decreases and fewer price increases.

## 5 Expenditure switching to imports

In this section we show that the changes in relative prices described above are associated with changes in retail expenditures on imported goods. We document the dynamics of the aggregate import share and then examine variation across individual goods.

### 5.1 Aggregate import share

We denote the aggregate import share by  $S_{yh}$ , defined as the sum of expenditures on imports over  $h = 1, \dots, 17$  months starting in January of year  $y = 2013, 14, 15$  relative to the sum of expenditures on imports and Swiss-produced goods over the same time horizon. We compare import shares across years over comparable time horizons, rather than comparing monthly or quarterly import shares relative to the last month or quarter of 2014, due to seasonalities of imports in our data.<sup>41</sup>

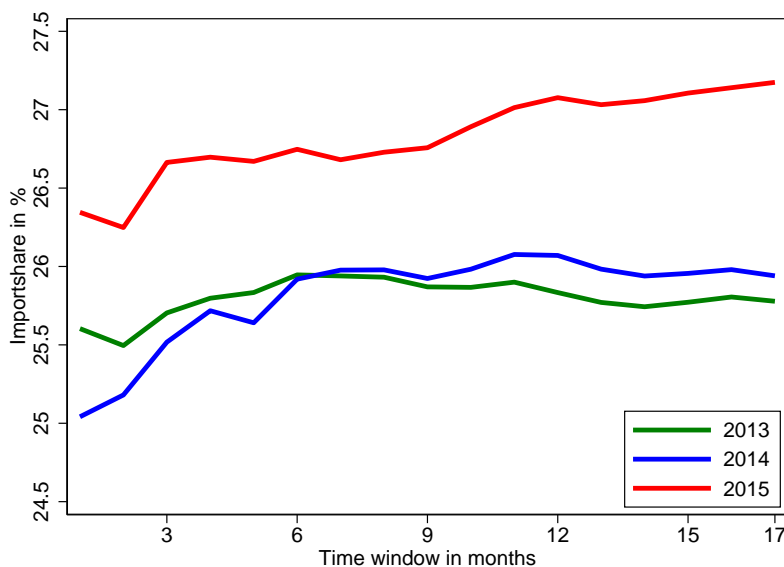
Figure 8 documents that aggregate import shares in 2014 are similar to those in 2013 for each time horizon. In 2015, there is a clear increase in import shares at each time horizon, even in the early months after the CHF appreciation. As shown in Table 9, the rise in the import share over different time horizons (corresponding to our quarterly price measures) ranges between 0.8 and 1.3 percentage points relative to the average between 2013 and 2014, or between 3.1 and 4.9 log percent differences. The increase in the import share is larger at longer time horizons.<sup>42</sup>

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<sup>41</sup>We display in Appendix F.1 import shares by month. In constructing  $S_{yh}$ , our choice of the longest horizon,  $h = 17$ , is based on the latest month in the Nielsen dataset, May 2016. For  $h > 12$  and  $y = 14$ , we include the first  $(h - 12)$  months of the year rather than including post-appreciation months in 2015. Recall that in our baseline we consider products that can be matched to border product categories with more than 7 border prices per quarter in 2014. We report in the appendix results based on more and less restrictive product-category samples.

<sup>42</sup>As shown in Table A.1 in the appendix, while real imports of goods and services rose in 2015, the ratio of aggregate nominal imports to GDP fell (in contrast to the rise in the aggregate import share for non-durable consumer goods in our data). Blaum (2019) examines how the response of intermediate goods imports (which are not included in our data) to exchange rate movements may differ from that of final goods imports.

**Figure 8:** *Aggregate import share in total expenditures*



*Notes:* This figure reports the aggregate import share,  $S_{yh}$ , for years 2013, 2014, and 2015 and horizons  $h = 3, 6, 9, 12, 15, 17$  months. The aggregate import share is the total sum of expenditures on imported goods over the corresponding monthly time horizon in the year divided by the sum of total expenditures (imports and Swiss-produced goods) over the same time period.

The increase in the aggregate import share is partly accounted for by an increase in import shares within product categories and partly by reallocation of expenditures across product categories. The within component, calculated by fixing the weights of individual product categories at the level of import expenditures in 2014 (reported in Table 9), is between 45% and 70% as large as the overall increase in the aggregate import share. The within component is quantitatively more important at longer time horizons.

How large are changes in aggregate import shares compared with changes in relative prices? We calculate the log change in relative prices as the log change in import prices minus the log change in prices across all goods (weighing imports and Swiss-produced goods by 2014 expenditures). For import prices we use changes in either border prices or retail prices, as described in the previous section. We then calculate the ratio of log differences in aggregate import shares with respect to log changes in relative prices by monthly time horizon in 2015.

As shown in Table 9, based on retail import prices, this ratio is 5.4 at the three-month horizon and ranges between 2.4 and 2.9 at horizons longer than three months. In contrast, based on border import prices this ratio ranges between 0.6 and 1. The ratio of import share changes relative to relative price changes is smaller based on border prices because retail import prices fell by much less and more gradually than border prices. This pattern is especially pronounced at the three-month horizon. The cross-sectional results that follow below display a similar



**Table 9: Aggregate expenditure switching**

Monthly horizon	aggregate import share			agg import share, fixed category weights			ratio agg. import share diff / price diff	
	avg 13-14	15	log diff	avg 13-14	15	log diff	imp. price measure	
			15 vs 13-14			15 vs 13-14	border	retail
3	25.6	26.7	4.0	25.8	26.2	1.8	-0.9	-5.4
6	25.9	26.8	3.1	26.1	26.5	1.7	-0.6	-2.6
9	25.9	26.8	3.3	26.0	26.5	2.0	-0.6	-2.4
12	26.0	27.1	4.3	25.9	26.6	2.6	-0.9	-2.7
15	25.9	27.1	4.7	25.9	26.7	3.1	-1.0	-2.9
17	25.9	27.2	4.9	25.9	26.8	3.4	-1.0	-2.9

*Notes:* This table reports import shares and their evolution over various monthly horizons. The first three columns report, in turn, the 2013-14 average import share, the 2015 average import share, and the log-percent difference between 2015 and 2013-14. The next three columns repeat the first three columns weighting product categories by import expenditures in 2014. The last two columns report the ratio of log changes in aggregate import shares (from column 3) with respect to changes in relative prices (obtained from Table 3).

pattern.

## 5.2 Changes in import shares and currency of invoicing at the border

We next analyze variation in import share changes across goods and relate these to invoicing currency. We then leverage this cross-sectional variation to provide an alternative measure of sensitivity of import shares to relative prices.

We first estimate the relationship between changes in expenditure shares on imported goods within product categories and pre-shock EUR invoicing in the corresponding border category.

For this, we define the share of expenditures on imported good  $i$  within its retail product class,  $S_{iyh}$ , as the sum of expenditures on good  $i$  over  $h$  months starting in January of year  $y = 2013, 14, 15$  relative to the sum of expenditures on imports and Swiss-produced goods in retail product class  $g(i)$  over the same time horizon. We consider panel regressions of the form

$$s_{iyh} = \sum_{y'=13,15} \beta_{y'h} \times \mathbb{I}_{y'=y} \times EURShare_{g(i)} + \alpha_{yh} + \lambda_{ih} + \varepsilon_{iyh}, \quad (8)$$

for monthly horizons  $h = 3, 6, 9, 12, 15, 17$  and imported goods  $i$ , where  $s_{iyh} = \log(S_{iyh})$ . For each horizon, we consider a balanced sample of products for which  $s_{iyh}$  is observed in all three years 2013, 2014, and 2015.

We also consider a second version of equation (8) using import share-adjusted EUR invoicing shares,  $(1 - ImpShare_{g(i)}) \times EURShare_{g(i)}$ , both calculated in 2014. To understand this formulation, note from equation (9) below that for a given change in the price of imports, the

magnitude of the change in the import price relative to the product category price is decreasing in the import share. In the limit, in a product category with import share equal to 1, relative import prices and import shares are constant over time. We use import share-adjusted EUR invoicing shares as an instrument in the 2SLS regression below. Finally, we consider a third specification in which, in addition to the interaction term, we also include  $(1 - ImpShare_{g(i)})$ .

**Table 10:** *Expenditure switching and invoicing*

	(1) 3m	(2) 6m	(3) 9m	(4) 12m	(5) 15m	(6) 17m
<i>Panel (a). EUR-invoicing share</i>						
$EURShare \times \mathbb{I}13$	0.033 [0.056]	0.090 [0.052]	-0.008 [0.063]	0.024 [0.047]	0.036 [0.051]	0.037 [0.054]
$EURShare \times \mathbb{I}15$	0.119 [0.057]	0.127 [0.047]	0.080 [0.047]	0.111 [0.048]	0.115 [0.055]	0.096 [0.058]
Adjusted $R^2$	0.93	0.94	0.94	0.94	0.93	0.93
<i>Panel (b). Interaction of import share with invoicing</i>						
$EURShare \times (1 - ImpShare) \times \mathbb{I}13$	0.077 [0.069]	0.096 [0.061]	0.006 [0.067]	0.007 [0.055]	0.035 [0.058]	0.040 [0.059]
$EURShare \times (1 - ImpShare) \times \mathbb{I}15$	0.207 [0.073]	0.179 [0.058]	0.143 [0.057]	0.179 [0.058]	0.191 [0.064]	0.175 [0.067]
Adjusted $R^2$	0.93	0.94	0.94	0.94	0.93	0.93
<i>Panel (c). Import share and interaction of import share with invoicing</i>						
$(1 - ImpShare) \times \mathbb{I}13$	0.063 [0.060]	-0.003 [0.057]	0.048 [0.063]	0.000 [0.039]	-0.001 [0.042]	0.000 [0.045]
$(1 - ImpShare) \times \mathbb{I}15$	-0.033 [0.044]	-0.038 [0.041]	0.017 [0.038]	0.007 [0.042]	0.003 [0.046]	0.014 [0.051]
$EURShare \times (1 - ImpShare) \times \mathbb{I}13$	0.007 [0.104]	0.099 [0.098]	-0.046 [0.111]	0.006 [0.077]	0.036 [0.082]	0.040 [0.085]
$EURShare \times (1 - ImpShare) \times \mathbb{I}15$	0.244 [0.093]	0.221 [0.079]	0.124 [0.077]	0.172 [0.077]	0.188 [0.086]	0.159 [0.093]
Adjusted $R^2$	0.93	0.94	0.94	0.94	0.93	0.93
Observations	6279	7068	7563	8046	8118	8160
Unique products	2093	2356	2521	2682	2706	2720

*Notes:* This table reports estimates of  $\beta_{13h}$  and  $\beta_{15h}$  from equation (8) for each monthly time horizon and specification. The dependent variable is the log of expenditure share of each imported good within retail product class. The independent variable is the EUR invoicing share (interacted with the 2013 or 2015 dummy) in the upper panel, the EUR invoicing share times domestic expenditure share in the middle panel, and the EUR invoicing share times domestic expenditure share and the domestic share on its own in the lower panel. Standard errors are clustered at the level of retail product class.

Table 10 presents estimates of  $\beta_{13h}$  and  $\beta_{15h}$  for each monthly time horizon and specification. Estimates of  $\beta_{13h}$  are small and largely insignificant across all specifications and time horizons,

indicating no strong relationship between changes in import shares and EUR invoicing before 2015.

Estimates of  $\beta_{15h}$ , in contrast, are positive and statistically significant at most horizons and specifications. Our point estimates imply that the expenditure share of imported goods rises by roughly 12% more in (hypothetically) fully EUR-invoiced categories than in categories that are fully CHF-invoiced at three- and six-month horizons in 2015, significant at the 5% and 1% levels, respectively. If we consider the interaction term in the regression in the bottom two panels, estimates remain largely significant. Estimates using interacted invoicing shares imply that, evaluated at the median import share of 23% across product categories in 2014, the rise in expenditure shares of imported goods in fully EUR-invoiced categories relative to CHF-invoiced categories ranges between 13% and 18% at three- and six-month horizons in 2015. We report sensitivity analysis in Appendix F.2.

### 5.3 Sensitivity of import shares to relative prices

To measure the sensitivity of import expenditure shares to relative import prices within a product class, we consider the following regression

$$\Delta s_{i15h} = \alpha_h + \beta_h \times \left[ \Delta p_{i15h}^{imp} - ImpShare_{g(i)14} \times \Delta p_{g(i)15h}^{imp} - (1 - ImpShare_{g(i)14}) \times \Delta p_{g(i)15h}^{dom} \right] + \varepsilon_{it}, \quad (9)$$

where for any variable  $x_{i15h}$ ,  $\Delta x_{i15h} = x_{i15h} - x_{i14h}$ . We estimate this equation in the balanced sample of all imported goods  $i$  for  $h = 3, 6, 9, 12$  and, in the appendix, also for  $h = 15, 17$ .

In order to examine the sensitivity of import shares to prices at different layers between the border and the retail levels, we consider three alternative measures of import prices,  $p_{iyh}^{imp}$  and category-level prices  $p_{g(i)yh}^{imp}$ . First, we use border prices of the corresponding border category,  $p_{g(i)yh}^{bor}$ , for both  $p_{iyh}^{imp}$  and  $p_{g(i)yh}^{imp}$ . Second, we use for both  $p_{iyh}^{imp}$  and  $p_{g(i)yh}^{imp}$  a measure of retail import prices given by ‘distribution services’-augmented border prices,  $p_{g(i)yh}^{bor+dis}$ .<sup>43</sup> Third, we use import retail prices,  $p_{iyh}^{ret}$ , for  $p_{iyh}^{imp}$  and then construct category-level prices,  $p_{g(i)yh}^{imp}$ , as the weighted average (using 2014 expenditures) of retail import prices within the corresponding retail product class.

We consider two alternative measures of domestic prices,  $p_{g(i)yh}^{dom}$ . First, we calculate a weighted average (using 2014 expenditures) of retail domestic prices within the corresponding product category. Second, we use an aggregate (as opposed to good-specific) price of domestic goods,

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<sup>43</sup>Specifically, we assume that retail import prices  $p_{iyh}^{imp}$  and  $p_{g(i)yh}^{imp}$  are weighted averages of border prices,  $p_{g(i)yh}^{bor}$ , and an aggregate price index of private services (Private Dienstleistungen) in the Swiss CPI. We assume a weight on border prices of 0.59 and on services of  $(1 - 0.59)$ , where 0.59 corresponds to the average sensitivity of retail import prices to border prices reported in Table 6 during 15Q1 and 15Q2.

given by the official CPI for Swiss-produced goods.<sup>44</sup> For each specification of equation (9), we report estimates of  $\beta_h$  based on each of the three measures of import prices and two measures of domestic prices, resulting in a total of six estimates for each time horizon.

Motivated by the findings in Section 5.2, we leverage heterogeneity in pre-shock import shares and EUR invoicing shares in border product category  $g(i)$  as driver of heterogeneous responses of relative prices to the appreciation. We consider 2SLS estimations of equation (9) where the first stage relates import-adjusted EUR invoicing shares in 2014,  $EURShare_{g(i)} \times (1 - ImpShare_{g(i)})$ , to relative price changes. The exclusion restriction, following the same logic as in the discussion after equation (4), is that import-adjusted EUR invoicing shares in 2014 are uncorrelated with other drivers of retail quantity changes in 2015 including (i) shifts in demand, and (ii) good-specific sensitivity of expenditures to prices. Once again, while we believe that this instrument somewhat alleviates endogeneity concerns, we cannot a priori rule out violations of the exclusion restriction.<sup>45</sup>

We report 2SLS estimates in Table 11. The first stage is highly significant, except for the specification using the combination of good-specific retail import prices and product category-specific retail domestic prices, for which F stats are around 6 at three-, six- or nine-month horizons. F stats are higher (close to or above 10) when weighting all observations equally (or when weighting observations equally within border product category) or when using modal prices to aggregate prices within regions, retailers, and weeks, as reported in Appendix F. For these alternative choices, point estimates of  $\beta_h$  are similar to our baseline.<sup>46</sup>

Estimates of  $\beta_h$  based on border prices as the measure of import prices are statistically significant at the 1% level and close to 1 at three-, six-, and nine-month horizons, implying that a 1% decline in the relative border price of imported goods is associated with an increase in import shares (within product categories) of around 1%. Point estimates at nine-month or higher horizons are slightly higher, close to 1.5. Point estimates are very similar under the two measures of domestic prices.

When we consider distribution-augmented border prices as the measure of import prices, the estimated sensitivity of import shares to relative import prices is higher than that based on

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<sup>44</sup>A rationale for this second measure of domestic prices based on the CPI for Swiss-produced goods (Inlandgüter) is that retail domestic prices by product category are the sum of an aggregate component and measurement error. This second measure of domestic prices results in stronger first-stage power and point estimates that are within confidence bands of those based on the first measure.

<sup>45</sup>For example, one could build a model featuring endogenous invoicing currency choice that is based on desired pass-through by exporters, and where the latter is related to the demand elasticity at the retail level, which varies across product categories. Note, however, that in standard models of variable markups conditional pass-through is determined not by the demand elasticity level but by the curvature of the demand elasticity.

<sup>46</sup>We note that OLS estimates of  $\beta_h$ , reported in Table F.11 in the appendix, are close to zero and largely insignificant. As discussed in Feenstra et al. (2018), OLS estimates of the elasticity of substitution between domestic and imported goods may be downward biased due to measurement error in prices and endogeneity from demand shocks that are correlated with prices.

**Table 11:** *Sensitivity of import shares to relative prices*

	3m		6m		9m		12m	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Border imp. price	-1.21 [0.45]	-1.12 [0.41]	-1.02 [0.34]	-0.98 [0.33]	-0.95 [0.39]	-0.87 [0.35]	-1.43 [0.47]	-1.27 [0.42]
F first stage	126.7	237.6	123.7	243.2	85.4	183.9	59.6	142.6
Border +distr. imp. price	-2.27 [0.89]	-1.97 [0.73]	-1.89 [0.66]	-1.75 [0.60]	-1.87 [0.81]	-1.59 [0.64]	-2.90 [1.07]	-2.31 [0.77]
F first stage	48.1	231.1	41.8	230.5	27.8	167.5	18.3	129.8
Retail imp. price	-5.10 [2.68]	-3.81 [1.61]	-4.23 [2.09]	-3.60 [1.59]	-3.81 [2.30]	-2.79 [1.41]	-5.84 [3.63]	-3.85 [1.84]
F first stage	6.1	16.9	6.5	13.3	5.2	12.8	3.6	10.8
Observations	2092	2092	2352	2352	2517	2517	2677	2677
Aggreg. dom. price	NO	YES	NO	YES	NO	YES	NO	YES

*Notes:* This table presents estimates of  $\beta_h$  in equation (9), as well as first stage F statistics. The dependent variable is the log change from 2014 to 2015 within a time horizon in the market share of good  $i$  in its retail product class,  $\Delta s_{i15h}$ . The independent variable is the log change in the price of imported good  $i$  relative to the product class price index, instrumented by import-adjusted EUR invoicing shares in 2014. To measure changes in prices of imported goods, panel (a) uses border prices, panel (b) adjusts border prices for changes in the official CPI for private services (assuming a weight on the latter of 41%), and panel c) uses retail prices of imported goods. To measure changes in domestic prices, odd-numbered columns use a weighted average of retail domestic prices within the corresponding product class, and even-numbered columns instead use the CPI for Swiss-produced goods. Standard errors are clustered at the level of retail product class. Results for 15 and 17 month horizons are reported in the Appendix.

border prices. At the three-, six-, and nine-month horizons, estimates of  $\beta_h$  are close to 2, with significance ranging between 1% and 5%. Estimates of  $\beta_h$  at longer horizons are close to 2.5 with significance between 1% and 5%. The degree of expenditure switching is higher because prices of private services, which we use to construct distribution-augmented border prices, fall by less than border prices.

Next, we consider good-specific retail prices as the measure of import prices. This measure of relative prices is closer to the measure one would use to estimate demand elasticities at the retail level, but implies more noisy estimates (and weaker first-stage F stats using product category-specific retail domestic prices) given the large degree of idiosyncratic movements in good-level prices. Point estimates of  $\beta_h$  are higher than those based on distribution-augmented border prices and subject to larger standard errors. The estimated sensitivities of import shares to relative prices within a product category range between 3.8 and 5.8 if we use good-specific domestic prices, with significance between 5% and 10% in the first nine-month or less horizons. If we use aggregate domestic prices, estimates sensitivities range between 2.7 and 3.7 — with lower standard errors and significance between 1% and 5% at 12-month horizons or less. The point estimates based on the two alternative measures of domestic

prices are within the confidence intervals of each other. Finally, we note that point estimates are larger at the three-month horizon (consistent with the aggregate results in Table 9), but differences across time horizons are not statistically significant given large standard errors.

We report in Appendix F.3 additional sensitivity analysis of our 2SLS estimates. While the magnitude and significance of the estimates differs across specific time horizons and measures, the two main takeaways are quite robust. First, there is a significant degree of expenditure switching away from domestic goods and to imports, observed both on aggregate import shares and cross-sectional variation in import shares across individual goods. Second, in terms of magnitudes, the sensitivity of expenditure shares to changes in relative prices (instrumented by import-adjusted invoicing shares) is around one for the border-level measure of import prices, and at least twice as high for the retail-level measure of import prices. Import shares are more sensitive to relative prices at the retail level than at the border level due to a muted decline in retail prices compared with border prices.

## 6 Taking stock

In this paper, we provide a range of facts on how prices and expenditures of consumer goods in Switzerland responded to a unique exchange rate shock: the SNB's removal of the lower bound on the EUR/CHF exchange rate on January 15, 2015. This policy change happened against the backdrop of a stable macroeconomy and resulted in a large, unanticipated, and lasting appreciation of the Swiss franc. To investigate its impact, we examine border data on prices and invoicing, as well as household-level data on prices and expenditures of non-durable consumer goods. This allows us to link currency of invoicing to border prices, retail prices, and expenditure allocations at the consumer level.

We first document large differences in border price pass-through by invoicing currency in the first year after the appreciation, even when conditioning on non-zero price changes. However, differences dissipate at longer time horizons. These observations are consistent with models of endogenous invoicing based on desired pass-through at early time horizons. Via simple accounting exercises we argue that, given differences in desired pass-through across goods, counterfactual shifts in currency of invoicing at the border have a bigger impact on the aggregate rate of pass through than counterfactual changes in the degree of nominal price stickiness.

Second, we show that differences across border product categories in price changes by invoicing currency at the border carry over to consumer prices and allocations. Specifically, after the appreciation, EUR invoicing at the border is associated with: (i) larger reductions in retail prices of imported goods, (ii) larger increases (decreases) in the frequency of price decreases

(increases) of imported goods, (iii) larger reductions in retail prices of Swiss-produced goods (in categories with substantial import competition), and (iv) larger increases in import shares in the corresponding product category.<sup>47</sup>

Third, leveraging the exchange rate shock and invoicing variation across product categories, we measure the sensitivity of retail import prices to border prices at roughly 50% after two quarters. We also measure the sensitivity of import shares to relative prices within product categories at roughly unity based on border import prices, and at least twice as high based on retail import prices. Elasticity estimates are higher using retail prices than using border prices because of the muted response of retail prices compared with border prices. A similar logic may apply for estimates of trade elasticities based on tariff variation.

Since we have limited our analysis to non-durable consumer expenditure data, we have not focused on the aggregate impact of the 2015 CHF appreciation on the Swiss economy. As shown in Table A.1 in the appendix, the growth rate of Swiss real GDP was lower in 2015 compared with 2013 and 2014, but other forces may have contributed to the observed aggregate fluctuations. The measures that we provide may help discipline key elasticities in general equilibrium models designed to perform counterfactuals on the macroeconomic impact of nominal exchange rate movements. The 2015 CHF appreciation episode may also be informative about additional margins of adjustment beyond consumer import expenditure switching, including cross-border shopping and import substitution at the level of intermediate goods.

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<sup>47</sup>The last observation on allocations complements our findings in Auer et al. (2019) that EUR-invoiced products experienced less of a decline in export values when compared with CHF-invoiced industries. Interestingly, the link between invoicing and export response shown in Auer et al. (2019) is stronger at longer horizons, whereas the link between invoicing and import share changes that we document in this paper is stronger at shorter horizons.

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