Endogenous Product Adjustment and Exchange Rate Pass-Through∗

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Abstract

We document how product quality responds to exchange rate movements and quantify the extent to which these quality changes affect the aggregate pass-through into export prices. We analyze the substantial sudden appreciation of the Swiss franc post-removal of the 1.20-CHF-per-euro lower bound in 2015 using transaction-level export data representing a large share of total exports. We find that firms upgrade product quality after the appreciation. Furthermore, they disproportionately remove lower-quality products from product ranges. This quality upgrading and quality sorting effect accounts for approximately one-third and one-tenth of total pass-through one year after the appreciation, respectively. We cross-check our results with the microdata underlying the Swiss export price index, which includes an adjustment factor for quality based on firms’ reported product replacements, and obtain similar results.

JEL classification: E3, E31, E50, F41

Keywords: large exchange rate shocks, exchange rate pass-through, quality adjustment.

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1 Introduction

Understanding the impact of exchange rate changes on the prices of exports and imports is a key question in international macroeconomics. Pass-through into the prices of internationally traded goods is usually found to be incomplete in the aggregate (see Burstein and Gopinath, 2013, for a survey). The margin of adjustment is that firms adjust prices by less than the exchange rate because of, for example, nominal rigidities in the invoicing currency, adjustment in markups, local distribution costs, or, in the case of pass-through into export prices, imported intermediate inputs.¹

Another possible margin of adjustment, which is less intensively documented, is that firms change the products that they sell abroad, in addition to adjusting prices.² Adjusting products means that firms can change the quality of an existing product or adjust the set of products on the market toward products with higher or lower levels of quality. In this paper, we study how the product quality of exported goods in a small, open economy responds to an exchange rate shock and the extent to which this adjustment accounts for exchange rate pass-through.

The exchange rate shock that we study is the large, sudden, and unexpected appreciation of the Swiss franc on January 15, 2015, shown in Figure 1. This appreciation was observed after the Swiss National Bank (SNB) removed the lower bound on the CHF against the euro, which it had maintained since its introduction on September 6, 2011. This episode is well suited for studying the effects of an exchange rate shock on a small open economy because it occurred after a period with very stable prices and an exchange rate that hardly fluctuated for more than three years before the shock.³ Additionally, other macroeconomic aggregates, such as GDP growth, unemployment, and interest rates, were very stable in Switzerland during this

¹See, for example, Engle (2002), Burstein, Neves, and Rebelo (2003), Atkeson and Burstein (2008), Gopinath and Itskhoki (2010), and Amiti, Itskhoki, and Konings (2014, 2019).
²For example, after the substantial appreciation of the Swiss franc in January 2015, the Swiss National Bank (SNB) conducted a survey of exporting firms to learn about their strategies to counter the negative effects of the exchange rate shock. The surveyed firms reported optimizing the mix of products as one of their main strategies for remaining competitive (SNB, 2015).
³See also Kaufmann and Rennik (2017, 2019), Bonadio, Fischer, and Sauré (2020), Auer, Burstein, and Lein (2021) and Auer, Burstein, Erhardt, and Lein (2019), who studied the effect of this exchange rate shock on prices. Funk and Kaufmann (2020) showed the implications for wage adjustments in the aftermath of this exchange rate shock and the associated negative inflation rates.
three-year period such that changes in prices or product quality adjustments are unlikely to be a result of the lagged effects of other large aggregate shocks. Furthermore, the decision to remove the exchange rate lower bound was triggered by external developments in the euro area (expectations of quantitative easing), not by developments in the domestic economy.

Figure 1: CHF/EUR exchange rate and 2015 CHF appreciation

Notes: This figure shows the CHF/EUR exchange rate from January 2011 to December 2016. The dashed line indicates the day of the removal of the lower bound on the CHF against the euro on January 15, 2015.

Using transaction-level export data from the Swiss Federal Customs Agency (FCA), covering a large share of all exports from Switzerland, we study how the quality of exported products responds to the exchange rate shock. We focus on exports for two main reasons. First, we do so because the CHF appreciation affected all products from exporters in Switzerland, while it only affected the products exported to Switzerland for foreign exporters (which are Swiss imports). Arguably, a foreign exporter that exports only a small share of total production to Switzerland would not adjust product quality to the CHF appreciation since the bilateral exchange rates of other currencies are not affected by the CHF shock, while a foreign exporter
for which Switzerland is the main export market may choose to adjust product quality. Since we cannot observe whether imports come from a firm exporting mainly to Switzerland or a firm exporting only a small share of production to Switzerland, we do not focus on imports into Switzerland here. Second, the focus on exports allows us to exclude potential changes in demand for quality in Switzerland induced by the appreciation, for example, through non-homothetic preferences. We examine two margins of quality adjustments. First, products can upgrade (downgrade) in quality. Second, the distribution of products within a product category can sort toward products with higher (lower) quality; thus, products with low (high) quality tend to exit disproportionately. We find that both quality adjustment margins are important and that Swiss exporting firms, which became less competitive abroad following the currency appreciation, tended to improve the quality of their products (quality upgrading) and to remove products from the market that had relatively low quality within their product category (quality sorting).

We further decompose exchange rate pass-through (ERPT) into price and product quality adjustment. For most export prices used in studies quantifying ERPT, prices are adjusted for quality. Thus, if product quality endogenously responds to the exchange rate, quality changes impact estimates of ERPT through the quality adjustment term. We document how large this effect is, and we find that quality upgrading accounts for approximately one-third of the overall pass-through one year after the exchange rate shock. Using a counterfactual analysis, we furthermore show that another 7% of pass-through is accounted for by quality sorting because products with low quality are more likely to exit the market. The remainder is due to changes in quality-adjusted prices.

Our results are robust to several aggregation approaches, and we cross-validate the results using the microdata underlying the Swiss export price index (EPI) from the Swiss Federal

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4We conduct a similar analysis for imports that we report and describe in Appendix A. We find that on average quality of imported products improves, suggesting that higher-quality exporting firms tend to import higher quality intermediate inputs, consistent with, e.g., Bas and Strauss-Kahn (2015), Kugler and Verhoogen (2012), or Hallak and Sivadasan (2013). Our findings are also consistent with higher demand for high-quality imports following the appreciation, which made higher quality imports relatively cheaper for Swiss households, in line with models of nonhomothetic preferences, such as, e.g., Fieler (2011) and Auer, Chaney, and Saure (2018).
Statistical Office (SFSO). In these data, export prices are collected via surveys, and exporting firms are asked to indicate when the quality of their products changes. In this case, firms are asked about the current and, importantly, the last-period price of the product with quality changes. This approach allows the statistical office to include corrections for quality changes in its official EPI. Since our purpose is to study the effect of these quality changes on pass-through, we exploit this variation between prices adjusted for quality and prices not adjusted for quality to quantify the effect of quality adjustments on pass-through into quality-adjusted prices. We find effects in the same direction and similar magnitude: quality adjustment accounts for approximately one-third of the overall pass-through in this dataset one year after the appreciation.

Our paper is related to the literature focusing on the role of quality in ERPT. One strand of this literature relates pass-through at the product level to product quality. For example, Chen and Juvenal (2016) show that higher-quality goods face lower demand elasticity in the export market and therefore that exporters can pass through a larger share of an exchange rate change into prices. Another strand of this literature endogenously relates the quality of traded products to exchange rates. For example, Auer and Chaney (2009) show theoretically that exports should shift toward higher quality after an exchange rate appreciation and find some weak evidence for that prediction in US data. Fauceglia, Plaschnick, and Maurer (2017) and Fauceglia (2020) show for the same period we study that Swiss exporters have tended to export higher quality on average after the appreciation. Our findings that average product quality improves after the exchange rate appreciation are consistent with these studies. We contribute to this literature by documenting that product quality endogenously responds to an exchange rate appreciation, suggesting that firms adjust their product scope, and we quantify the effect of these quality adjustments on aggregate ERPT by asking how much of the aggregate pass-through is due to adjustment of prices of existing products, and how much is due to the quality changes.

Related predictions can be derived from Atkeson and Burstein (2008), Melitz and Ottaviano (2008), Mayer, Melitz, and Ottaviano (2014), Berman, Martin, and Mayer (2012), Bernini and Tomas (2015), Auer, Chaney, and Saure (2018), Bastos, Silva, and Verhoogen (2018), Medina (2020), or Chen and Juvenal (2020). Some of these studies also relate pass-through to destination-country income via nonhomothetic preferences.

An endogenous response of quality to an exchange rate appreciation is also consistent with Medina (2020).
One recent paper examines the endogenous response of product quality and its implications for pass-through: Goetz and Rodnyansky (2021) show that an online apparel retailer in Russia offered lower quality in its domestic market after the 2014 depreciation of the ruble. They show that the retailer imported fewer high-quality products after the devaluation relative to low-quality products due to a quality sorting effect, accounting for approximately 12% of aggregate pass-through. We show that their results also carry over to the case of a large appreciation, exported products, and a broad set of product categories. Furthermore, we decompose the aggregate ERPT into a price adjustment component and the effect of product quality upgrading, in addition to the effect of quality sorting. In particular, our results suggest that the contribution of product upgrading to ERPT is economically important while we find a similar effect of quality sorting as Goetz and Rodnyansky (2021).

Our results are also related to the literature emphasizing important differences between quality-adjusted and quality-unadjusted trade prices: Feenstra and Romalis (2014) show that much of the variation in export unit values is explained by quality. Nakamura and Steinsson (2012) show that product replacement bias, which is related to product upgrading and sorting, is large and that pass-through estimates are significantly larger when accounting for such bias. We show that the quality-adjustment term is responsive to changes in the exchange rate, particularly in the medium run, therefore confirming that using quality-adjusted prices or unit values is important not only for cross-country comparisons but also when studying ERPT.

This paper is structured as follows. In Section 2, we describe the two datasets and outline their complementary features. Section 3 explains the quality estimation and provides evidence on quality upgrading and quality sorting. Section 4 assesses the aggregate effects on ERPT.
while Section 5 cross-validates our results in the alternative dataset. Section 6 concludes.

2 Data

This section describes our datasets and presents descriptive statistics. Our main analysis is based on transaction-level trade data from the FCA. These data include quantities and unit values of the universe of trade flows and therefore allow us to distinguish product adjustments due to quality sorting from those due to quality up-/downgrading. We show that quality adjustments are also more prevalent after the exchange rate shock in the microdata underlying the official Swiss EPI provided by the SFSO.

The data from the Swiss FCA comprise the universe of export transactions registered at the Swiss customs office. Each transaction includes the free on board (FOB) value in Swiss francs and volume of the transaction, a Harmonized System 8-digit product classification (HS8), in which the first 6 digits define the international product group (HS6), and the last two digits are Switzerland-specific product categories; and a 3-digit statistical key specific to the FCA dataset that further divides the HS8 classification. In addition, it includes the date of transaction, the zip code of the exporting firm and the country of destination. Since the data do not contain a unique firm identifier, we follow Bonadio, Fischer, and Sauré (2020) and define product identifiers using the combination of zip code, 8-digit product classification, statistical key, and destination country.

We restrict our data to exports to countries within the euro area and omit transactions that report either no value or no information on volume. We restrict to the euro area because the Swiss franc’s floor was defined in terms of the EUR/CHF exchange rate, and the appreciation against the euro was thus very sharp and persistent. We were provided with data from

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8In total, we can observe 98.7% of total trade. See also Egger and Lassmann (2015) and Bonadio, Fischer, and Sauré (2020) for applications and descriptions of the dataset.

9Even tough some products contain information on units in addition to mass, we consistently rely on the mass measure to ensure comparability across products. We exclude observations that omit information on mass from the analysis (0.15% of transactions).

10Since exporting firms are likely to export a single product to more than one destination country, we also present robustness checks for product identifications based on zip code, 8-digit product classification, and statistical key combinations only. The results are robust; see Appendix B.
2014 to 2016. The data are not at the same level of detail in earlier years, which is why we start our analysis in 2014. As in Auer, Burstein, and Lein (2021), we move all of the dates backward by 14 days such that the shock originally occurring on January 15, 2015, in our data occurred on January 1, 2015. We do so to ensure that 2015Q1 includes all data after the shock to the EUR/CHF. In this dataset, we refer to the price $p$ of a product $i$ in a transaction by constructing FOB unit values ($value/volume$).\footnote{This definition has been used frequently in the trade literature, including, for example, Berman, Martin, and Mayer (2012), Khandelwal, Schott, and Wei (2013), Chen and Juvenal (2016) or Manova and Yu (2017).} Because we must compare products over time, we cannot conduct our analysis at a very high (daily) frequency, since most products are not exported on a daily or weekly basis. We therefore aggregate the product-level data to a quarterly frequency by summing over all transactions. Hence, we compute quarterly unit values as total values over total volume per product $i$ in a given quarter, $p_{i,q} = \sum_k value_{i}/\sum_k volume_{i}$, which is the weighted average of underlying prices across transactions $k$ observed within that quarter $q$.

Our second data source, which we use to cross-check the key patterns in the data, is the microdata underlying the Swiss producer price index (PPI) collected by the SFSO. This index includes a sub-index that comprises only exports, which is labeled the Swiss EPI. We use the data from January 2012 onward.\footnote{The EPI data are available from 2011 onward; however, as noted also in Kaufmann and Renkin (2019), there is some unusual volatility in some price series, which seem to be related to difficulties in collecting prices in the first year after launching the export price survey.} The data are collected using firm surveys (either online or via regular mail). Firms list their main products and associated selling prices and complete a separate form for exports such that export prices for a product can differ from prices in the domestic market. In the survey, firms are asked to indicate when they replace a product on the market with a new product. If firms indicate that the new product is similar to the old one but with different quality (for example, a new version of the old product), the new price is adjusted for quality by asking firms to indicate the last-period price of the new product since two product lines usually co-exist for some months before the new product completely replaces the old product (see also SFSO (2016)).\footnote{If the new product is almost identical and of similar quality to the old, no product adjustment is recorded in the index construction. If the new product is not directly comparable to the old product, the price series of the old product is terminated, and a new series for the new product is initiated SFSO (2016).} In this case, the price series
of the old and new products are combined, where the price information in the overlapping period serves as a quantification of the change in price that is due to a change in quality. Because prices refer to the first days of the survey month, the data recorded in January do not include the shock period, which is why we move all of the dates one month backward such that 2015Q1 includes prices from the post-shock period.\footnote{\textsuperscript{14}}

We chose the FCA data for the main analysis because they have the advantage that we can observe quantities per transaction, allowing us, as we describe below, to estimate quality and to distinguish quality upgrading from quality sorting. Furthermore, it includes the universe of transactions registered and is therefore very comprehensive.\footnote{\textsuperscript{15}} The disadvantage is that prices must be proxied by unit values and that the detailed data are available only from 2014 onwards, limiting the possibility to conduct a pretrend analysis. These disadvantages are not present in the SFSO data, which includes prices, not unit values, and is available from 2012 onwards, thus allowing for a pretrend analysis.\footnote{\textsuperscript{16}} The SFSO dataset also allows us to observe quality changes as indicated by firms themselves; thus, this information is not inferred from an econometric estimation and thus not driven by assumptions underlying these estimates. However, we cannot use the SFSO dataset to observe quality sorting because a product exit is typically not recorded directly in the month when the product exits. If a firm does not complete the survey, the standard procedure is that the SFSO carries forward the price from the previous survey and, after at least three months of non-response, takes action to determine whether the product no longer exists. These carry-forward prices are not flagged. Thus, a product exit is often recorded later than it actually happened. We therefore use the SFSO data as a cross-check of our main findings and to check for robustness regarding unit values vs. prices, as well as estimated vs. firm-indicated quality changes.

\footnote{\textsuperscript{14}The SFSO data are published monthly, therefore, we first aggregate the microdata also at a monthly frequency. However, most of the products in the EPI are surveyed only on a quarterly basis \cite{SFSO2016}, which is why we report pass-through rates at a quarterly frequency.}

\footnote{\textsuperscript{15}The information on quality sorting in the EPI is limited because it does not include the universe of exported products, as the FCA data do. It is therefore difficult to tell whether products are no longer traded, or firms do not respond to the survey.}

\footnote{\textsuperscript{16}From 2012 to 2014, the exchange rate was very stable. Therefore, we should expect that no pretrends exist.}
In Panel A of Table 1, we report the number of products, product groups (as defined by the combination of 8-digit product code and statistical key), and quarterly observations for the FCA data. Overall, we observe approximately half a million products from more than 7,000 8-digit product groups. The number of observations is close to one million. The number of products and observations rises somewhat over time. The corresponding data for the SFSO survey are reported in Panel B. Since this is a representative sample of export products, we observe a much smaller number of products (between 2,574 and 3,710) from between 708 and 941 distinct firms, yielding between 27,450 and 33,320 monthly observations per year.

### Table 1: Descriptive statistics

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of products</td>
<td>489,526</td>
<td>514,670</td>
<td>528,784</td>
</tr>
<tr>
<td>Number of product classes</td>
<td>7,653</td>
<td>7,362</td>
<td>7,376</td>
</tr>
<tr>
<td>Number of observations</td>
<td>938,634</td>
<td>984,107</td>
<td>1,004,971</td>
</tr>
<tr>
<td></td>
<td>2014</td>
<td>2015</td>
<td>2016</td>
</tr>
<tr>
<td>Number of products</td>
<td>2,574</td>
<td>3,710</td>
<td>2,800</td>
</tr>
<tr>
<td>Number of firms</td>
<td>708</td>
<td>941</td>
<td>812</td>
</tr>
<tr>
<td>Number of observations</td>
<td>27,450</td>
<td>33,320</td>
<td>31,009</td>
</tr>
</tbody>
</table>

*Notes:* The upper panel reports the transaction-level data from the FCA. The lower panel reports the microdata underlying the Swiss EPI collected by the SFSO.

3 Product changes

In this section, we describe how we estimate product quality in the FCA dataset and how we adjust prices for quality. We further show how we distinguish between quality upgrading and quality sorting.
3.1 Estimation of product quality

In this subsection, we describe how we derive our quality estimate. Following Khandelwal, Schott, and Wei (2013), we assume that consumer preferences incorporate quality. Under the assumption of a constant elasticity of substitution, when comparing two products in the same industry classification with the same price in the same period with different quality levels, the higher-quality product should be demanded in larger quantities. With the observations of prices and quantities at the product level, we can therefore infer the level of quality. Similar to Khandelwal, Schott, and Wei (2013), Martin and Mejean (2014) and Manova and Yu (2017), we estimate quality per product on annual data because seasonal factors can influence our quarterly estimates, and quality adjusts more slowly than prices.\footnote{Moreover, Martin and Mejean (2014) argue that focusing on yearly quality changes limits the potential bias induced by unstable preferences.}

The quality for each product-year observation can be estimated from the OLS regression

$$v_{i,y} + \sigma p_{i,y} = \alpha_{d,y} + \alpha_j + \epsilon_{i,y},$$

where $y$ is the year, $v_{i,y}$ is the yearly log volume of product $i$, $p_{i,y}$ is the associated log price, $\alpha_{d,y}$ is a destination-year dummy that controls for differences in destination country demand, and the HS6 product group (denoted by $j$, where $i \in j$) fixed effect $\alpha_j$ is included because levels of prices and quantities might not be comparable across product categories.\footnote{To perform a quality comparison, the products must be comparable in terms of quantities consumed and utility provided. Similar to Martin and Mejean (2014), we use the HS6 product classification as the basis for the quality comparison instead of HS8. HS6 is the most detailed level based on the international HS system, and digits 7-8 of the HS system refer to the customs regime and are not related to product characteristics but are informative of the exporting firm.}

Moreover, we follow Manova and Yu (2017) and assume a demand elasticity of $\sigma = 5$. We then derive our estimate of log quality $\hat{\lambda}_{i,y}$ as the regression residual $\epsilon_{i,y}$ scaled by the demand elasticity

$$\hat{\lambda}_{i,y} = \frac{\epsilon_{i,y}}{\sigma - 1}.$$

We use this quality estimate $\hat{\lambda}_{i,y}$ to construct the quality-adjusted price for each product $i$ and each quarter $q$ as $p_{i,q}^{adj} = p_{i,q} - \hat{\lambda}_{i,y}$ (where $q \in y$).

\footnote{Moreover, Martin and Mejean (2014) argue that focusing on yearly quality changes limits the potential bias induced by unstable preferences.}
3.2 Product upgrading

We first examine in a simple descriptive analysis whether existing products tend to be upgraded on average after the exchange rate appreciation. To do so, we regress the change in the quality estimate \( \hat{\lambda}_{iy} \) from one year \( y - 1 \) to the next on a constant and product group-destination fixed effects \( \alpha_{jd} \),

\[
\hat{\lambda}_{i,y} - \hat{\lambda}_{i,y-1} = \beta + \alpha_{jd} + \epsilon_{i,y}.
\]

The key parameter that we report is \( \beta \) since it indicates, within product group-destination country cells, the extent to which the quality of products that existed in 2014 (before the appreciation) rose in 2015 (after the appreciation). We also compare it to differences in quality between 2015 and 2016 to examine whether we find a difference for the period where the exchange rate does not change much.

Table 2: Evidence for quality upgrading

<table>
<thead>
<tr>
<th></th>
<th>( \Delta ) quality 2015 vs 2014</th>
<th>( \Delta ) quality 2016 vs 2014</th>
<th>( \Delta ) quality 2016 vs 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.02***</td>
<td>0.03***</td>
<td>0.00</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
<td></td>
</tr>
<tr>
<td>HS6/destination FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.06</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>No. of observations</td>
<td>253,007</td>
<td>228,769</td>
<td>262,136</td>
</tr>
</tbody>
</table>

Notes: Standard errors in brackets, clustered at HS-8 product level; *** \( p < 0.001 \), ** \( p < 0.01 \) and * \( p < 0.05 \).

Table 2 shows the results. Quality changes are positive between 2014 and 2015 on average, suggesting that quality largely improved after the exchange rate shock. Furthermore, quality upgrades between 2014 and 2015 (where the exchange rate appreciated by 12.3%) are significant and on average approximately ten times larger than the insignificant small increase between 2015 and 2016 (where the exchange rate depreciated only slightly by +2.5%). The difference between 2014 and 2016 shows that the effect is persistent (the appreciation of the exchange rate was 10.1% between 2014 and 2016). We thus conclude that, on average, firms tend to upgrade their products. Whether this upgrade is large or small in economic terms cannot be
evaluated from this simple statistic. We evaluate the role of quality upgrading in aggregate ERPT in Section 4.

A robustness check with an alternative quality measure based on Martin and Mejean (2014), described and reported in Appendix C, also shows an increase in the average quality of exports. We further show in Appendix D that exports to destination countries with a higher GDP per capita tend to upgrade quality more than exports to destination countries with a lower GDP per capita, consistent with models of nonhomothetic preferences. In addition, in Appendix I.1 we report the estimates of changes in quality by sector. We observe positive quality changes in the largest export sectors, often characterized by a large proportion of differentiated products.

3.3 Product sorting

To evaluate whether exporters tend to sort their product scope toward products with higher quality, we first show in Appendix E that a positive correlation between quality and revenue exists, suggesting that firms follow quality sorting strategies (Manova and Yu, 2017). In line with the notion of quality sorting, we then test whether high-quality products are less likely to exit the export market after the exchange rate shock, while low-quality products are more likely to exit. To do so, we aggregate the data yearly, and we run the following regression

\[ I_y^D (D = 1) = \beta_0 + \beta_1 X_{i}^{2014} + \alpha_j + \epsilon_i, \]

where \( I_y^D (D = 1) \) is a dummy that is equal to 1 if a product is not exported in year \( y \in 2015, 2016 \) but was exported in 2014. Depending on the specification, \( X_{i}^{2014} \) is the quality estimate \( \hat{\lambda}_{i,2014} \), the price \( p_{i,2014} \), or the quality-adjusted price \( p_{i,2014}^{adj} \) before the appreciation. We run these three specifications for each set of dummies \{2015, 2016\}. \( \alpha_j \) is the HS6 product group dummy. Standard errors are clustered at the zip-code level.

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19 Similar effects are found for quality sorting described in the next section.
20 We do not include product entries in our analysis since product sorting largely concerns dropping products from a firm’s product line and because, by definition, we have no price for the preshock period for products that enter after the shock.
21 We construct the corresponding yearly price \( p_{i,y} = \sum_k value_{i} / \sum_k volume_{i} \), where \( k \in y \).
Table 3: Relationship between quality and exits

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>-0.04***</td>
<td>-0.04***</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>-0.01***</td>
<td>-0.01***</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quality-adjusted price</td>
<td></td>
<td></td>
<td>0.23***</td>
<td>0.22***</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

HS-6 productgroup FE | Yes | Yes | Yes | Yes | Yes | Yes |
$R^2$ | 0.08 | 0.08 | 0.07 | 0.07 | 0.16 | 0.15 |
No. of observations | 489,263 | 489,263 | 489,263 | 489,263 | 489,263 | 489,263 |

Notes: Constant not shown. The first (second) column in each dependent variable corresponds to exited in 2015 (2016). Clustered at the zip-code level; *** p<0.001, ** p<0.01 and * p<0.05.

Table 3 shows that low-quality products are more likely to cease being exported in 2015 and 2016 (columns 1 and 2, respectively). Furthermore, we find that the same applies for products with a higher quality-unadjusted price (columns 3 and 4). High quality-adjusted prices, however, are more likely to be dropped (columns 5 and 6), in line with the notion that products with high quality-adjusted prices are less competitive.

4 Aggregate effects on pass-through

In this section, we estimate the contribution of product adjustments to aggregate ERPT. In particular, we show how quality-unadjusted prices evolve and compare them to prices adjusted for quality (showing the effect of quality upgrading on ERPT) and how prices would have evolved had products with lower quality not been dropped from the set of exported products (showing the effect of quality sorting on ERPT).

4.1 Counterfactual with no quality sorting

To examine the effect of quality sorting on pass-through, we ask how prices would have evolved without quality sorting. To do so, we extrapolate transactions that occurred in 2014 but not
in 2015/2016 to create a counterfactual series of products that no longer existed in 2015 and 2016. We construct these transactions under the assumption that prices had evolved with the median price for other products in the same product group, while we assume that the quality of these products remained unchanged. We calculate counterfactual prices for these products in three steps.

First, since a product can be exported in multiple quarters within a year, we calculate the log-change for each quarterly observation of product $i$’s (quality-unadjusted) price in quarter $q$ of year $y$ and the weighted average price across all quarters in year $y + 1$, \[ \Delta \bar{p}_{iq,y+1} = \sum_{k=Q1}^{Q4} \omega_{ik,y+1} p_{ik,y+1} - p_{iq,y} \], where $\omega_{ik,y+1}$ is the share of exports of product $i$ in quarter $k$ in total exports of product $i$ in year $y + 1$. These products indexed by $i$ comprise all products that do not exit in 2015 or 2016.

Second, we calculate the weighted average price change across quarters within a product $i$, \[ \Delta \tilde{p}_{i,y+1} = \sum_{q=Q1}^{Q4} \omega_{iq,y} \Delta \bar{p}_{iq,y+1} \], where $\omega_{iq,y}$ is the fraction of exports in quarter $q$ in all exports of product $i$ in year $y$.

Third, we use the median yearly price change within an HS6 product group $j$ (\( \Delta \tilde{p}_{j,y}^{MED} \)) to approximate the price change between $y$ and $y + 1$ for products that were observed before the shock but exited thereafter. Hence, we impute the price in year $y + 1$ for each exiting product in each quarter that it was exported in year $y$ as \( \hat{p}_{iq,y+1} = p_{iq,y} + \Delta \tilde{p}_{j,y}^{MED} \). To derive the quality-adjusted price for imputed exports, we assume constant quality and use the quality estimate from the previous year: \( \hat{p}_{adj,q,y+1}^{\text{adj}} = \hat{p}_{iq,y+1} - \hat{\lambda}_{i,y} \). We repeat this procedure for 2016 including the imputed values of 2015.

4.2 Pass-through estimation

In this subsection, we report estimates of ERPT and the contributions of quality sorting and quality upgrading to it. To do so, we report pass-through estimates for three (counterfactual) series of export prices. The first is pass-through into prices adjusted for quality, including imputed prices for products that exited in 2015 or 2016 as described in subsection 4.1.
series provides a counterfactual pass-through that controls for the effect of quality upgrading and quality sorting. We therefore label pass-through this the ERPT in a scenario with “no upgrading, no sorting” (scenario 1). Why do we label this series “no upgrading”, when prices are adjusted for quality? Consider a (quality-unadjusted) price of a product that is unchanged after the exchange rate shock. Pass-through into this price would be zero. However, consider this product improved in quality, therefore the quality-adjusted price goes down and pass through is not zero. We regard the quality-adjusted price as the one that controls for this quality upgrading, therefore the effect of the quality change is taken out of the data, therefore it is labelled “no upgrading”. In our analysis below, we compare the differences between two (counterfactual) series. If we compare a series for prices unadjusted for quality and one for prices adjusted for quality, the difference between the two will quantify the effect of quality upgrading on prices and pass-through.

Second, we report pass-through into prices not adjusted for quality, including the counterfactual prices of products that were dropped from the set of exported goods. This series gives us the pass-through into prices that include effects of quality upgrading but not include the effects of quality sorting. We label this scenario “with upgrading, no sorting” (scenario 2).

Third, pass-through into prices that are unadjusted for quality and where product exits are, as in reality, not included in the data. This series is that of observed prices not adjusted for quality. We label this pass-through the ERPT in a scenario with “with upgrading, with sorting” (scenario 3)\[22\]

The pass-through rate for each of the three series explained above is estimated by running the regression

\[ p_{t,q}^{scen.1,2,3} = \alpha_i + \sum_{q=2014Q1}^{2016Q4} \beta_q Q_q + \epsilon_{t,q} \]  

\[ (1) \]

\[22\]In principle, we have a fourth scenario, “no upgrading, with sorting”. Since we focus on differences between scenarios later in this section, the effect of upgrading can also be computed as the difference between the “no upgrading, with sorting” and “with upgrading, with sorting” scenarios. The results that we obtain are very similar, as we report in Appendix \[F\]. We chose the comparison using the imputed observations because it is arguably closer to the SFSO EPI data, which often impute observations before they exit, thus easier to compare. See the discussion in Section \[E\] for details.
where $p_{\text{scen.}1,2,3}^{q}$ is the (counterfactual) price series of scenario 1, 2, or 3, as explained in the paragraphs above, $\alpha_i$ are product fixed effects, and $Q_q$ is a quarterly dummy that is equal to 1 for a given quarter and zero otherwise. The quarter just before the shock, 2014Q4, is chosen as the baseline quarter. Standard errors are clustered at the zip-code level. The $\beta_q$ coefficients provide estimates for the average price difference between period $q$ and 2014Q4 (in percent).

**Figure 2: Aggregate effects on pass-through**

![Aggregate effects on pass-through](image)

*Notes:* This figure shows the regression coefficients $\beta_q$ and 95% CIs of regression (1). The series "with upgrading, with sorting" uses observed prices, the series "with upgrading, no sorting" uses observed and imputed prices, and the series "no upgrading, no sorting" includes observed and imputed quality-adjusted prices. The dashed vertical line indicates the preshock quarter 2014Q4.

Figure 2 shows the estimates of the price changes in percentages (relative to 2014Q4) of each of the three scenarios together with the percentage change in the EUR/CHF exchange rate (relative to 2014Q4). The red line plots the coefficient estimates of the $\beta$’s for each quarter for quality-adjusted prices, including imputed prices for products that exited (scenario 1, no upgrading and no sorting). Table 4 shows the associated pass-through rates in the second
row (estimates of $\beta$ divided by the first row). The first row of the table shows the difference in exchange rate between 2014Q4 and the quarter indicated in the column header.

Pass-through in the first four quarters after the shock would have been on average 66% (74% in 2016) had no products sorted out of the market and were effects of quality changes removed from the price series. If quality changes were not controlled for, but imputed prices for products that exit the market were included (scenario 2, with upgrading and no sorting), ERPT would be lower (green line in Figure 2, estimates reported in row three of Table 4). The interesting part is the difference between scenarios 1 and 2 because it quantifies the effect of quality upgrading. The pass-through would be 51%, thus 15 percentage points lower in 2015 (48% and 26 percentage points lower in 2016).

Table 4: Pass-through rates and CHF/EUR appreciation

<table>
<thead>
<tr>
<th>Scenario</th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No upgrading, no sorting</td>
<td>0.61</td>
<td>0.62</td>
<td>0.74</td>
<td>0.70</td>
<td>0.74</td>
<td>0.82</td>
<td>0.74</td>
<td>0.66</td>
</tr>
<tr>
<td>Upgrading, no sorting</td>
<td>0.49</td>
<td>0.46</td>
<td>0.53</td>
<td>0.55</td>
<td>0.60</td>
<td>0.52</td>
<td>0.43</td>
<td>0.38</td>
</tr>
<tr>
<td>Upgrading, with sorting</td>
<td>0.47</td>
<td>0.45</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.38</td>
<td>0.30</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Notes: This table shows the percentage change in the EUR/CHF in the first row, together with pass-through rate for each scenario by quarter.

If the effects of quality changes were included in prices and product sorting were also included (scenario 3, with upgrading and with sorting), the pass-through rate would be 48% in 2015 (36% in 2016). The difference between scenarios 3 and 2 thus quantifies the role of product sorting. The difference in pass-through rates is 3 percentage points in 2015 and 12 percentage points in 2016. These estimates suggest that quality sorting tends to occur sometime after the exchange rate shock, arguably because it requires more time for firms to bring new, higher-quality products to the market (quality sorting) than to adjust existing products (quality upgrading). This outcome is in line with Bonadio, Fischer, and Sauré (2020), who used daily data and reported no unusual exits around the time of the shock. Short-run pass-through estimates are thus not significantly affected by quality changes and are largely a result of price adjustments of existing products.

Considered together, the effect of both quality upgrading and quality sorting is reflected in the
difference between scenarios 1 and 3. The pass-through including both adjustment margins is 18 percentage points lower in 2015 (38 percentage points lower in 2016).

How much of the aggregate pass-through into export prices is due to price adjustment of unchanged products, due to quality upgrading and due to quality sorting? To answer this question, we decompose the total pass-through (the difference between the exchange rate change and the blue line in Figure 2) into pass-through that is due to changes in prices and pass-through that is due to quality adjustments. Since the effect of quality upgrading is shown in the difference between scenarios 1 and 2 and the effect of quality sorting in the difference between scenarios 2 and 3, we can use a simple decomposition to quantify the effect of each margin of adjustment (price adjustment, quality upgrading, quality sorting).

Denote the pass-through rates for each scenario scen = 1, 2, 3 by $\Lambda_{q}^{\text{scen}} = \beta_{q} \Delta e_{q}$, where $\Delta e_{q}$ is the log-difference of the exchange rate in quarter $q = 2015Q1,...,2016Q4$ and $2014Q4$, and $\beta_{q}$ is the average change in price $q$ quarters after the shock, estimated in equation (1). We decompose the aggregate pass-through into three components,

$$\frac{\ln(\Lambda_{q}^{\text{scen1}})}{\ln(\Lambda_{q}^{\text{scen3}})} + \frac{\ln(\Lambda_{q}^{\text{scen2}}/\Lambda_{q}^{\text{scen1}})}{\ln(\Lambda_{q}^{\text{scen2}})} + \frac{\ln(\Lambda_{q}^{\text{scen3}}/\Lambda_{q}^{\text{scen2}})}{\ln(\Lambda_{q}^{\text{scen3}})},$$

where the first term quantifies the contribution of changes in prices, the second term quantifies the contribution of quality upgrading, and the third term the contribution of quality sorting.

For example, the aggregate pass-through, which includes both price adjustments and quality adjustments after 3 quarters, is $\ln(0.50)$, as shown in the last row in Table 4. The contribution of price adjustments to aggregate pass-through is $\ln(0.74)/\ln(0.50)$, the contribution of quality upgrading is $\ln(0.53/0.74)/\ln(0.50)$, and the contribution of quality sorting is $\ln(0.50/0.53)/\ln(0.50)$.

This outcome results in the observation that, after 3 quarters, 43% of the aggregate pass-through is due to price adjustments, 48% is due to quality upgrading, and 8% is due to quality sorting.\footnote{We use values that are not rounded to compute the values in Table 5, yielding slightly different numbers. The corresponding values in Table 5 are 45%, 47% and 9%, respectively.}

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Table 5: Contribution of margins of adjustment to aggregate pass-through

<table>
<thead>
<tr>
<th></th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price adjustment</td>
<td>0.65</td>
<td>0.60</td>
<td>0.45</td>
<td>0.53</td>
<td>0.44</td>
<td>0.21</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>Quality upgrading</td>
<td>0.31</td>
<td>0.37</td>
<td>0.47</td>
<td>0.35</td>
<td>0.31</td>
<td>0.46</td>
<td>0.44</td>
<td>0.40</td>
</tr>
<tr>
<td>Quality sorting</td>
<td>0.03</td>
<td>0.03</td>
<td>0.09</td>
<td>0.12</td>
<td>0.25</td>
<td>0.33</td>
<td>0.31</td>
<td>0.31</td>
</tr>
</tbody>
</table>

Notes: This table shows the contribution of each margin explained in the text to the overall aggregate exchange rate pass-through. "Price adjustments" corresponds to series "no upgrading, no sorting", "Quality upgrading" to "with upgrading, no sorting" and "Quality sorting" to "with upgrading, with sorting".

Table 5 shows the results of this decomposition for each quarter. Of the total pass-through in 2015, 56% on average is due to pass-through into prices (adjusted for quality, including imputed prices for product exits), 37% is due to quality upgrading, and 7% is due to quality sorting. In 2016, these results are 30%, 40%, and 30%, respectively. Thus, while in the short run, adjustment of prices is the most important component of pass-through, the effect of quality adjustments becomes more important in the medium run, after around one year.

As a robustness check, we compute the same decomposition while not imputing observations for product exits. That is, in principle we have a fourth scenario, “no upgrading, with sorting”. The effect of upgrading can also be computed as the difference between a “no upgrading, with sorting” and the “with upgrading, with sorting” scenarios. The results that we obtain are very similar, as we report in Table F.2 in Appendix F.

5 Cross-validation in alternative data

In this section, we cross-check our results based on the FCA data using the microdata underlying the Swiss EPI from the SFSO. Section 2 explains the data in greater detail. Based on the information about prices and price changes of products that change quality, we construct two series: one where we adjust prices for quality, as in the official price index, and one where we do not adjust prices for quality.

Figure 3 plots the official EPI as a red line (prices are quality adjusted, comparable to the “no upgrading, no sorting” scenario). This series represents our reconstruction of the official
index based on the microdata. It shows a similar pattern to our baseline data in Figure 2 with a pass-through rate of, on average, 35% in 2015 and 48% in 2016. Table 6 reports the pass-through rates per quarter. Although with a slightly muted dynamic, largely due to the lower data collection frequency, most of the decrease in both indexes occurred during 2015.

**Figure 3: Pass-through in the export price index**

![Pass-through in the export price index](image)

*Notes: The reference period for data collection is the 1st to the 8th of a given month. For expository purposes, the indexes are shifted by one month such that January 2015 corresponds to prices collected from February 1 to 8. The ticks on the x-axis refer to the end of the quarter.*

To reconstruct a series that does not control for the effect of quality changes, we aggregate the microprice data without adjusting prices for quality. The aggregation procedure using industry-level weights is the same as for the official price index. In this series (prices not adjusted for quality, comparable to the line “with upgrading, no sorting”), prices revert almost entirely to their preshock levels by the end of 2016 (blue line in Figure 3 and last row 24Figure G.1 in Appendix G provides a comparison between our reconstruction based on the microdata and the official EPI. It does not match the official EPI exactly because we had to use more aggregate weights than the official index (we were not provided with weights per product, only per industry), and we omit the oil-related product categories 19 (Mineralölprodukte) and 6 (Erdöl and Erdgas) from the analysis to avoid confounding effects due to falling oil prices during the period under investigation. Therefore, our reconstruction only resembles the official index excl. energy, but the differences are very small.
in Table 6).

<table>
<thead>
<tr>
<th></th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality adjusted</td>
<td>0.27</td>
<td>0.35</td>
<td>0.39</td>
<td>0.38</td>
<td>0.44</td>
<td>0.51</td>
<td>0.50</td>
<td>0.46</td>
</tr>
<tr>
<td>Quality unadjusted</td>
<td>0.22</td>
<td>0.27</td>
<td>0.21</td>
<td>0.10</td>
<td>0.07</td>
<td>0.11</td>
<td>0.04</td>
<td>0.00</td>
</tr>
</tbody>
</table>

*Notes: This table shows the pass-through for both SFSO series by quarter.*

Table 7 shows the corresponding decomposition of aggregate pass-through using the same procedure as described for Table 5 above. In line with our findings in the FCA dataset, we can attribute approximately 33% (76%) of the aggregate pass-through to quality adjustments 1 (2) year(s) after the shock. In addition, in this dataset, we can observe the share of products that reports a quality change, which increase from 3.65% in 2014 to 11.54% in the two years after the appreciation. Similar to the results based on the FCA data, we observe higher long-run pass-through if we adjust prices for quality, while quality unadjusted prices revert to their preshock levels after 2 years. This finding corroborates the role of quality adjustments for aggregate ERPT obtained from the analysis of the FCA data above.

<table>
<thead>
<tr>
<th></th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price adjustment</td>
<td>0.87</td>
<td>0.80</td>
<td>0.60</td>
<td>0.42</td>
<td>0.31</td>
<td>0.31</td>
<td>0.22</td>
<td>0.13</td>
</tr>
<tr>
<td>Quality upgrading and sorting</td>
<td>0.13</td>
<td>0.20</td>
<td>0.40</td>
<td>0.58</td>
<td>0.69</td>
<td>0.69</td>
<td>0.78</td>
<td>0.87</td>
</tr>
</tbody>
</table>

*Notes: This table shows the contribution of each margin explained in the text to the overall exchange rate pass-through. "Price adjustments" corresponds to series "Quality adjusted" and "Quality upgrading and sorting" to "Quality unadjusted".*

Additionally, the SFSO data allow us to study the two series over a longer history than the FCA data. Figure H.1 in Appendix H shows that there are no pretrends during the two years with a very stable exchange rate prior to the appreciation.

6 Conclusion

The pass-through of exchange rate shocks into export prices is usually found to be incomplete. In addition to changing prices, firms have other margins for responding to exchange rate
shocks. One is by changing the quality of their products, thereby affecting pass-through into quality-adjusted prices. Another margin is to remove or add products from their product line, thereby also changing the set of products that contribute to the aggregate price index.

In this paper, we document that, one year after the surprise large appreciation of the CHF against the EUR in January 2015, approximately one-third of aggregate pass-through into Swiss export prices came from two margins of product adjustment: first, products improved quality (quality upgrading); and second, low-quality products disproportionately exited the market. The rest was due to price adjustment of existing, unchanged products.

These findings suggest that the adjustment of product scope is a margin that firms use to respond to exchange rate shocks and that estimates of pass-through are partially due to this product adjustment, rather than the adjustment of quality-unadjusted prices. Furthermore, if firms shift their sets of products toward products for which demand is less sensitive to exchange rate changes, these findings help to reconcile the observations that larger and long-lived exchange rate appreciations seemed to raise firm productivity (which is often associated with quality), at least this is an observation for Switzerland highlighted in Amstad and di Mauro (2017).

While this paper focuses on documenting the quality response after a large exchange rate shock and the contributions of these product adjustments to aggregate estimates of exchange rate pass-through, we have not shown how firms achieve the average improvement in quality in their production, for example, by substitution of higher-quality intermediate inputs. We leave this topic for future research.
References


Appendix to “Endogenous Product Adjustment and Exchange Rate Pass-Through”

A Pass-through into import and domestic prices
   A.1 FCA data
   A.2 SFSO data

B Robustness alternative product identifier

C Alternative quality measure

D Quality adjustments and destination country income

E Further evidence for quality sorting

F Pass-through estimation excluding imputed observations

G Comparison to the official export price index

H Pretrend analysis

I Export share and quality changes
A Pass-through into import and domestic prices

A.1 FCA data

In this section, we show our counterfactuals corresponding to Figure 2 for imports. Moreover, we split the imports into intermediate inputs and final goods. The overall results show similar patterns to exports. That is, we observe an improvement in quality through quality upgrading and sorting. We then decompose imports into intermediate inputs and final goods. We observe an increase in quality in imported intermediate inputs accompanying the increase in export quality. This observation confirms similar results in the literature, for example, Bas and Strauss-Kahn (2015), Kugler and Verhoogen (2012) or Hallak and Sivadasan (2013).

Moreover, the decomposition reveals larger changes in quality in imported final goods, indicating increased demand for higher-quality goods following increased purchasing power of Swiss households after the appreciation. These findings are in line with results suggesting that higher-income countries import and export higher-quality goods (Fieler 2011) and strengthen models associating willingness to pay for quality with income, e.g., Auer, Chaney, and Sauré (2018).
Figure A.1: Pass-through into import prices

(a) Total

(b) Intermediate inputs

(c) Final goods

Notes: These figures show the regression coefficients $\beta_q$ and the 95% CIs of regression 1 for imports in total and for the subgroups “intermediate inputs” and “final goods”. The series “with upgrading, with sorting” uses observed prices, the series “with upgrading, no sorting” uses observed and imputed prices, and the series “no upgrading, no sorting” includes observed and imputed quality-adjusted prices. The dashed line indicates the preshock quarter 2014Q4.

A.2 SFSO data

In this section, we show our counterfactuals corresponding to Figure 3 for the import and the domestic price index in Figure A.2. In the left panel for imports, we observe no difference between our series including and excluding quality adjustments. However, import data have the caveat that the buyer and not the producer of the product reports adjustments...
to the SFSO, potentially influencing the observed dynamics. In the right panel, we observe a similar dynamic for domestic products (products in the producer price index that are sold in the domestic market) with some quality improvements, as for exports, but in a smaller magnitude.\footnote{\textsuperscript{A1}}

**Figure A.2: Official import price index and domestic price index**

(a) Imports  
(b) Domestic

*Notes:* The reference period for data collection is the 1st to the 8th of a given month. For expository purposes, the indexes are shifted by one month such that January 2015 corresponds to prices collected from February 1 to 8. The ticks on the x-axis refer to the end of the quarter.

\footnote{\textsuperscript{A1}We exclude quality adjustments reported in January 2016 due to the revision of the index in December 2015.}
B Robustness alternative product identifier

As a robustness check, Figure B.1 shows our ERPT result if we exclude the destination country from the product definition and the quality estimation. That is, our product $i$ is defined by the combination of zip code, 8-digit product classification and statistical key, and our quality estimate is based on the residual of the regression:

$$v_{i,y} + \sigma p_{i,y} = \alpha_y + \alpha_j + \epsilon_{i,y},$$

The results reported in Figure B.1 indicate a similar role of quality upgrading and a somewhat greater ERPT into quality adjusted prices.

**Figure B.1**: Aggregate effects on pass-through: robustness product identifier

*Notes*: This figure shows the regression coefficients $\beta_q$ and the 95% CIs of regression. The series "with upgrading, with sorting" uses observed prices, the series "with upgrading, no sorting" uses observed and imputed prices, and the series "no upgrading, no sorting" includes observed and imputed quality-adjusted prices. The dashed line indicates the preshock quarter 2014Q4.
C Alternative quality measure

In this section, we use an alternative measure of quality changes. Following the approach developed by Aw and Roberts (1986) and Boorstein and Feenstra (1987) and recently outlined by Martin and Mejean (2014), we focus on consumption baskets and examine changes in market shares to measure changes in aggregate quality following the appreciation. The intuition of this approach is that the mean quality of exports increases when consumption reallocates toward expensive products that deliver more utility for the consumer.

To be consistent with Martin and Mejean (2014), we aggregate our data to yearly observations $y$ and use the HS6 definition to define a product group $j$. We do so by totaling value and volume over all of the transactions in a given year. We then measure the change in quality within a product group-destination country cell $jd$ between years as:

$$
\Delta \log \lambda_{jdy} = \sum_z (\omega^N_{zjd,y-1} - \omega^R_{zjd,y-1}) \Delta \omega^R_{zid,y}
$$

where we total across zip codes $z$, $\omega^N_{zjd,y-1}$ is the nominal market share of zip code $z$ in product group-destination country cell $jd$ in year $y - 1$, and $\omega^R_{zjd,y-1}$ is the real market share.

Under the assumption that the price and quality of a product are positively correlated, this measure is positive if demand shifted toward those zip codes that have a larger market share in nominal than in real terms ($\omega^N_{zjd,y-1} > \omega^R_{zjd,y-1}$). These exporters are particularly those with high prices (Martin and Mejean, 2014). Assuming a positive correlation between prices and quality, this finding implies that exports reallocate toward high-quality exporters between years $y$ and $y - 1$, increasing the average quality of exports.

To test for a quality increase, we regress the (yearly) change in the quality estimate $\Delta \log \lambda_{jdy}$ on a constant and destination fixed effects $\alpha_d$ to control for differences in destination countries:

$$
\Delta \log \lambda_{jdy} = \beta + \alpha_d + \epsilon_{idy},
$$

The key parameter that we report is $\beta$, which indicates the extent to which, after controlling
for destination fixed effects \( \alpha_d \), our aggregate quality measure increased for firms exporting in year \( y \) and \( y - 1 \).

**Table C.1: Destination country and quality upgrading**

<table>
<thead>
<tr>
<th></th>
<th>( \Delta \log \lambda_{jd}, 2015, 2014 )</th>
<th>( \Delta \log \lambda_{jd}, 2016, 2015 )</th>
<th>( \Delta \log \lambda_{jd}, 2016, 2014 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>0.07***</td>
<td>0.06***</td>
<td>0.06***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Destination FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No. of observations</td>
<td>30,675</td>
<td>30,707</td>
<td>28,919</td>
</tr>
</tbody>
</table>

*Notes: Standard errors in brackets, clustered at HS-6 product group; *** p<0.001, ** p<0.01 and * p<0.05*

The results in Table C.1 confirm that we observe, on average, a quality increase across destination countries. However, this approach does not allow us to derive quality-adjusted prices.
D Quality adjustments and destination country income

In this section, we show that there is a positive relationship between the extent of quality upgrading (sorting) and the export destination country’s GDP per capita (GDPPC).

For quality upgrading, we estimate the equation

\[ \Delta \lambda_{jd} = \beta_0 + \beta_j + \alpha \ln(GDP_{pcd}) + \epsilon_{jd} \]

where \( \lambda_{jd} \) is the weighted average quality change within HS6 product group-destination country cell \( jd \). \( GDP_{pcd} \) is the GDPPC from destination country \( d \) (data obtained from the World Bank World Development indicator database). We depict the estimated relationship in Figure D.1. The coefficient \( \alpha \) is estimated at 0.04 (robust standard error 0.008).

**Figure D.1:** Correlation between quality upgrading and destination country GDP per capita

*Notes:* This figure shows a binscatter with 20 bins of destination country log GDP per capita (GDPPC) and the estimated change in quality within HS6 product group destination country cell.
Similarly, for quality sorting, we estimate the equation

\[ \text{exitshare}_{jd} = \beta_0 + \beta_j + \alpha \ln(GDPpc_d) + \epsilon_{jd} \]

where \( \text{exitshare}_{jd} \) is the share of products that exit either in 2015 or in 2016 within HS6 product group-destination country cell \( jd \). We show the estimated relationship in Figure D.2. The coefficient \( \alpha \) is estimated at 0.08 (robust standard error 0.004).

**Figure D.2: Correlation between share of product exits and destination country GDP per capita**

![Graph showing correlation between share of product exits and destination country GDP per capita](image)

*Notes:* This figure shows a binscatter with 20 bins of destination country log GDP per capita (GDPPC) and the share of product exits within HS6 product group destination country cell. Exit of product in either 2015 or 2016.

We observe similar dynamics if we use the alternative quality estimates based on the methodology outlined in Appendix C. We show the estimated relationship in Figure D.3. The coefficient is estimated at 0.02 (robust standard error 0.005).
Figure D.3: Robustness: correlation between quality change and destination country GDP per capita

Notes: This figure shows a binscatter with 20 bins of destination country log GDP per capita (GDPPC) and the estimated change in quality described in the robustness analysis in Appendix C.

Because we cannot observe the destination country in the microprice data underlying the export price index from the SFSO, we cannot conduct a robustness analysis on that dataset.
Further evidence for quality sorting

To test whether Swiss exporters follow quality sorting, we first test for a positive correlation of export prices and export revenues across products within a zip code and across zip code-destination country within a product group. To do so, we run the following regression:

$$\bar{p}_{i,q} = \beta_0 + \text{revenue}_{i,q} + \alpha_{x,q} + \epsilon_{i,q}$$

where $\bar{p}_{i,q}$ are quarterly demeaned prices, $\text{revenue}_{i,q}$ are log quarterly sales, and $\alpha_{x,q}$ is either a product group-quarter fixed effect (table E.1) or a zip code-quarter fixed effect (table E.2). We cluster standard errors at the zip-code level.

Table E.1: Relationship between revenues and prices I

<table>
<thead>
<tr>
<th>(log) prices (HS8)</th>
<th>(log) prices (HS6)</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>(log) revenue</td>
<td>0.03***</td>
<td>0.03***</td>
</tr>
<tr>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.01)</td>
</tr>
<tr>
<td>Product/quarter FE</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.09</td>
<td>0.13</td>
</tr>
<tr>
<td>No. of observations</td>
<td>2,796,904</td>
<td>2,797,359</td>
</tr>
</tbody>
</table>

Notes: Constant not shown. In the first (second) column, prices are demeaned with the quarterly average across HS8 (HS6) product groups. Standard errors in brackets, clustered at the zip-code level; *** p<0.001, ** p<0.01 and * p<0.05.

Table E.1 shows a positive correlation between prices (quality) and revenues, across zip code-destination country within a product group-quarter, indicating that Swiss exporters follow quality sorting as opposed to efficiency sorting (Manova and Yu [2017]).

Across product group-destination country within a zip code-quarter, Table E.2 shows a positive correlation between prices (quality) and revenues, again is in line with Swiss exporters following quality sorting as opposed to efficiency sorting (Manova and Yu [2017]).
Table E.2: *Relationship between revenues and prices II*

<table>
<thead>
<tr>
<th></th>
<th>(log) prices (HS8)</th>
<th>(log) prices (HS6)</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>(log) revenue</td>
<td>0.02***</td>
<td>0.02***</td>
<td>0.28***</td>
</tr>
<tr>
<td></td>
<td>(0.00)</td>
<td>(0.00)</td>
<td>(0.00)</td>
</tr>
<tr>
<td>Zip code/quarter FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.09</td>
<td>0.09</td>
<td>0.26</td>
</tr>
<tr>
<td>No. of observations</td>
<td>2,803,285</td>
<td>2,803,797</td>
<td>2,923,329</td>
</tr>
</tbody>
</table>

Notes: Constant not shown. In the first (second) column, prices are demeaned with the quarterly average across HS8 (HS6) product groups. Standard errors in brackets, clustered at the zip-code level; *** $p<0.001$, ** $p<0.01$ and * $p<0.05$. 

A12
Pass-through estimation excluding imputed observations

Figure F.1 shows our ERPT decomposition excluding imputed observations and Tables F.1 and F.2 show pass-through rates and the decomposition of aggregate pass-through into margins of adjustment, respectively. The effects of quality upgrading and sorting are similar as in the main analysis.

**Table F.1: Pass-through rates: No imputed observations**

<table>
<thead>
<tr>
<th>Series</th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>No upgrading, with sorting</td>
<td>0.65</td>
<td>0.66</td>
<td>0.77</td>
<td>0.70</td>
<td>0.77</td>
<td>0.82</td>
<td>0.75</td>
<td>0.69</td>
</tr>
<tr>
<td>Upgrading, with sorting</td>
<td>0.47</td>
<td>0.45</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.38</td>
<td>0.30</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**Notes:** This table shows the pass-through for each series by quarter.
### Table F.2: Contribution of margins of adjustment: No imputed observations

<table>
<thead>
<tr>
<th></th>
<th>2015Q1</th>
<th>2015Q2</th>
<th>2015Q3</th>
<th>2015Q4</th>
<th>2016Q1</th>
<th>2016Q2</th>
<th>2016Q3</th>
<th>2016Q4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price adjustment</td>
<td>0.58</td>
<td>0.53</td>
<td>0.38</td>
<td>0.51</td>
<td>0.38</td>
<td>0.21</td>
<td>0.24</td>
<td>0.26</td>
</tr>
<tr>
<td>Quality upgrading and sorting</td>
<td>0.42</td>
<td>0.47</td>
<td>0.62</td>
<td>0.49</td>
<td>0.62</td>
<td>0.79</td>
<td>0.76</td>
<td>0.74</td>
</tr>
</tbody>
</table>

*Notes:* This table shows the contribution of each margin explained in the text to the overall aggregate exchange rate pass-through. "Price adjustments" corresponds to series “no upgrading, with sorting” and "Quality upgrading and sorting" to “with upgrading, with sorting”.

A14
G Comparison to the official export price index

As mentioned in the main text, we aggregate the micro export price data using industry weights, while the SFSO aggregates using first weights for each firm within an industry and then weights for the industry, to obtain the aggregate EPI. We were not provided with firm weights (for confidentiality reasons). Furthermore, we exclude oil-related products from our analysis to avoid potential confounding effects of the oil price change in 2014. Our reconstruction based the SFSP industry weights, weighting firms within an industry equally, shows that the deviations are relatively small: Figure G.1 shows the dynamics of the official EPI in blue and our reconstruction (quality adjusted) in red.

**Figure G.1: Export price index**

Notes: The reference period for data collection is the 1st to the 8th of a given month. For expository purposes, the indexes are shifted by one month, such that January 2015 corresponds to prices collected from February 1 to 8. The ticks on the x-axis refer to the end of the quarter. Source original index: SNB
H Pretrend analysis

Figure H.1 shows the dynamics of the EPI including quality adjustments (in blue) and excluding quality adjustments (in red) for a longer time horizon. We do not observe any pretrends prior to the appreciation, suggesting that the price and quality changes we observe are not a continuation of existing trends.

**Figure H.1: Dynamics of the export price index**

*Notes:* The reference period for data collection is the 1st to the 8th of a given month. For expository purposes, the indexes are shifted by one month, such that January 2015 corresponds to prices collected from February 1 to 8. The ticks on the x-axis refer to the end of the quarter.
I Export share and quality changes

Table I.1 shows the 20 largest HS2 sectors sorted by export share and the average change of our quality estimate ($\Delta \lambda_j$) between 2014 and (2015) 2016. We observe larger changes in the quality estimates in sectors characterized by a larger proportion of differentiated products ($\rho_j$) (eg. “Aircraft, spacecraft and parts thereof”, “Pharmaceutical products”, “Clocks and watches and parts thereof”) compared to sectors with lower shares (e.g., “Raw hides and skins (other than furskins) and leather”, “Iron and steel” or “Coffee, tea, mate and spices”). Product differentiation is based on the Rauch (1999) classification of differentiated products. Splitting the 20 largest sectors by median quality change yields a significantly different average proportion of differentiated products in sectors with larger quality change (0.84) compared to smaller quality changes (0.54, $p=0.031$ two-sided t-test).
### Table I.1: Export share and quality changes

<table>
<thead>
<tr>
<th>Sector</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmaceutical products</td>
<td>19.2</td>
<td>20.5</td>
<td>21.8</td>
<td>0.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Pearles, stones, precious metals and articles thereof; imitation jewellery; coin</td>
<td>11.8</td>
<td>11.8</td>
<td>12.8</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td>Organic chemicals</td>
<td>11.1</td>
<td>12.3</td>
<td>12.7</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>Nuclear reactors, boilers, machinery and mechanical appliances; parts thereof</td>
<td>9.4</td>
<td>10.4</td>
<td>10.3</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Raw hides and skins (other than furskins) and leather</td>
<td>7.8</td>
<td>0.1</td>
<td>0.1</td>
<td>-1.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Optical, measuring, medical (and other) instruments and apparatus</td>
<td>6.2</td>
<td>7.1</td>
<td>7.1</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Clocks and watches and parts thereof</td>
<td>5.4</td>
<td>5.4</td>
<td>4.6</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Electrical machinery and equipment; recorders and reproducers</td>
<td>5.0</td>
<td>5.3</td>
<td>5.1</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Plastics and articles thereof</td>
<td>2.9</td>
<td>3.1</td>
<td>3.0</td>
<td>0.1</td>
<td>0.5</td>
</tr>
<tr>
<td>Iron or steel articles</td>
<td>1.6</td>
<td>1.8</td>
<td>1.7</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Vehicles; other than railway or tramway rolling stock</td>
<td>1.4</td>
<td>1.6</td>
<td>1.5</td>
<td>0.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Coffee, tea, mate and spices</td>
<td>1.3</td>
<td>1.4</td>
<td>1.3</td>
<td>-0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Essential oils and resinoids; perfumery, cosmetic or toilet preparations</td>
<td>1.3</td>
<td>1.4</td>
<td>1.3</td>
<td>0.0</td>
<td>0.7</td>
</tr>
<tr>
<td>Aluminium and articles thereof</td>
<td>1.3</td>
<td>1.5</td>
<td>1.5</td>
<td>0.0</td>
<td>0.6</td>
</tr>
<tr>
<td>Chemical products n.e.c.</td>
<td>0.9</td>
<td>1.0</td>
<td>0.8</td>
<td>0.1</td>
<td>0.7</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>0.9</td>
<td>0.9</td>
<td>0.8</td>
<td>-0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>Paper and paperboard; articles of paper pulp, of paper or paperboard</td>
<td>0.8</td>
<td>0.9</td>
<td>0.7</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Tools, implements, cutlery, spoons and forks, of base metal</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Paints, varnishes and products replated to tanning, dyeing and colouring</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Aircraft, spacecraft and parts thereof</td>
<td>0.7</td>
<td>0.9</td>
<td>0.7</td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Notes:** Columns (1) to (3) denote the yearly export share of each of the largest 20 HS2 sectors. \( \Delta \lambda_j \) indicates the weighted average change of our quality estimate between 2014 and (2015) 2016. \( \rho_j \) shows the proportion of differentiated products (Rauch, 1999).