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Heterogeneity in the exchange rate pass-through to consumer prices: the Swiss franc appreciation of 2015

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Abstract

This paper analyzes the exchange rate pass-through to consumer prices for 85 categories of goods and services in Switzerland. The pass-through estimates are computed using a synthetic difference-in-differences approach that exploits the large Swiss franc appreciation that followed the unexpected removal of the Swiss franc-Euro floor in January 2015. The overall 1-year all-items pass-through is 0.12, which shows that the pass-through is highly incomplete. There is an important heterogeneity across product categories, where pass-through can be as high as 0.80. These variations are linked to the international trade characteristics of the products, as the prices of goods with a high degree of international tradability, with a high import share, or that depend on tourism are shown to be more sensitive to the exchange rate.

Keywords: Exchange rate pass-through, Inflation, Currency appreciation, Product heterogeneity

JEL Classification: E31, F31, F41

1 Introduction

Understanding the transmission of exchange rate shocks to prices is of prime importance for monetary policy in small open economies like Switzerland. This relationship between exchange rates and prices is often referred to as the exchange rate pass-through, and identifying the determinants of its cross-country and cross-industry differences has been a major research topic in international economics.

This paper estimates the exchange rate pass-through to consumer prices using data from the 2015 Swiss franc appreciation. While the literature on the exchange rate pass-through is extensive, this study contributes to the existing research by (i) taking an alternative and more causal approach based on the difference-in-differences methodology, and (ii) providing pass-through estimates for a broad range of categories of goods and services, which allows to study the heterogeneity between product categories.

The Swiss National Bank (SNB) introduced an exchange rate floor on the Swiss franc on September 6, 2011. This change of policy results from considerable pressure for the Swiss franc to appreciate following the European debt crisis. The safe haven position of Switzerland plays a significant role in the appreciation pressure on the Swiss franc (Baltensperger and Kugler, 2016), attracting foreign capital during external crises and global uncertainty (Ranaldo and Söderlind, 2010). Consequently, the sovereign debt crisis that started in Greece undermined the stability of the whole euro area, leading to a Swiss franc appreciation. As such, the EUR/CHF rate decreased from 1.28 in January 2010 to 1.12 in August 2010, namely an appreciation of 12.5% in only 8 months that was detrimental to Swiss exports. With interest rates already close to zero, the SNB decided to respond with foreign exchange interventions and to introduce an explicit minimum rate on the EUR/CHF at 1.20 Swiss franc per Euro to prevent a domestic appreciation (Hui et al., 2016).

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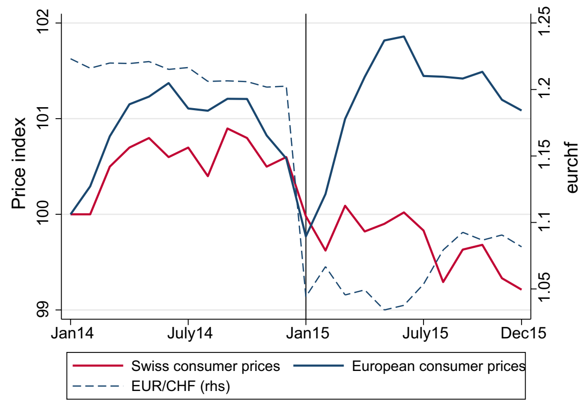

Fig. 1 Aggregate consumer prices before and after the currency appreciation. *Notes* Monthly HICP all-items index with January 2014 prices normalized to 100. Europe is a GDP-weighted price average of 33 European countries excluding Switzerland. Data source: Eurostat (2022)

This floor was maintained until January 15, 2015, when the SNB surprised financial markets by renouncing its exchange rate commitments. The underlying reason can be traced back to the European Central Bank (ECB) quantitative easing program, which made the minimum rate too expensive to maintain as it required ever-increasing purchases of foreign exchange (Lleo and Ziemba, 2015). This decision came together with the implementation of negative interest rates by the SNB. Financial markets reacted with a sudden appreciation of the Swiss franc, with the EUR/CHF rate decreasing as low as 0.975 on the day of the announcement. The Swiss franc then depreciated and stabilized in the 1.04 to 1.09 range for the rest of the year, so that the Swiss franc appreciated by approximately 10% overall. All the available evidence suggests that the SNB's decision surprised the market (Mirkov et al., 2019). Swiss consumer prices subsequently dropped following the announcement (Fig. 1), reflecting how the cheaper import costs were passed on to consumer prices. The decline in Swiss prices is exceptional considering it happened in a period of rising prices in Europe. The discrepancy between the inflation that should have happened in Switzerland and the decline of prices that was observed instead shows how large and impactful the exchange rate shock was.

The theoretical literature on the exchange rate pass-through is summarized in Menon (1995) and Burstein & Gopinath (2014). The pass-through to consumer prices is often incomplete due to imperfect competition, product heterogeneity, tariffs, trade structure, and non-tariff barriers. That is, exchange rate shocks are not transmitted one-to-one to consumer prices. Empirical estimates of the pass-through can thus differ across product categories because these forces apply differently to different types of goods and services.

A large empirical literature study investigated the exchange rate pass-through. The most common estimates of the pass-through to consumer prices make use of VAR methods over long periods of time. This methodology has been used extensively to compute estimates for most countries across the world[1]. Using the VAR methodology, Stulz (2007) estimates an average 1-year pass-through to consumer prices of 0.17 in Switzerland during the 1967–2004 period. A more recent approach to the pass-through identification is to exploit large exchange rate shocks. In particular, the Swiss franc appreciation of 2015 has been used by Auer et al. (2019), Bonadio et al. (2020), Kaufmann & Renkin (2019), and Freitag % Lein (2022) to analyze various aspects of the exchange rate pass-through to border prices. Auer et al. (2021) also use this episode to compute the pass-through to retail consumer prices, estimating a 1-year pass-through of 0.075 for retail domestic products and 0.366 for retail imported products.[2] Lastly, differences in pass-through estimates have been explained by the degree of international tradability (Edwards & Cabezas, 2022), the import share of goods (Breinlich et al., 2022; Fleer et al., 2016), and the invoice currency for border prices (Auer et al., 2021).

This paper proposes a difference-in-differences (DID) approach to estimate the exchange rate pass-through to consumer prices. Contrary to the common VAR approach, this methodology leverages specific and large shocks instead of long time series to compute the pass-through. Given a large enough one-sided shock, parallel pre-trends, and a comparable counterfactual, the DID approach can more closely identify the pass-through than simple VAR methods. In the Swiss appreciation case using Europe as a control group, these conditions would be met if the EUR/CHF franc shock largely affected Swiss consumer prices but not European consumer prices. This is the case to a large degree since Switzerland is a small open economy relying heavily on trade with European countries, but its small relative size makes Swiss shocks negligible for the European economy. Two versions of the DID are proposed: a standard DID using a GDP-weighted

[1] See for instance Ihrig et al. (2006), McCarthy (2007), and Hahn (2003) for estimates of the exchange rate pass-through to consumer prices in the US and Europe, and Ito et al. (2005), Ogundipe and Egbetokun (2013), and Sansone et al. (2016) for examples of estimates in Asian, African, and South American countries.

[2] Other recent papers have also leveraged the 2015 Swiss franc shock, for instance to estimate the unequal welfare effects of changes in consumer prices (Auer et al., 2022), the effect of cross-border shopping and distance to border following the exchange rate shock (Burstein et al. 2022), or the effect of downward nominal wage rigidity following a decline of consumer price (Funk & Kaufmann, 2022).

average of European countries as the control group, and a synthetic DID based on Arkhangelsky et al. (2021) which selects the European countries weights to make its pre-shock consumer prices as parallel to Swiss consumer prices as possible. These estimates are computed for 85 product categories using the Harmonized Index of Consumer Prices (HICP) data from Eurostat (2022).

The results outline an important pass-through heterogeneity across categories of goods and services. The 1-year exchange rate pass-through to the all-items consumer price index is 0.12. However, the pass-through of the individual product categories ranges from − 0.31 to 0.80, which shows the large difference that exist between products. Aggregating the results by groups, the average pass-through is 0.18 for Food & Beverages, 0.14 for Household Products, 0.15 for Services, 0.09 for Services excluding holiday and air transport, and 0.29 for Industrial and Other goods. The pass-through heterogeneity of the products can be linked to the degree of international tradability, with services and nontradables having close to no pass-through. Notable exceptions to this are tourism-related services, who faced a large price drop due to a decline of foreign demand following the currency appreciation. Moreover, the fraction of imported goods in consumer expenditures (import share) can also be linked to the differences in pass-through between product categories. Lastly, the invoice currency of the goods could not be tied to the heterogeneity, most likely due to the lack of data for non-retails goods.

These estimates contribute to the pass-through literature in two ways. First, they show that a DID approach provides results that are quantitatively similar to the common VAR approach but with a higher degree of identification. Moreover, this alternative approach requires less data, does not rely on a sophisticated model, and can be easily computed for many categories of products. Second, they provide a deeper understanding of the pass-through mechanism by analyzing the heterogeneity between product categories. Indeed, they further develop the recent results of Edwards & Cabezas (2022), Breinlich et al. (2022), and Auer et al. (2021) regarding the role of the degree of tradability, the import share, and the invoice currency in the exchange rate pass-through by extending their analyses to services and non-retail goods.

The paper is organized as follows. Section 2 introduces the data. Section 3 analyzespre-trends of consumer prices in Switzerland and in Europe. Section 4 presents theestimates of the exchange rate pass-through to consumer prices for all categoriesof goods and services. Section 5 explores how tradability, the import share, andthe invoice currency could explain the pass-through heterogeneity across productcategories. Section 6 concludes.

2 Data

Consumer price data are taken from the Harmonized Index of Consumer Prices (HICP). Based on the more widely known Consumer Price Index (CPI), the HICP aims for all participating countries to use the same methodology to allow for international comparisons. Given its aim to be a pure price index, the HICP measures prices in their local currency and normalizes them over time. The data are freely available and collected by the Statistical Office of the European Union: Eurostat (2022).

The HICP provides panel data describing the monthly evolution of consumer prices for 34 countries in the European continent[3]. The period used is January 2014 to December 2015, with the Swiss franc shock happening in January 2015. The prices are separated by categories of goods and services based on the Classification of Individual Consumption According to Purpose (COICOP), for example *meat*, *footwear*, or *transport insurance*. The dataset originally contains prices for 468 categories but many of them are unavailable on a monthly basis for Switzerland before 2015. Therefore, less granular categories were used, which still represent the whole CPI basket but only one level higher in the COICOP categorization. The final results thus include 85 categories of goods and services, which are listed in Tables 5, 6, 7, and 8.

Using the full sample of 33 European countries rather than a subsample such as the eurozone or the European Union members is justified by Switzerland trade situation. In order to provide causal estimates, the DID methodology requires the shock to have impacted only Switzerland but not its counterfactual. However, because of its geographic position, Switzerland main European trade partners at the time of the shock were Germany, Italy, France, the UK, and Austria (Legge & Lukaszuk, 2018). As such, the Swiss franc shock must have had some impact on these countries, which were also some of the largest members of the Union and eurozone. The broader sample is thus more likely to be independent from Swiss shocks while still providing a representative control group. Moreover, taking the largest available sample is best for the synthetic DID approach, as it gives the algorithm the most potential counterfactuals to work with. For the standard DID, each country is weighted by its GDP in 2015 to make the single *Europe* measure.

Most of the analysis presented in this paper uses 24 months of data: one year before the shock (2014) and one year after (2015). Only the dynamic DID presented

[3] List of countries: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Iceland, Norway, Switzerland, UK, North Macedonia, Serbia, Turkey.

in Fig. 3 uses an additional year of data before the shock (2013) in order to further analysis pre-trends. Studying a horizon of one year after the shock is motivated by previous empirical studies on the exchange rate pass-through. For instance, in the case of Brexit, Corsetti et al. (2022) found that the full pass-through to British export prices took 9 months. In Switzerland, Auer et al. (2021) point toward a 1-year impact of the shock on retail prices, and Stulz (2007) observes that the pass-through to consumer prices reaches its long-run level after 12 months. As such, analyzing the average response over the 12 months following the 2015 appreciation is likely to capture most of the pass-through effects while still remaining close enough to the shock to avoid other large exogenous fluctuations.

This paper also uses data on international tradability, import shares, invoice currencies, and EUR/CHF to analyze the exchange rate shock and the pass-through heterogeneity between product categories. The international tradability of a good or service is the degree to which it can be sold in a different location from where it was produced, and this paper uses the Bureau of Labor Statistics (BLS) category-level tradability data of Johnson (2017). The import share refers to the import intensity of a product, that is the share of imported goods in the total domestic consumption for that good. This paper uses the Swiss Federal Statistical Office (SFSO) estimates of the import shares for Switzerland, which can be requested from the SFSO directly but are not part of an official release. These estimates are available for the relevant product categories on the author's repository. Regarding the invoice currencies, this paper uses the EUR-invoicing share data of Auer et al. (2021), which measures the share of foreign-invoiced goods at the border. Lastly, the EUR/CHF data used in Fig. 1, throughout the text, and to compute the implied pass-through are taken directly from the Swiss National bank: SNB (2022).

3 Pre-trends

A necessary assumption for DID inference is that Swiss and European prices would have followed parallel trends without the Swiss franc shock (Abadie, 2005). In practice, this assumption is addressed by comparing trends in the treatment and control groups before the shock to see if they were parallel. This kind of pre-trend testing is neither necessary nor sufficient for the parallel trend assumption to hold and needs to be paired with a qualitative argument comparing the two groups (Kahn-Lang & Lang, 2020). As a small open economy in the middle of Europe, Switzerland relies heavily on its EUR/CHF exchange rate for economic growth, so that the shock had a significant impact on the Swiss economy. On the other hand, Switzerland is only a small trading partner for the whole of Europe, so that the overall continent was only slightly impacted by these local fluctuations. As a result, Europe can be used as an imperfect control group displaying the inflation that should have happened in Switzerland without the Swiss franc appreciation.

The pre-trend assumption can be analyzed with a simple test based on linear time trends. Usually, the assumption is verified by plotting the pre-trends, as shown in Fig. 1. However, this needs to be checked for each of the 85 HICP category, which would not be convenient with plots. Instead, this paper proposes a simple pre-trend test relying on a linear trend model. For each product category i, consumer prices in the 12 months before the shock (January–December 2014) are linearly regressed on time for both Switzerland and Europe:

$$\begin{aligned} p_{it}^{\text{CH}} &= \alpha_i^{\text{CH}} + \beta_i^{\text{CH}} t + \epsilon_{it}^{\text{CH}} \\ p_{it}^{\text{EU}} &= \alpha_i^{\text{EU}} + \beta_i^{\text{EU}} t + \epsilon_{it}^{EU} \end{aligned} \tag{1}$$

Under the parallel pre-trend assumption, the resulting time trends should be equal ($\beta_i^{\text{EU}} - \beta_i^{\text{CH}} = 0$). This can be tested using the standard error and Z test statistic of Clogg et al. (1995): $Z_i = (b_i^{\text{EU}} - b_i^{\text{CH}})/\sqrt{se(b_i^{\text{EU}})^2 + se(b_i^{\text{CH}})^2}$, which follows a standard normal distribution. The literature commonly disregards such numerical pre-trend tests in favor of qualitative arguments, but this solution remains useful when many DID regressions need to be performed.

The pre-trend assumption holds for most product categories. It also holds for the overall all-items index, as illustrated in Fig. 1. The detailed product-level difference and test result are reported in Tables 5, 6, 7, and 8, where the test holds for more than half of the product categories at the $\alpha = 10\%$ level. Nevertheless, a non-negligible share of the product categories display non-parallel pre-trends since the test fails for 26 products at $\alpha = 1\%$, 35 products at $\alpha = 5\%$, and 41 products at $\alpha = 10\%$. These relatively inconsistent pre-trends justify the need for a synthetic DID design, which builds custom control groups for each product category such that pre-trends parallelism is maximized.

Alternative control groups can also be considered. Even though the HICP dataset is limited to European countries, subsets of countries that share some similarities with Switzerland could be better counterfactuals. For instance, the European Union and Eurozone for their political significance, all countries excluding southern Europe due to the ongoing austerity measures, all Germanic countries due to their proximity to Switzerland, all direct neighbors of Switzerland, the countries that do not use the euro, or the 10 countries with the highest GDP per capita. The exact members of these alternative samples as well as the average pre-trend difference across all goods are reported in Table 1. These results

Table 1 Pre-trend tests of alternative control groups

Control group	Mean pre-trend difference	N	Countries
Europe (baseline)	0.29	33	Austria, Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, Iceland, Norway, UK, North Macedonia, Serbia, Turkey
European Union	−1.94	28	Baseline minus Norway, Serbia, Iceland, North Macedonia, Turkey
Eurozone	−0.49	19	Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, Spain
Europe excluding south	0.32	29	Baseline minus Italy, Spain, Greece, Portugal
Germanic countries	5.26	2	Austria, Germany
Direct neighbors	4.31	4	France, Italy, Austria, Germany
Non-EUR currency	−3.91	9	UK, Bulgaria, Czech Republic, Denmark, Croatia, Hungary, Poland, Romania, Sweden
High GDP per capita	0.92	10	Luxembourg, Ireland, Norway, Denmark, Netherlands, Iceland, Austria, Sweden, Germany, Belgium

Pre-trend differences are computed for all categories of the HICP by running two time trend regressions on the Swiss and control group prices (equation 1), using monthly data from January to December 2014. The pre-trend difference is defined as the difference between the two resulting slope coefficients: $b_i^{\text{control}} - b_i^{\text{CH}}$. Only the average difference across all 85 HICP categories is shown. N denotes the number of countries in the proposed control group

give further confidence in using the whole of Europe as a control group as it minimizes the mean pre-trend slope difference across all categories of goods. Moreover, Fig. 2 provides a convincing argument that the pre-trends for all of Europe and Switzerland are relatively parallel, even more so than other control groups. Moreover, using a small subsample of countries such as the Germanic control group may provide convincing pre-trends on the all-items index (as seen in Fig. 2) but poor results on individual categories (as seen in the high average in Table 1).

An additional pre-trend analysis can be carried with a dynamic DID on the 2013–2015 period. Instead of the post-treatment dummy used in the standard DID, this regression allows for dynamic lags and leads as well as country and time fixed effects (ϕ_t, ψ_s). It includes 24 pre-trend months (2013–2014) and 12 post-treatment months (2015), with December 2014 dropped to avoid perfect multicollinearity. Standard errors are clustered at the country level. Practical implementation was carried out using the two-way fixed-effect regression of Clarke and Tapia-Schythe (2021). Using t as a subscript for time-to-treatment in months and i for countries, the regression predicts consumer prices (p_{it}) on a dummy treatment variable for Switzerland after the shock ($treat_{it}$):

$$p_{it} = \alpha + \phi_t + \psi_s + \sum_{s=-24}^{-2} \beta_s \text{treat}_{is} + \sum_{s=0}^{12} \beta_s \text{treat}_{is} + \epsilon_{it} \quad (2)$$

The dynamic DID further confirms that Europe and Switzerland have parallel pre-treatment aggregate prices. The coefficients β_s are displayed in Fig. 3. With perfectly parallel pre-trends, all pre-treatment coefficients should be 0. These results show that a large part of pre-treatment

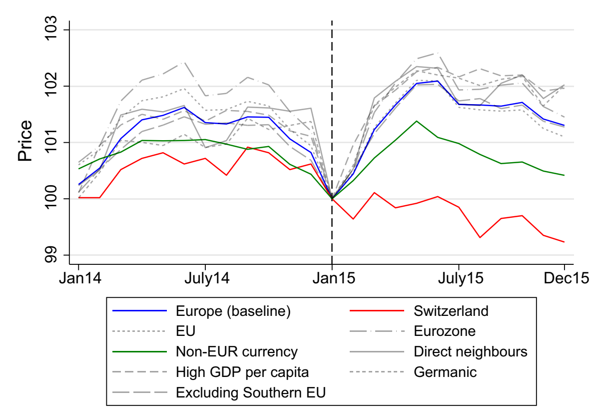

Fig. 2 Aggregate consumer prices for alternative control groups. *Notes* Monthly HICP all-items index with January 2015 prices normalized to 100. The components of the alternative control groups are defined in Table 1. Data source: Eurostat (2022)

coefficients are not statistically different than 0 at the 95% confidence level and remain below 1 in absolute value, giving confidence that the pre-trend assumption holds empirically.[4]

This analysis is also carried out for alternative control groups in appendix Fig. 8. It shows that the pre-trend assumption would also hold for these alternative groups,

[4] The post-treatment part of the plot also provide some of the coefficients that are used in the later DID analysis of section , which are voluntarily omitted from the present section since it focuses solely on pre-trend dynamics. However, it is important to note that most of the pass-through is concentrated on 4 months following the shock and stabilizes afterward, giving empirical confidence in the 1-year time frame used in the later analysis.

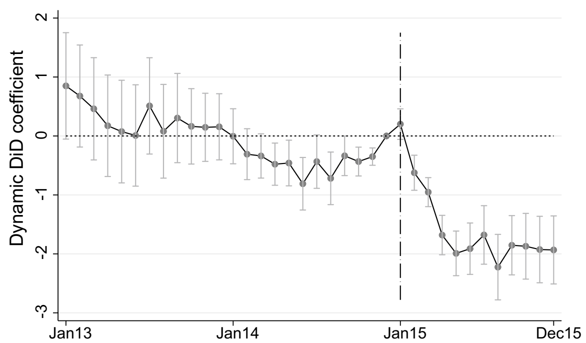

Fig. 3 All-items dynamic DID coefficients. *Notes* DID regression of the HICP all-items index with dynamic lags/leads, as well as country and time fixed effects, following regression 2. Standard errors are clustered at the country level. Coefficients are computed from the HICP monthly all-items consumer price index from January 2013 to December 2015, using post-January 2015 Switzerland as a treatment and 33 European countries as a GDP-weighted control group. Bands show the 95% confidence interval for each coefficient. Data source: Eurostat (2022)

with higher standard errors but quantitatively similar results. This adds further robustness to the choice of keeping all European countries, instead of a subset of countries.

4 Pass-through estimates

4.1 Synthetic DID methodology

The pass-through estimates are computed using the synthetic DID method of Arkhangelsky et al. (2021). In essence, the synthetic DID works similarly to the standard DID except that it automatically weights each country of the control group to maximize pre-trend parallelism, creating a "synthetic" control group. In more details, a synthetic control is defined as a weighted combination of the untreated units such that the control group is as close to possible to the pre-treatment treated group, providing more robust estimates than individual controls. They are especially useful to estimate the effects of treatments affecting a small number of large entities, such as countries (Abadie, 2021). The setup presented in this paper is thus a great match for this method, with only one treated unit (Switzerland) and 33 untreated control units (European countries). Instead of the arbitrary GDP weights used in the standard DID, synthetic controls compute weights minimizing the distance between lagged outcomes for the treated and untreated units[5]. Synthetic controls can be applied to the DID case and result in the synthetic DID method from Arkhangelsky et al. (2021), which is used in this paper through their *synthdid* R package implementation. By weighting controls to match pre-exposure trends, the synthetic DID method weakens the reliance on the parallel trend assumption and provides more robust estimates than the standard DID. This method is especially relevant given that some specific product categories have weak pre-trend similarities, as discussed in section . The weights from the minimization problem generates synthetic prices that are then used as a control group.

The DID regression is as follows. Using t as a subscript for time in months and i for countries (Switzerland and the control group), the DID regresses consumer prices (p_{it}) on a dummy for Switzerland (CH_i), a dummy for the post-treatment periods (PT_t), and the interaction of the two ($\mathrm{DID}_{it} := \mathrm{CH}_i \times \mathrm{PT}_t$):

$$p_{it} = \alpha + \beta CH_i + \gamma PT_t + \delta DID_{it} + \epsilon_{it} \tag{3}$$

The DID estimator is then the coefficient δ, describing the interaction effect of the treatment group and post-treatment period. This regression is run on the prices of each of the 85 categories of goods and services, for both the GDP-weighted control group (Standard DID) and the synthetic control group (Synthetic DID). With the shock taking place in January 2015, the regression uses January-December 2014 prices to compute the synthetic control weights, and January-December 2015 as the post-treatment period. It thus computes the 1-year impact of the exchange rate shock.

The synthetic DID standard errors are computed with the placebo method of Arkhangelsky et al. (2021), and the standard DID with Newey–West standard errors. The variance of the synthetic DID estimates could also be computed using a bootstrap or jackknife estimator. However, the findings of Arkhangelsky et al. (2021) hint that placebo provides more robust and accurate results, making it the new standard method in the synthetic DID literature. The placebo method assesses the behavior of the estimator when replacing the treatment unit (Switzerland) with untreated controls (European countries). The method then uses these permutations to estimate the level of noise and compute the variance of the estimator[6]. The standard DID uses Newey–West heteroskedasticity and autocorrelation consistent standard errors (HAC) given that prices are autocorrelated and that the EUR/CHF shock may have impacted their variance. These issues are already solved by design of the placebo method.

The synthetic DID method has been modified to exclude the ten most volatile countries in each iteration, which reduces its standard errors. Indeed, the baseline

[5] See section I of Arkhangelsky et al. (2021) for the detailed minimization problem.

[6] See Algorithm 4 of Arkhangelsky et al. (2021) for more details on how the placebo estimator computes the variance.

method of Arkhangelsky et al. (2021) selects the country weights to maximize pre-trends similarity, but it does not consider the variance of the underlying prices in its maximization problem. As a result, it may place too much weight on countries that had exceptionally volatile prices in 2015 for some product categories. This does not impair the DID estimator, but it yields standard errors that are unnecessarily large. The standard DID is less prone to this volatility because its GDP weights place the most emphasis on Western Europe, which had more stable prices overall. One solution to this issue is to exclude the countries with the highest variance in prices in 2015 in each of the 85 synthetic DID regressions. The results of this modification for a different number of countries are displayed in Table 4, which shows that the synthetic DID has standard errors that are almost twice those of the standard DID with HAC. Excluding five countries does not reduce the variance sufficiently, and excluding fifteen starts to modify the DID results too much. This paper thus excludes ten countries, which reduces standard errors by 40% on average while still yielding DID estimates that are extremely close to those of the baseline synthetic DID. With 33 European countries, excluding ten countries still preserves more than two thirds of the sample at each iteration. The average synthetic error remains 16% larger than in the standard DID, but this volatility correction eliminates most of the gap between the two. Removing the most volatile countries is not equal to using a subsample (such as the alternative control groups proposed in section) because different countries are removed for each category of good. A more sophisticated solution would be to include the variance of prices in the optimization problem of the synthetic DID, which would go beyond the applied scope of this paper.

In practice, the all-items synthetic control group is close to the baseline control group (Fig. 4). However, one can notice that the pre-trends are more parallel to Swiss prices with the synthetic control than with the baseline control group. As such, the synthetic algorithm still manages to produce a convincingly parallel control group despite removing part of the sample to reduce standard errors. For the all-items HICP index, the excluded ten most volatile countries are Estonia, Belgium, UK, Turkey, Malta, Iceland, Ireland, Sweden, Denmark, and the Netherlands[7].

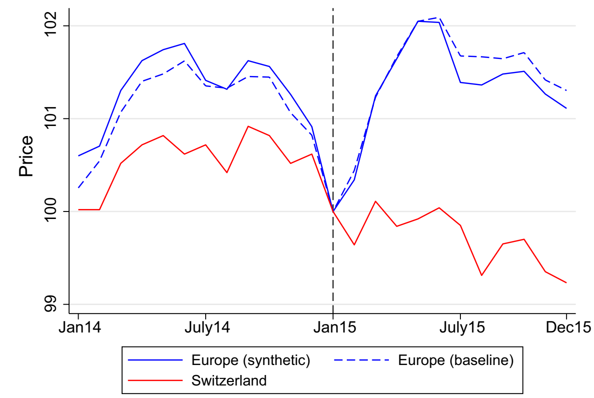

Fig. 4 Synthetic control group prices. *Notes* Monthly HICP all-items index with January 2014 prices normalized to 100. Europe (baseline) is a GDP-weighted price average of 33 European countries excluding Switzerland. Europe (synthetic) is the control group implied by the synthetic DID method of Arkhangelsky et al. (2021), using the same sample of 33 European countries but excluding for the 10 countries with the most volatile prices in 2015. Data source: Eurostat (2022)

The synthetic DID coefficients δ can then be used to compute the exchange rate pass-through to consumer prices. With prices being normalized to January 2015, the DID coefficients estimate the impact of the shock on the average 1-year prices in percent. We can thus divide them by the 1-year EUR/CHF spot rate (S_t) differential caused by the shock to get the elasticity of consumer prices to the exchange rate:

$$\text{pass-through} = \frac{\delta}{\Delta S_t}, \text{ where } \Delta S_t := \frac{S_{31.12.2015} - S_{14.01.2015}}{S_{14.01.2015}} \tag{4}$$

This elasticity corresponds to the pass-through. As an example, a DID coefficient of −1.57 would estimate that the shock reduced Swiss consumer prices by 1.57%. Given that the exchange rate declined by −10.07% by the end of 2015, this gives an implied pass-through of $\frac{-1.57}{-10.07} = 0.156$, which means that a 1% exchange rate shock results in a 0.156% change in consumer prices.

The identifying assumptions are as follows. The first assumption is that the EUR/CHF shock had a sizable impact on Swiss consumer prices, making it the main driver of the gap in inflation between Switzerland and Europe in 2015. This assumption is met to a large degree given that Switzerland is a small open economy that relies heavily on trade with European countries, and that the 2015 exchange rate shock was one of the largest short-term appreciation the Swiss franc ever faced. Moreover, the IMF Economic Outlooks of this period, such as (IMF, 2015), highlighted how developed economies recovered in 2015 with increasing consumer prices, making it even more clear that Swiss

[7] The synthetic weights are as follows for the all-items index: Serbia: 0.064; Lithuania: 0.058; France: 0.055; Cyprus: 0.054; Croatia: 0.052; Spain: 0.051; Italy: 0.051; Romania: 0.050; Luxembourg: 0.049; Norway: 0.049; North Macedonia: 0.049; Germany: 0.048; Portugal: 0.048; Greece: 0.047; Slovenia: 0.047; Poland: 0.047; Bulgaria: 0.047; Austria: 0.046; Latvia: 0.045; Czech Republic: 0.043; Hungary: 0; Slovakia: 0; Finland: 0. Note that the algorithm does not need to use all countries to produce its weights, which is why 3 countries have a weight of 0.

Table 2 Aggregate estimates of the exchange rate pass-through to consumer prices

Group	Mean pass-through	Median pass-through	Range of pass-through
Food & Beverages	0.18	0.15	−0.01 to 0.39
Household products	0.14	0.15	−0.31 to 0.49
Services	0.15	0.09	0.02 to 0.69
Services excl. tourism	0.09	0.07	0.02 to 0.49
Industrial and other goods	0.29	0.25	−0.10 to 0.80
All-items (unweighted)	0.18	0.14	−0.31 to 0.80
All-items index (HICP weights)	0.12		

1-year pass-through of the 2015 EUR/CHF shock to Swiss consumer prices implied by the synthetic DID method of Arkhangelsky et al. (2021). Pass-through is computed from the DID coefficients using Eq. 4. Regressions use the HICP consumer price data with pre-treatment from January 2014 to January 2015 and post-treatment from February 2015 to December 2015. Effect is estimated on Swiss prices using 33 European countries as a synthetic-weighted control group. The detailed group-level results are presented in Tables 5, 6, 7, and 8. The unweighted all-items index is a simple average over all categories of goods, and the weighted all-items index is the overall pass-through weighted by HICP weights, as computed by Eurostat (2022)

prices were largely impacted by the shock since they decreased. The second assumption is that the EUR/CHF shock only impacted Switzerland, but not Europe, as otherwise Europe would also have been treated. Despite some inevitable spillovers to European prices, Switzerland is only a minor trade partner for the whole of Europe so that the Swiss franc appreciation likely only had a negligible effect on European consumer prices. The last assumption necessary for DID inference is that the two groups are comparable, with Swiss and European prices following parallel trends. This assumption is partially verified and is improved by synthetic controls, as discussed in section . Given the small open economy status of Switzerland, it is well established that European inflation is imported to a large degree in Switzerland through the exchange rate, especially when fixed, and that price trends in Switzerland and Europe are thus highly cointegrated. Overall, the identifying assumptions are met to an unusually high degree given that they are based on aggregate macroeconomic data, which makes any micro-identification strategy difficult (Nakamura & Steinsson, 2018). The DID framework thus provides results that are more closely identified than in the standard VAR approach that is usually used to compute pass-through estimates.

4.2 Exchange rate pass-through to consumer prices

The aggregate result is a 1-year pass-through of 0.12, meaning that only 12% of the EUR/CHF shock was passed on to the all-items consumer price index. This shows that the pass-through is incomplete, as the exchange rate shock is not reflected one-to-one in prices. This estimate is in line with the VAR estimation of Stulz (2007), which found evidence of an average 1-year pass-through to consumer prices of 0.17 in 1976–2004 for Switzerland.

The product-level results are separated in four groups. *Food & Beverages* contains retail goods such as meat, wine, and processed food. *Household Products* includes non-food goods commonly used by households such as books, pharmaceutical products, and tobacco. *Services* presents different types of services such as air transport, education, and restaurants. *Industrial and other goods* contains durable and non-durable industrial goods, as well as goods not classified elsewhere such as *energy*, *vehicles*, and *liquid fuels*. A summary of the results of each group is presented in Table 2. It shows that the price of services have a lower pass-through than goods, especially when services linked to tourism are removed (such as hotels, package holidays, and air transport). The large pass-through heterogeneity between individual categories of goods can be observed across all groups, as seen in the wide range of pass-through estimates.

The detailed product-level pass-through is presented in Table 5 for Food & Beverages, Table 6 for Household Products, Table 7 for Services, and Table 8 for Industrial and Other goods. The few negative coefficients observed concern mainly clothing and footwear. There does not appear to be a reasonable explanation of why these prices rose in Switzerland relative to Europe when they should have declined. They are thus considered isolated cases that were not the result of the exchange rate increase. It is interesting to note that the prices of petroleum-based fuels and vehicles reacted much more than other categories of goods, which explains why the average of Industrial and Other goods is relatively higher. This result is coherent given that Switzerland does not have any significant domestic petrol or car production, making their prices more elastic to exchange rate shocks.

The standard DID and synthetic DID coefficients are close but not equal. Overall, the standard DID coefficients are higher in magnitude than the synthetic DID coefficients, with an average pass-through of 0.24 against

0.20 for the baseline synthetic estimation, or 0.18 for the synthetic excluding 10 countries (Table 4). As a result, coupled with its slightly lower variance, the standard DID coefficients are also more often significant than the synthetic DID. Based on the results of Arkhangelsky et al. (2021), it is more likely that this surprising result emerges from an overestimation of the standard DID rather than a failure of the synthetic DID, given the more robust pre-trends of the synthetic DID.

5 Tradability, import share, and invoice currency

With the pass-through ranging from −0.31 to 0.80, there is a significant heterogeneity in the price reaction of different categories of goods and services to the exchange rate shock. This section analyzes three potential explanations to these differences: the degree of international tradability, the import share, and the invoice currency.

International tradability refers to the degree to which a good or service can be sold in a different country than the one it was produced in. As such, the price of a good with a low degree of tradability should be less affected by exchange rate shocks as it is not imported and cannot be easily substituted with a foreign alternative. Empirical evidence of this effect is provided by Edwards and Cabezas (2022), who found that tradable goods have higher pass-through than nontradables. Johnson (2017) provides estimates of the degree of international tradability for each CPI category[8], which can be linked to the exchange rate pass-through estimates computed in section . Indeed, goods with a high degree of tradability are more impacted by changes to import costs and should be easily substitutable with cheaper imports in case of a currency appreciation, thus having a high elasticity of prices to the exchange rate. As such, a linear regression should yield a positive relationship between tradability and pass-through estimates. The results of such a regression are presented in Fig. 5 and show a positive link between the pass-through and tradability for each subclass of goods.

The import share refers to the fraction of imported goods in consumer expenditures. In the case of Brexit, Breinlich et al. (2022) pointed out that the prices of goods with a higher import share are more affected by exchange rate fluctuations as they are more sensitive to changes in import costs. Import share data for Switzerland can be obtained from the SFSO and can be analyzed in a similar fashion as for international tradability. The results of regressing the pass-through on products' import share are presented in Fig. 6 and show a positive link between the pass-through and the import share for all subclass of goods except services, which are all produced locally.

The foreign invoicing share refers to the share of goods being sold in EUR at the border, as opposed to being sold in the domestic currency. These estimates are taken from Auer et al. (2021), which computes them for retail goods[9]. Their results outline the role of the foreign invoicing share in the exchange rate pass-through, with foreign-invoiced goods being more affected by the fluctuations due to the changes in import costs. Figure 7 shows the results of regressing the pass-through estimates on the EUR-invoicing share, which could be expected to be positive. Contrary to the regressions using tradability and the import share, these results are inconclusive since the regression is indeed positive but not statistically significant. However, the lack of clear relationship may well be due to a sample too small to yield convincing results as well as to the usage of consumer prices instead of import prices. Indeed, Auer et al. (2021) focuses on the import prices of retail goods, which are mostly food and beverages. As such, only 12 categories of goods can be matched to their EUR-invoicing share, as opposed to the other regressions that include more than 70 categories of goods. Overall, this hints that the role of the invoice currency needs more sophisticated identification methods such as those used by Auer et al. (2021).

These regressions are summarized in Table 3. While they are not causal, they give an idea of the correlation between the trade characteristics of the products and their pass-through. As illustrated in Figs. 5 and 6, regressions (1) and (2) show a significant link between the pass-through of goods and their degree of tradability and import share. Even though the correlation is slightly positive, regression (3) does not provide significant results for the EUR-invoicing share, as illustrated in Fig. 7. Regression (4) takes the three independent variable together, where only the import share remains significant, even though the sample may once again be too small to make

[8] Johnson (2017) computes its tradability measure by using the input–output tables produced by the Bureau of Economic Analysis, which show total production, imports, and exports by product category for the USA. It thus infer the tradability of goods and services by the degree to which the US outputs are traded internationally, that is: $\textit{tradability} := \textit{output}/\max\{\textit{import}, \textit{export}\}$. The detailed tradability data by product categories can be found in Table A-1 of Johnson (2017)

[9] The EUR-invoicing shares can be found in table B.5 of the online appendix of Auer et al. (2021), and only cover Food & Beverages goods. Their estimates can be matched for 12 of the 85 HICP categories, with the EUR-invoicing share in parenthesis: beer (0.66); bread and cereals (0.285); coffee, tea and cocoa (0.07); fish and seafood (0.33); fruits (0.16); meat (0.11); milk, cheese and eggs (0.52); non-alcoholic beverages (0.00); oils and fat (0.10); sugar, jam, honey, chocolate and confectionery (0.198); vegetables (0.16); wine (0.12). Aggregate categories use a simple average of the granular categories, e.g., the EUR-invoicing share of bread and cereals is an average of the share for bread and the share for cereals.

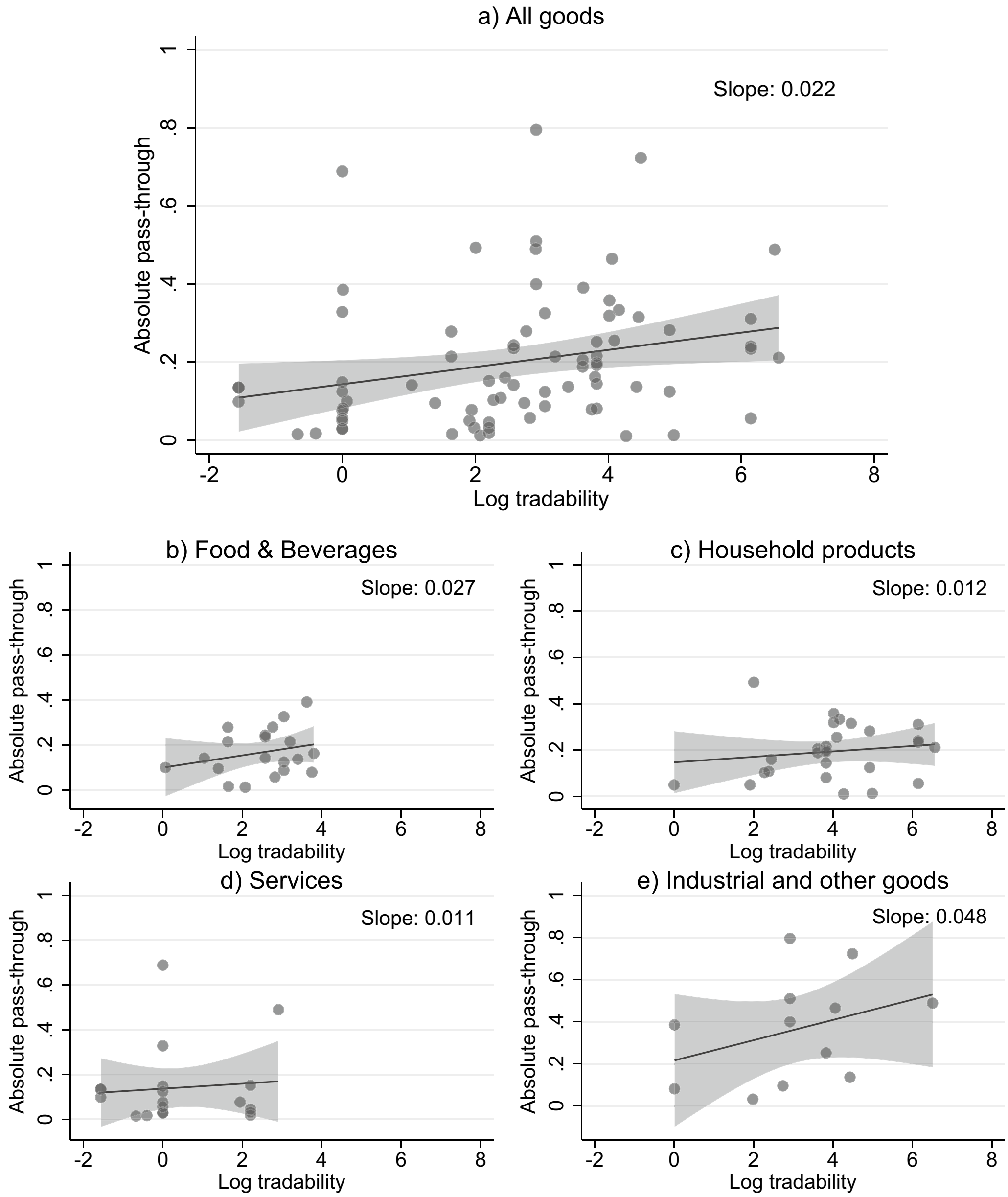

Fig. 5 International tradability and pass-through across HICP categories. *Notes:* Linear regression of the synthetic pass-through estimates on tradability for HICP goods and services, separated by class. The slope of the regression lines are shown in the charts. Tradability is taken in log value due to how it is computed in the BLS index of Johnson (2017), with most values in the 0–50 range and some extreme values in the 600–700 range. Pass-through is taken in absolute value due to a few negative values. Bands show the 95% confidence interval of the regressions

this effect relevant. Regression (5) removes the EUR-invoicing share to increase the sample size and adds an interaction effect. Again, only the import share remains significant, which hints for it being the main determinant of pass-through heterogeneity.

The impact of tradability and the import share can also be seen in individual categories. Services are more inelastic to exchange rate shocks than goods because they are mostly nontradable. The exception of services linked to tourism comes not from a substitution effect regarding

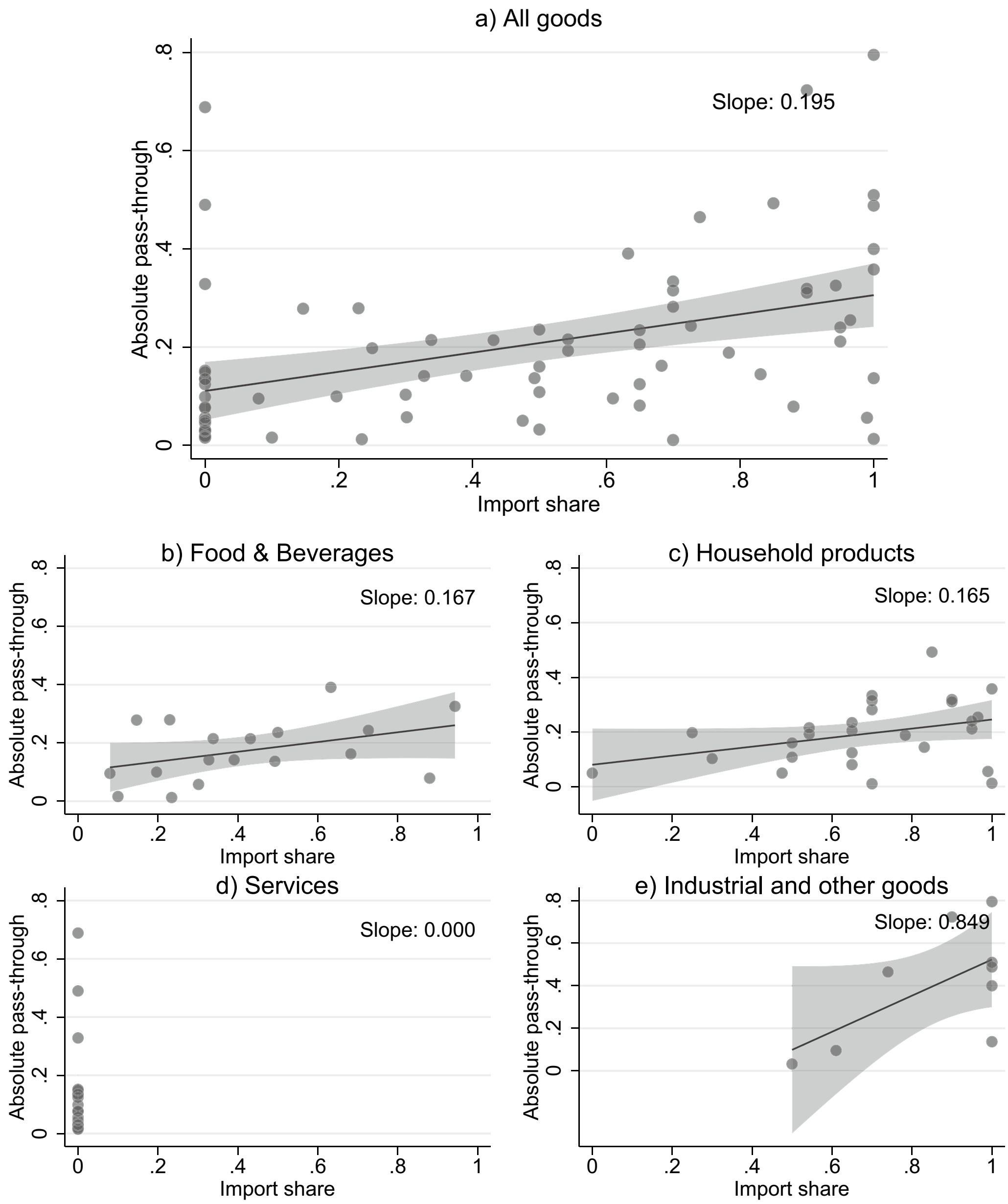

Fig. 6 Import share and pass-through across HICP categories. *Notes:* Linear regression of the synthetic pass-through estimates on the import share for HICP goods and services, separated by class. The slope of the regression lines are shown in the charts. Import share data is retrieved from the SFSO. Pass-through is taken in absolute value due to a few negative values. Bands show the 95% confidence interval of the regressions

domestic goods but rather from a lower foreign demand, due to the currency appreciation making holidays in Switzerland more expensive for foreigners (Abrahamsen et al., 2015). The relatively high pass-through of non-perishable household products like *Books* can be traced back to cross-border retail shopping and international delivery services (such as Amazon), which offer an easy substitution for domestic goods (Baggs et al., 2018).

6 Conclusion

The estimation of the exchange rate pass-through to consumer prices is challenging, as the broad range of factors affecting consumer prices makes full identification impossible. Nonetheless, large unexpected exchange rate changes such as the Swiss franc appreciation following the removal of the Swiss franc-Euro floor in January

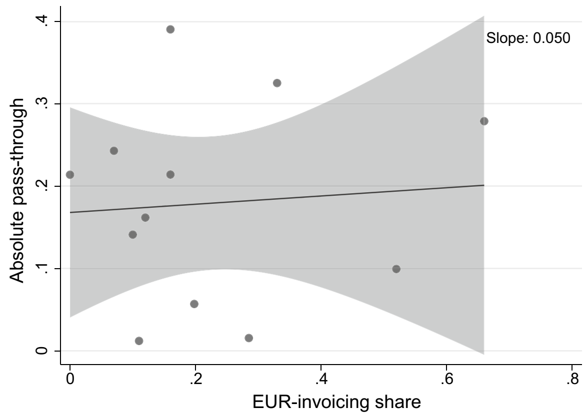

Fig. 7 EUR-invoicing share and pass-through across retail HICP categories. *Notes:* Linear regression of the synthetic pass-through estimates on the EUR-invoicing share for HICP retails goods only. The slope of the regression lines is shown in the charts. EUR-invoicing share data are retrieved from Auer et al. (2021). Pass-through is taken in absolute value due to a few negative values. Bands show the 95% confidence interval of the regressions

Table 3 Imports and pass-through heterogeneity

	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
ln(tradability)	0.022**			0.020	−0.009
	(0.009)			(0.028)	(0.027)
Import share		0.195***		0.313**	0.300**
		(0.059)		(0.099)	(0.100)
EUR-invoicing share			0.050	0.195	
			(0.146)	(0.129)	
ln(tradability) × Import share					−0.015
					(0.030)
Constant	0.143***	0.111***	0.168***	−0.047	0.113***
	(0.029)	(0.030)	(0.048)	(0.075)	(0.034)
Number of goods	78	73	12	12	73
R-squared	0.07	0.18	0.01	0.58	0.19
Adjusted R-squared	0.05	0.16	−0.09	0.42	0.15

Linear regressions of the absolute pass-through on international tradability and the import share, with robust standard errors. Tradability is taken in log due to its exponential scale. Tradability data is taken from the BLS estimates of Johnson (2017), the import shares data from the SFSO, and the EUR-invoicing share for retail goods from Auer et al. (2022). Not all product categories can be matched, so the number of observations is lower than 85. p^{*}<0.1; p^{**}<0.05; p^{***}<0.01

2015 provide a great opportunity for causal identification methods to partially identify and isolate the effect of the exchange rate on prices. Compared to the traditional VAR methodology, the DID approach thus has the advantage of providing more closely identified pass-through estimates while requiring less data.

The results show an important heterogeneity between product categories, where the pass-through ranges from − 0.31 to 0.80. These differences may be linked to the degree of international tradability and the import intensity of the good in Switzerland. For instance, services, dairy products, and bread are nontradables and are produced locally, so they have the lowest pass-through. Some goods such as books, fuel, sport or car equipment are considered nontradables, yet Switzerland does not or cannot produce them locally, which makes them have a high pass-through. Goods that are both highly tradable and imported in Switzerland, such as vehicles and audio–visual equipment, have the highest pass-through. Notable exceptions to this are tourism-related products, which have large pass-through no matter what. These results imply that the products whose prices will be most impacted by exchange rate shocks are those that: (i) are internationally tradable, (ii) cannot be locally produced, and (iii) rely on tourists.

An important development to this analysis would be to study the dynamics and speed of pass-through, not only for aggregate prices (as shown in Fig. 3) but for all HICP categories. Another development, which is already being studied by Auer et al. (2022), is to analyze expenditure switching heterogeneity as a potential complementary explanation for differences in price reaction. The argument of Auer et al. (2021) on the foreign invoice currency could also be extended beyond retail goods with the right data. Finally, the same DID methodology could be applied to other shocks to get estimates for other countries or for other periods in time, as the pass-through is known to vary across business cycles (Fleer et al., 2016) an the EUR/CHF shock may well be an isolated episode for the pass-through.

This paper contributes to growing literature on the transmission of exchange rate shocks to prices, as well as on the heterogeneity in pass-through across product categories. Microeconometric price datasets are becoming increasingly more prevalent in central banking and in research[10], calling for a more thorough knowledge of how exchange rate fluctuations impact prices on a granular basis and for new micro-based approaches to such macroeconomic topics.

[10] See for example the SNB product-level micro data that is currently used to study price rigidities in Switzerland (Rudolf & Seiler, 2022) or the ECB Price-Setting Microdata Analysis Network (PRISMA) project, which has numerous applications in progress for price rigidity (Gautier et al., 2022) and monetary policy targets (Adam et al., 2022) in Europe.

Appendix

See Fig. 8 and Tables 4, 5, 6, 7, and 8.

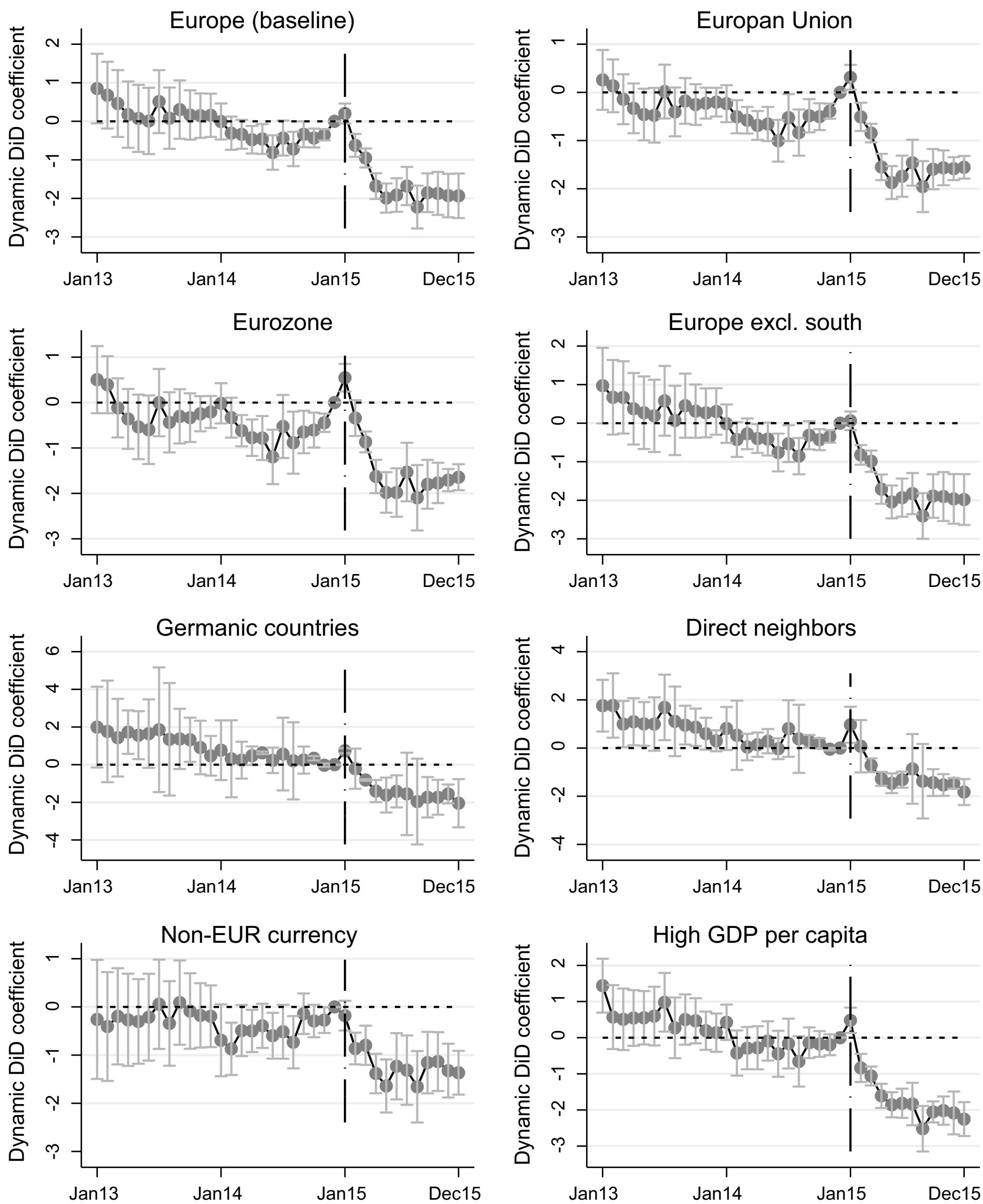

Fig. 8 All-items dynamic DID coefficients for alternative control groups. *Notes:* DID regression with dynamic lags/leads, as well as country and time fixed effects, following regression 2. Standard errors are clustered at the country level. Coefficients are computed from the HICP monthly all-items consumer price index from January 2013 to December 2015, using post-January 2015 Switzerland as a treatment. The alternative treatment groups are detailed in Table 1. Bands show the 95% confidence interval for each coefficient

Table 4 Comparison of different DID methods

Method	All-items pass-through	Average pass-through	Average standard error	Range of pass-through
Standard	0.16	0.24	0.86	− 0.58 to 1.01
Standard with HAC	0.16	0.24	1.06	− 0.58 to 1.01
Synthetic	0.16	0.20	2.04	− 0.34 to 0.83
Synthetic excl. 5 countries	0.12	0.19	1.43	− 0.32 to 0.83
Synthetic excl. 10 countries	0.12	0.18	1.23	− 0.31 to 0.80
Synthetic excl. 15 countries	0.11	0.18	0.99	− 0.30 to 0.92

Average results of different DID methods, including a synthetic DID volatility correction that excludes the most volatile countries for each product category. The synthetic DID follows Arkhangelsky et al. (2021) and uses the Eurostat HICP consumer prices excluding missing data, with pre-treatment from January 2014 to January 2015 and post-treatment from February 2015 to December 2015. The standard DID follows Eq. 3. Effect is estimated on Swiss prices using 33 European countries as a control group. The implied 1-year pass-through is computed from the DID estimates using Eq. 4. The average pass-through, its range, and the average DID standard error are the mean over all categories of goods and services

Table 5 Estimates of the exchange rate pass-through to consumer prices for Food & Beverages

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
All-items HICP	0.01	−1.64***	−1.23**	0.12
	(0.04)	(0.26)	(0.48)	
Food (overall index)	−0.17**	−1.58***	−1.42	0.14
	(0.07)	(0.32)	(0.92)	
Alcoholic beverages	0.01	−1.52***	−1.38**	0.14
	(0.04)	(0.25)	(0.64)	
Beer	-0.1	−3.19***	-2.81***	0.28
	(0.09)	(0.52)	(0.76)	
Bread and cereals	−0.01	−0.66***	−0.16	0.02
	(0.03)	(0.19)	(0.56)	
Coffee, tea, and cocoa	0.38**	−4.35***	−2.45**	0.24
	(0.15)	(1.34)	(1)	
Fish and seafood	0	−3.36***	−3.28**	0.33
	(0.07)	(0.52)	(1.43)	
Fruits	−0.79***	−2.17	−3.93	0.39
	(0.15)	(1.82)	(2.65)	
Meat	−0.02	−1.36***	0.12	−0.01
	(0.09)	(0.45)	(1.05)	
Milk, cheese, and eggs	−0.08	−0.48	−1	0.1
	(0.06)	(0.29)	(1.37)	
Mineral waters, soft drinks, fruit and vegetable juices	0.11	−1.75***	−2.8***	0.28
	(0.08)	(0.43)	(0.94)	
Non-alcoholic beverages	0.17***	−2.33***	−2.16***	0.21
	(0.07)	(0.51)	(0.82)	
Oils and fats	−0.24***	−0.48	−1.42	0.14
	(0.06)	(0.63)	(2.29)	
Processed food	−0.02	−1.1***	−1.25*	0.12
	(0.04)	(0.24)	(0.66)	
Seasonal food	−0.54**	−3.46***	−3.29*	0.33
	(0.22)	(0.97)	(1.9)	

Table 5 (continued)

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
Spirits	−0.01	−1.57***	−0.79	0.08
	(0.05)	(0.31)	(0.86)	
Sugar, jam, honey, chocolate, and confectionery	−0.06	0.07	−0.57	0.06
	(0.07)	(0.42)	(1.23)	
Vegetables	−0.06	−4.79***	−2.16	0.21
	(0.15)	(1.6)	(2.67)	
Wine	−0.06	−1.21***	−1.63**	0.16
	(0.37)	(0.38)	(0.7)	
Other food products	−0.15***	−2.1***	−2.37**	0.24
	(0.06)	(0.37)	(1.1)	

The DID estimates are computed using the Eurostat (2022) HICP consumer price data from January 2014 to December 2015, with Switzerland as the treated unit and 33 European countries as a control group. The treatment time (Swiss franc appreciation) is in January 2015, so that the pre-treatment period is from January to December 2014 and post-treatment from January to December 2015. Standard DID estimates are computed with Eq. 3 using a GDP-weighted control group, and synthetic DID estimates with the Arkhangelsky et al. (2021) method. Pre-trend difference is the difference in slope between two pre-treatment linear regressions for Europe and Switzerland (Eq. 1) which should be zero under the pre-trend assumption. The 1-year pass-through is implied from the synthetic DID estimates and is computed using Eq. 4. $p^{*}<0.1$; $p^{**}<0.05$; $p^{***}<0.01$

Table 6 Estimates of the exchange rate pass-through to consumer prices for Household Products

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
All-items HICP	0.01	−1.64***	−1.23**	0.12
	(0.04)	(0.26)	(0.48)	
Actual rentals for housing	0.15***	−2.18***	−0.5	0.05
	(0.02)	(0.68)	(1.25)	
Books	0.38	−8.25***	−4.97***	0.49
	(0.24)	(0.17)	(1.84)	
Clothing	−0.84	4.99**	2.42	−0.24
	(0.72)	(2.46)	(2.06)	
Electrical appliances for personal care	−0.02	−2.89***	−3.21***	0.32
	(0.1)	(0.57)	(0.65)	
Equipment for sport	−0.26**	−1.53***	−2.57**	0.25
	(0.12)	(0.07)	(1.28)	
Footwear	−0.89	2.61	0.56	−0.06
	(0.7)	(3.16)	(2.08)	
Household equipment	0.12*	−2.93***	−2.07***	0.21
	(0.06)	(0.66)	(0.62)	
Furniture and furnishings	0.12	−4.61***	−3.18***	0.32
	(0.13)	(1.02)	(0.86)	
Games, toys and hobbies	−0.09	−1.76***	−2.13**	0.21
	(0.08)	(0.34)	(0.97)	
Gardens, plants and flowers	0.09	−1.45**	−1.09	0.11
	(0.1)	(0.6)	(1.09)	

Table 6 (continued)

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
Garments	−0.91	5.87**	3.13	−0.31
	(0.76)	(2.64)	(1.97)	
Glassware, tableware and	0.09	−0.76	−0.81	0.08
	(0.06)	(0.53)	(0.82)	
Goods and services for routine	−0.14**	−0.72*	−1.04*	0.1
	(0.06)	(0.41)	(0.58)	
Household appliances	0.47***	−4.08**	−2.84***	0.28
	(0.08)	(1.61)	(0.84)	
Household textiles	−0.02	−2.54***	−2.36**	0.23
	(0.09)	(0.29)	(1.05)	
Major household appliances	0.45***	−3.87**	−3.36***	0.33
	(0.09)	(1.63)	(0.85)	
Non-durable household goods	−0.23***	−0.41	−1.25	0.12
	(0.08)	(0.49)	(0.95)	
Other personal effects	−0.03	−1.62***	−1.99*	0.2
	(0.08)	(0.44)	(1.13)	
Other recreational items	0.04	−1.47***	−1.46*	0.14
	(0.06)	(0.31)	(0.75)	
Personal care	0.04	−2.48***	−1.94***	0.19
	(0.05)	(0.24)	(0.54)	
Pets and related products and services	0.21***	−1.18*	0.5	−0.05
	(0.07)	(0.61)	(0.4)	
Pharmaceutical products	0.19***	−2.39***	−0.11	0.01
	(0.05)	(0.46)	(0.83)	
Spare parts and accessories for personal transport equipment	0.03	−3.5***	−3.61***	0.36
	(0.03)	(0.77)	(0.91)	
Telephone and telefax equipment	0.4**	−5.82***	0.13	−0.01
	(0.18)	(1.88)	(2.77)	
Stationery	0.12	−3.6***	−1.61	0.16
	(0.09)	(0.32)	(1.28)	
Tobacco	0.01	−1.99***	−0.96	0.1
	(0.03)	(0.75)	(1.32)	
Tools and equipment for house and garden	0.06	−1.17***	−1.9***	0.19
	(0.08)	(0.44)	(0.66)	

The DID estimates are computed using the Eurostat (2022) HICP consumer price data from January 2014 to December 2015, with Switzerland as the treated unit and 33 European countries as a control group. The treatment time (Swiss franc appreciation) is in January 2015, so that the pre-treatment period is from January to December 2014 and post-treatment from January to December 2015. Standard DID estimates are computed with Eq. 3 using a GDP-weighted control group, and synthetic DID estimates with the Arkhangelsky et al. (2021) method. Pre-trend difference is the difference in slope between two pre-treatment linear regressions for Europe and Switzerland (Eq. 1) which should be zero under the pre-trend assumption. The 1-year pass-through is implied from the synthetic DID estimates and is computed using Eq. 4. $*p < 0.1; **p < 0.05; ***p < 0.01$

Table 7 Estimates of the exchange rate pass-through to consumer prices for Services

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
All-items HICP	0.01	−1.64***	−1.23**	0.12
	(0.04)	(0.26)	(0.48)	
Services (overall index)	0.11**	−2.05***	−1.02	0.1
	(0.05)	(0.54)	(0.64)	
Accommodation services	1.28***	−5.89**	−1.53	0.15
	(0.32)	(2.54)	(1.19)	
Audio–visual equipment repair	0.12*	−5.13***	−4.92***	0.49
	(0.06)	(1.9)	(1.36)	
Cleaning, repair, and hire of clothing	0	−1.07***	−0.29	0.03
	(0.02)	(0.4)	(0.6)	
Communications	−0.08**	−0.06	−1.36	0.13
	(0.04)	(0.38)	(1)	
Cultural services	0.08***	−2.92***	−1.25	0.12
	(0.01)	(0.5)	(0.86)	
Education	0.18***	−2.04*	−0.17	0.02
	(0.03)	(1.15)	(0.38)	
Health	0.13***	−1.36***	−0.32	0.03
	(0.02)	(0.17)	(0.8)	
Maintenance and repair of the dwelling	0.07**	−1.6***	−0.15	0.02
	(0.03)	(0.51)	(0.4)	
Package holidays	0.43	−10.17***	−6.94**	0.69
	(0.61)	(3.16)	(3.41)	
Passenger transport by air	0	−4.15	−4.93	0.49
	(1.22)	(7.36)	(7.2)	
Recreational and cultural services	0.05***	−1.65***	−0.29	0.03
	(0.01)	(0.47)	(0.98)	
Restaurants and hotels	0.35***	−3.08***	−1.5*	0.15
	(0.05)	(0.21)	(0.81)	
Restaurants and café	0.13***	−2.41***	−0.77	0.08
	(0)	(0.56)	(0.53)	
Services related to housing	0.11***	−2.33***	−0.46	0.05
	(0.01)	(0.6)	(0.56)	
Services related to holidays and accommodation	0.77*	−7.94***	−3.31	0.33
	(0.4)	(2.34)	(2.65)	
Services related to recreation and personal care	0.11***	−2.15***	−0.57	0.06
	(0.01)	(0.5)	(0.46)	
Services related to transport	−0.03	−1.14	−0.78	0.08
	(0.19)	(1.28)	(1.36)	
Telephone and telefax services	−0.1***	0.96**	−0.99	0.1
	(0.04)	(0.38)	(1.39)	
Transport insurance	0.18***	−4.5***	−0.19	0.02
	(0.01)	(0.87)	(1.03)	
Miscellaneous services	0.05***	−1.4***	−0.73*	0.07
	(0.01)	(0.41)	(0.41)	

The DID estimates are computed using the Eurostat (2022) HICP consumer price data from January 2014 to December 2015, with Switzerland as the treated unit and 33 European countries as a control group. The treatment time (Swiss franc appreciation) is in January 2015, so that the pre-treatment period is from January to December 2014 and post-treatment from January to December 2015. Standard DID estimates are computed with Eq. 3 using a GDP-weighted control group, and synthetic DID estimates with the Arkhangelsky et al. (2021) method. Pre-trend difference is the difference in slope between two pre-treatment linear regressions for Europe and Switzerland (Eq. 1) which should be zero under the pre-trend assumption. The 1-year pass-through is implied from the synthetic DID estimates and is computed using Eq. 4. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table 8 Estimates of the exchange rate pass-through to consumer prices for Industrial and Other Goods

Product category	Pre-trend difference	Standard DID estimate	Synthetic DID estimate	Implied pass-through
All-items HICP	0.01	−1.64***	−1.23**	0.12
	(0.04)	(0.26)	(0.48)	
Industrial goods (overall index)	−0.05	−2.22***	−2.02***	0.2
	(0.11)	(0.79)	(0.69)	
Durable industrial goods	0.1***	−4.48***	−3.62***	0.36
	(0.04)	(0.99)	(0.68)	
Semi-durable industrial goods	−0.47	1.18	−0.67	0.07
	(0.4)	(1.31)	(1.49)	
Audio–visual equipment	0.12*	−5.13***	−4.92***	0.49
	(0.06)	(1.9)	(1.36)	
Carpets and other floor coverings	0.14*	0.75	0.96	−0.1
	(0.08)	(0.5)	(0.95)	
Electricity, fuels, and heat energy	−0.15**	1.15***	−0.82	0.08
	(0.08)	(0.37)	(1.25)	
Energy	0.05	−3.64	−3.88**	0.39
	(0.21)	(2.63)	(1.8)	
Transport fuels and lubricants	−0.15	−4.57	−4.03*	0.4
	(0.37)	(3.47)	(2.34)	
Information processing equipment	−0.18**	−1.54	−1.38	0.14
	(0.09)	(1.87)	(2.03)	
Liquid fuels	0.51	−7.18	−5.13*	0.51
	(0.6)	(8.97)	(2.77)	
Maintenance and repair materials	0.25***	−1.38***	0.32	−0.03
	(0.07)	(0.16)	(0.53)	
Motorcycles and bicycles	−0.06	−6.64***	−7.29***	0.72
	(0.05)	(0.58)	(1.27)	
Operation of transport equipment	−0.05	−3.33**	−2.65*	0.26
	(0.2)	(1.68)	(1.48)	
Purchase of vehicles	0.08***	−4.87***	−4.68***	0.46
	(0.01)	(0.89)	(0.78)	
Recreation and culture	0.13	−4.06***	−2.54***	0.25
	(0.15)	(0.71)	(0.92)	
Solid fuels	0.39*	−6.58***	−8.01***	0.80
	(0.21)	(1.55)	(1.02)	
Miscellaneous goods and services	−0.12***	−0.82**	−0.89**	0.09
	(0.02)	(0.34)	(0.37)	

The DID estimates are computed using the Eurostat (2022) HICP consumer price data from January 2014 to December 2015, with Switzerland as the treated unit and 33 European countries as a control group. The treatment time (Swiss franc appreciation) is in January 2015, so that the pre-treatment period is from January to December 2014 and post-treatment from January to December 2015. Standard DID estimates are computed with Eq. 3 using a GDP-weighted control group, and synthetic DID estimates with the Arkhangelsky et al. (2021) method. Pre-trend difference is the difference in slope between two pre-treatment linear regressions for Europe and Switzerland (eq. 1) which should be zero under the pre-trend assumption. The 1-year pass-through is implied from the synthetic DID estimates and is computed using Eq. 4. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$

Abbreviations

SNB: Swiss National Bank; ECB: European Central Bank; BLS: Bureau of Labor Statistics; HICP: Harmonized index of consumer prices; CPI: Consumer price index; EUR: Euro; CHF: Swiss franc; COICOP: Classification of individual consumption according to purpose; GDP: Gross domestic product; DID: Difference-in-differences; OLS: Ordinary least squares; VAR: Vector autoregression; HAC: Heteroskedasticity and autocorrelation consistent.

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Intern in Monetary Policy Analysis, Swiss National Bank. Part of the work on this paper was carried out while the author was a student at the University of Lausanne and at the University of Cambridge. The views, opinions, findings, and conclusions or recommendations expressed in this paper are strictly those of the author. They do not necessarily reflect the views of the Swiss National Bank. The Swiss National Bank takes no responsibility for any errors or omissions in, or for the correctness of, the information contained in this paper.

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Availability of data and materials
The HICP dataset of prices in Europe and in Switzerland is available in the Eurostat (2022) repository, https://ec.europa.eu/eurostat/databrowser/product/view/PRC_HICP_MIDX. The BLS international tradability data is available in Johnson (2017) (table A-1). The EUR-invoicing shares data is available in Auer et al. (2021) (online appendix table B.5). The EUR/CHF data are available from the SNB (2022) data portal, https://data.snb.ch/en/topics/ziredev/cube/devkum. The SFSO import shares data and the replication codes are available on the author's repository, https://github.com/AlexOktay/ERPT-Switzerland.

Declarations

Competing Interests
The author declares that he has no competing interests.

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