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Swiss Journal of Economics and Statistics (2025) 161:5
https://doi.org/10.1186/s41937-025-00137-6

Swiss Journal of
Economics and Statistics

RESEARCH

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Sectoral effects of exchange rate shocks: goods exports and the appreciation of the Swiss Franc in 2015

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Abstract

Using granular customs data, we construct a counterfactual of the evolution of Swiss goods exports under the premise that the minimum exchange rate policy would have been continued. We study the adjustment dynamics of aggregate and sectoral goods exports due to the exchange rate shock in January 2015 and examine potential differences between sectors. While Swiss total nominal exports drop in Swiss Franc, they increase in Euro. In real quantities, total exports remain largely unaffected indicating a high degree of resilience of the Swiss export industry. At the sectoral level, we observe a heterogeneous adjustment of exports consistent with varying degrees of supply-side adjustment flexibility.

Keywords Exchange rate shock, Goods exports, Export sectors, Synthetic control method

JEL Classification F14, F31, F41

1 Introduction

Exchange rate fluctuations are key determinants of the international and domestic propagation of macroeconomic shocks, with implications for, among others, relative prices, external imbalances, and the effectiveness of monetary policy. At the same time, exchange rate shocks are important drivers of the business cycle. Prominent examples are the abrupt and sharp depreciation of the British Pound after the Brexit referendum 2016 or the Swiss Franc (CHF) appreciation after the discontinuation of the minimum exchange rate policy by the Swiss National Bank (SNB) in 2015. More recently, exchange rate dynamics have also been discussed in connection with the protracted appreciation of the Swiss Franc during and after the COVID-19 recession or the Russian invasion of Ukraine. While economists have long been interested in the transmission of exchange rate fluctuations to economic activity, recent macroeconomic developments inducing turbulence in currency markets have renewed this interest (Auer et al., 2019, 2021; Bonadio et al., 2020; Dedola et al., 2021; Fernandes & Winters, 2021; Itskhoki & Mukhin, 2022).

In this paper we exploit the quasi-natural experimental setting of the discontinuation of the minimum exchange rate by the SNB vis-à-vis the Euro (EUR) to evaluate the sensitivity of aggregate and sectoral exports to exchange rate shocks. The SNB proclaimed and pursued a policy of an exchange rate floor of 1.2 Swiss Francs against the Euro from September 6, 2011, to January 15, 2015 (indicated by the shaded area in Fig. 1). The SNB policy shift in 2015 resulted in an unanticipated, sharp and persistent CHF appreciation. On January 15, 2015, the CHF strongly appreciated to a day low of 0.84, compared to the previous day low of 1.20 (CHF per EUR). The monthly average exchange rate fell from 1.20 in December 2014 to 1.10 in January 2015, a CHF appreciation of roughly 10 percent against the EUR. As evident through absent anticipation effects in forward-looking markets, the SNB policy shift

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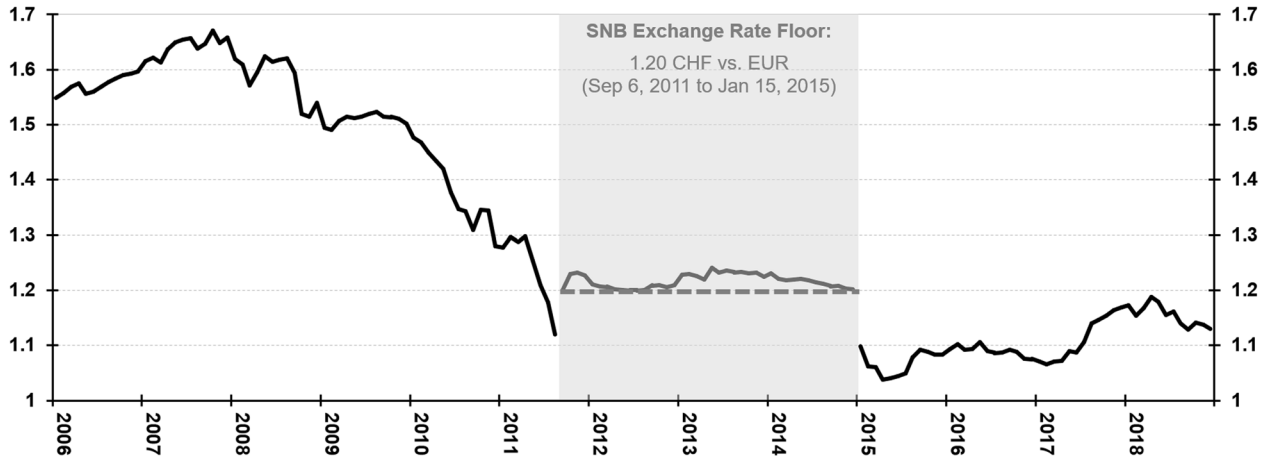

Fig. 1 Exchange rate (CHF per EUR, monthly averages). *Notes*: The figure shows the historical development of the CHF per EUR exchange rate. The shaded area indicates the period of the exchange rate floor against the EUR. Data are from the SNB

was unanticipated and surprised markets and pundits of monetary policy alike (Jermann, 2017).

We analyze the effects of the exchange rate shock on aggregate exports as well as on different categories of goods, with a particular focus on the distinction between exports in nominal values—both in domestic and foreign currency—and in real quantities. To the extent that the sectoral composition varies across countries, the reaction of total Swiss exports to the shock might be, at least to a certain extent, specific, for instance, because of the strong reliance on pharmaceutical/chemical products. And depending on, e.g., the short-run price elasticity of demand or the domestic net value added in the global value chain of the exported good, it is conceivable that the effects vary across sectors.[1]

To explore heterogeneities in the way how different industries respond to exchange rate fluctuations, we scrutinize the reaction of sectoral aggregates. For the construction of these aggregates, we exploit the rich information on the disaggregated level through administrative customs data made accessible through the United Nations International Trade Statistics Database (UN COMTRADE).

To evaluate the effects of the exchange rate shock, we employ the synthetic control method proposed by Abadie and Gardeazabal (2003), which allows us to conduct causal inference. Using trade data from a wide range of countries, we construct a counterfactual for the evolution of Swiss exports to obtain an indication for how these data would have developed if the minimum exchange rate policy had been continued. We then compare the counterfactuals with the realizations of goods exports.

Due to its nature, the shift in SNB policy in January 2015 does not only qualify as an exchange rate shock that is otherwise difficult to identify, it also represents a setting that is well suited for the application of the synthetic control method.[2] The period of SNB's minimum exchange rate floor policy is a phase with a very stable CHF per EUR exchange rate within the range of 1.24 and 1.20, facilitating the calibration of the synthetic control. Moreover, the post-event period was neither obscured by other major national or international economic shocks, nor was it followed by subsequent CHF exchange rate shocks, as visible in the stable CHF per EUR exchange rate of slightly below 1.10 between mid-2015 and the end of the sample in mid-2017. Finally, the appreciation was persistent and arguably large enough to precipitate substantial adjustment (Kaufmann & Renkin, 2017).

At the aggregate level, we observe a marked immediate effect of the exchange rate shock due to the conversion in the short run. Nominal Swiss exports in foreign currency (EUR) strongly increased due to the sudden Swiss Francs appreciation. While this pattern in the immediate aftermath of the shock is reminiscent of a J-curve type adjustment, the short-run effect of the conversion does not appear to be followed by a pronounced foreign demand adjustment in the mid-/long-run. As a result, the 2015 appreciation shock amounting to approximately 10 percent increased exports in EUR by approximately

[1] The extent to which effects vary across sectors is thus informative of the market structure firms operate in, i.e. the nature of demand firms face, and market segmentation across countries (Burstein and Gopinath, 2014).

[2] See Abadie (2021) for a detailed discussion of conditions for valid application of the synthetic control method. We elaborate on these conditions in Sect. 2 and in Sect. 5, where we examine whether these conditions hold in the context of this study.

8 percent over a horizon of 18 months. Considering the adjustment in domestic currency, we find that Swiss exports drop due to the shock by approximately 7 percent, at least in the short run. In real terms, Swiss exports remain largely unaffected, suggesting pronounced resilience of the Swiss export industry at the aggregate level. Our results imply that Swiss producers pass on part of the appreciation induced price increases with an almost perfect pass-through in the first months after shocks, and part of the exchange rate shock is attenuated by lowering sales prices after approximately one quarter.

Considering the adjustment at the sectoral level reveals that different drivers behind resilience and adjustment channels are active. Across sectors, the effects of the exchange rate shock are distinctly heterogeneous and dependent on the nature of goods. The *chemicals/pharmaceuticals* sector, which is by far the most important sector in Switzerland, is the main driving force behind the aggregate response. Due to the appreciation, nominal exports in foreign currency (EUR) gradually rose, with an increase amounting to about 9 percent on average over a one-year horizon, a similar order of magnitude as the size of the exchange rate shock. Looking at export prices we observe a swift and almost complete pass-through in foreign currency as the exchange rate shock sets in. However, the Swiss *chemicals/pharmaceuticals* sector reduced sales prices in domestic and foreign currency over the following months, so that aggregate exports in real quantities were virtually not affected by the exchange rate shock. Our results can be rationalized with high profit margins allowing for flexibility in the supply-side adjustment vis-à-vis the exchange rate shock. Exporters in this sector are relatively concentrated, tend to have higher margins, are more import-intensive, and are less financially constrained relative to other sectors. As a result, the *chemicals/pharmaceuticals* sector was able to significantly reduce prices in domestic currency (CHF) shortly after the shock had set in to counteract the increase in foreign currency (EUR) and thus stabilize foreign demand (real export quantities). As *chemicals/pharmaceuticals* is by far the largest sector in the Swiss export industry, it also drove the response of total exports to the appreciation shock.[3]

We also scrutinize the adjustment in the *mechanical engineering* and the *precision instruments/jewelry* sectors. In these sectors, the adverse effects of the 2015 appreciation were much more pronounced with nominal exports in EUR being largely unaffected by the appreciation even though prices were reduced less compared to *chemicals/pharmaceuticals* so that export quantities dropped markedly. Exporters in these sectors are less concentrated and have lower mark-ups compared to *chemicals/pharmaceuticals*. We find supply-side adjustment in *mechanical engineering* and *precision instruments/jewelry* to be less effective such that the foreign export price decreases were smaller compared to the *chemical/pharmaceutical* sector.

Overall, our results are consistent with existing firm-level evidence suggesting the prevalence of different degrees of market power and supply-side flexibility associated with profitability and the share of intermediary goods in the production process (see, e.g., Amiti et al., 2014; Li et al., 2015; Fernandes & Winters, 2021). We generalize these arguments to the sectoral level and provide indications for their quantitative relevance on the aggregate level. In addition, our estimation of the exchange rate shock effect allows us to not only study the immediate impact, but also the subsequent dynamics to capture different phases of the pass-through to prices as well as quantity adjustments.

Our paper relates to several strands of the literature studying the effects of exchange rate fluctuations on the macro- and micro-level. Previous literature assesses the effects of exchange rate fluctuations mainly on the aggregate level (e.g., Campa & Goldberg, 2005; Forbes et al., 2018), or is geared toward tracing firm-level effects and focuses on the micro level (e.g., Amiti et al., 2014; Li et al., 2015). Our analysis combines the advantages of both, macro- and micro-level analyses, and it allows us to trace the adjustment of both aggregate nominal values and real quantities. At the same time, we can take account of sectoral adjustment heterogeneities.

Specifically, our paper adds to a large literature on the effects of exchange rate fluctuations on economic activity and prices (see Burstein & Gopinath, 2014). Several papers study the exchange rate elasticity of export quantities and exchange rate pass-through using aggregate and firm-level data, where the exchange rate is taken as given. Campa and Goldberg (2005) and Goldberg and Campa (2010) study how changes in exchange rates translate into the aggregate price level through imports of intermediate and final goods. Berman et al. (2012) analyze pricing decisions of exporters in response to real exchange rate changes using a French firm-level data set with destination specific export values and volumes. Amiti et al. (2014) uncover heterogeneities in the pass-through of exchange rate fluctuations to export prices depending on the use of imports as inputs. Li et al. (2015) scrutinize the effects of exchange rate fluctuations using a large panel of Chinese firms. A distinct literature disentangles exogenous from endogenous dynamics in

[3] This is in line with Fernandes and Winters (2021), who study the response of Portuguese exporters to the Pound Sterling depreciation in the context of the Brexit referendum.

the exchange rate, and studies how the macroeconomy reacts to exchange rate shocks (Forbes et al., 2018). The strand of literature that is most closely related to our paper traces the effects of exogenous exchange rate variations by exploiting quasi-natural experiments that were arguably unanticipated in nature and mainly transmitted through the exchange rate.[4] Fernandes and Winters (2021) study the depreciation of the British Pound following the Brexit vote on physical quantities, prices as well as entry and exit of Portuguese exports. Auer et al., (2019, 2021) scrutinize the effects of the 2015 Swiss Franc shock on exports and imports and observe that nominal export values and prices vary with the currency of invoicing of border prices. Bonadio et al. (2020) study the speed of the exchange rate pass-through to imports depending on the currency of invoicing using daily data, while Steiner (2024) investigates the impact of the exchange rate shock on mark-ups. Freitag and Lein (2023) scrutinize endogenous product quality adjustment vis-à-vis the 2015 Swiss Franc shock and document that Swiss exporter shift their supply from lower-quality to higher-quality products or advance the quality of products in response to the appreciation.

A further line of research we contribute to comprises papers that apply the synthetic control method by Abadie and Gardeazabal (2003) in macroeconomic contexts. Puzzello and Gomis-Porqueras (2018) use this method to study the effect of joining the Euro on income. Born et al. (2019) study the effects of the Brexit vote on economic activity, while Born et al. (2021) use the SCM to identify the effect of Donald Trump's first presidency on growth and job creation.

The paper is structured as follows: Sect. 2 describes the used data and employed estimation strategy. After having outlined the main results in Sect. 3 we discuss further insights on the adjustment channels in Sect. 4. In Sect. 5, we evaluate the requirements for the application of the SCM and the robustness of our results. Section 6 concludes with a summary and discusses policy implications.

2 Empirical strategy

The impact of the exchange rate shock is evaluated applying the synthetic control method by Abadie and Gardeazabal (2003), which enables causal inference in a comparative case study setup where one unit is exposed to a treatment or intervention. Using trade data from a wide range of countries, we construct a counterfactual of the evolution of Swiss exports to obtain an indication for how these data would have developed if the minimum exchange rate policy had been continued. To construct the synthetic control, we exploit the rich information on the disaggregated level through international administrative customs data.

The applied SCM is geared toward a very specific comparative case study setup, where a treatment effect for a single treated unit (or only a few treated units) is estimated. Certain contextual factors have to be fulfilled for the SCM to deliver a reliable estimation of the effect of an intervention (see, e.g., Abadie, 2021). The environment created by the minimum exchange rate regime from September 6, 2011 to January 15, 2015, constitutes a very stable period, in which no distinct changes in the exchange rate of CHF against Euro occurred (see Fig. 1). We use this exceptional period to calibrate the synthetic control that serves as a benchmark against which we compare the actual development of Swiss exports from January 2015 until July 2017, a sufficiently long period to be able to detect effects of the appreciation. Moreover, as argued above, the discontinuation of the exchange rate floor precipitated an abrupt, unanticipated and substantial appreciation. To construct a realistic trajectory in form of the synthetic control, we select a group of OECD countries and make sure that the synthetic control is a good approximation of Swiss total and sectoral exports by applying appropriate predictors. One condition that is particularly crucial, yet difficult to assure or evaluate, is that the comparison group of countries is required to be unaffected by the event. While this is generally suggested by the small size of the Swiss economy reflected in small export shares to Switzerland by these countries (see below), we take several steps to remedy the concern of potential affectedness among donor countries in Sect. 5.[5]

2.1 Data

Due to the Automated System for Customs Data (ASYCUDA), an international system to administer cross-country customs put forward by the United Nations Conference on Trade and Development (UNCTAD), cross-country trade flows are well documented. The

[4] Moreover, our paper is related to an abundance of academic and applied papers discussing aggregate or sectoral effects of the exchange rate fluctuations on Swiss exports or GDP (see Bill-Körber and Eichler, 2017; Drechsel et al., 2015; Egger et al., 2017; Erhardt et al., 2017; Fauceglia, 2020; Fauceglia et al., 2018; Flückiger et al., 2016; Kaiser et al., 2017; Kaufmann and Renkin, 2017; Siliverstovs, 2016).

[5] The condition of no interference can be enforced in the study design by discarding from the donor pool those units with outcomes possibly affected by the intervention on the treated unit. However, a potential tension between this practice and having a good comparison group emerges. On the one hand, it is advisable to select units for the donor pool that are affected by the same regional economic shocks (other than the intervention) as the unit where the intervention takes place. On the other hand, if spillover effects are substantial and affect other units (for example in close geographical proximity), those units may provide a biased estimate of the counterfactual outcome without intervention for the unit affected by the intervention.

Table 1 Sectoral export share in national currency units (FOCBS nomenclature)

Share of exports in national currency units (sample averages 2011m10–2017m7)		
Sectors	**Switzerland**	**Average of donor pool countries**
1 Forestry and agricultural products, fisheries	2.9%	10.2%
2 Energy	1.1%	10.8%
3 Textiles, clothing, shoes	1.4%	4.1%
4 Paper, articles of paper and products of the printing industry	0.9%	2.8%
5 Leather, rubber, plastics	2.0%	3.8%
6 Products of the chemical and pharmaceutical industry	38.7%	13.0%
7 Stones and earth	1.1%	3.2%
8 Metals	5.5%	11.8%
9 Machines, appliances, electronics	15.0%	20.7%
10 Vehicles	2.5%	10.8%
11 Precision instruments, clocks and watches and jewelry	21.4%	3.8%
12 Various goods	0.6%	2.3%
13 Precious metals, precious and semi-precious stones	6.0%	2.4%
14 Works of art and antiques	0.8%	0.0%

Averages of the 28 OECD countries in the donor pool are unweighted

trade data we exploit are administrative customs data provided by the United Nations International Trade Statistics Database (UN COMTRADE). UN COMTRADE is the largest depository of international trade data and gives access to harmonized data on a very granular level and at monthly frequency.

For our analyses we need to define meaningful categories of goods in order to study sectoral developments in response to the exchange rate shock. Traded goods are classified on a common basis for customs purposes. This system is referred to as the harmonized system (HS). HS is a six-digit code system at the international level covering the universe of traded goods, but there are limitations to the use of the HS system for economic analysis as it follows a legal (i.e., customs) logic. However, the HS system can be mapped into economically meaningful categories classified, e.g., through the Standard International Trade Classification (SITC) or the Broad Economic Categories (BEC).[6] In addition, the FOCBS (Swiss Federal Office for Customs and Border Security) employs a nomenclature to categorize types of goods that as well builds on HS categories. While we retrieved international trade data from UN COMTRADE (HS six-digit level), we will work with sectoral sub-aggregates comprising types of goods in the FOCBS nomenclature.

Working with the FOCBS nomenclature has the advantage that the categorization of types of goods are geared toward a more appropriate characterization of industrial sectors.[7] These sectors are sufficiently homogeneous to allow for an adequate interpretation of the effects of exchange rate fluctuations, and capture those sectors that drive value chains in Switzerland. Types of goods comprised by the FOCBS system are shown in Table 1 together with sample averages for Switzerland and unweighted averages for the 28 OECD countries in the synthetic control donor pool, for which customs data as well as implicit deflators are available for October 2011 to July 2017.[8] A further advantage of the FOCBS nomenclature is that we can exclude sectors from the analyses that potentially confound the results. We drop the three sectors *energy*, *precious metals/precious and semi-precious stones* and *works of art and antiques* from the analysis (these three sectors together amount to an average share of around 8% of total exports over the sample period 2011m10–2017m7), as they can potentially alter the results due to non-cyclical and idiosyncratic factors or because they feature breaks in the reporting procedures

[6] SITC as well as BEC are only of limited usefulness for our analysis because the categories are either too crude or too heterogeneous in terms of goods type and demand elasticities.

[7] For further details and conversion tables for mapping EZV types of goods categories into HS nomenclature see https://www.bazg.admin.ch/bazg/en/home/topics/swiss-foreign-trade-statistics/methoden-metadaten/metadaten/waren.html.

[8] The donor pool consists of AUS, AUT, BEL, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GRC, HUN, IRL, ISL, ISR, ITA, JPN, LTU, LUX, LVA, NLD, NOR, NZL, POL, PRT, SVK, SWE. Note that the USA are not included as the open economy policy measures that we use as predictors are not applicable (see Footnote 11).

and therefore also distort total or sub-total aggregates.[9] We thus only consider sectors 1 and 3–12 in the analysis.

For the estimations in Sect. 3 and the discussion in Sect. 4 we employ aggregated and disaggregated sectoral data regarding country specific trade with the rest of the world.

Regarding the selection of additional predictors in the SCM, we also include the average real effective exchange rate[10] indexed to October 2011 as an indication for international competitiveness and quantitative indicators for policy choices in open economies associated with the so-called impossible trinity. The impossible trinity postulates that monetary independence, exchange rate stability, and financial openness cannot be achieved simultaneously. Aizenman et al., (2010, 2013) provide respective measures that are normalized between 0 and 1, with higher numbers reflecting more monetary independence (MI), more exchange rate stability (ERS) or more financial openness (OPEN).[11]

2.2 Data preparation

Using international trade data in the estimation exercise to construct counterfactuals for Swiss exports on the aggregate and disaggregate level involves several data processing steps. Most importantly, trade data are very volatile and likely exhibits seasonal patterns as well as potential classification changes or reporting errors. The data we use are administrative customs data which are not pre-processed. We thus remove the seasonal and the calendar component of all series by applying the Census X-13 method developed by the U.S. Census Bureau. However, seasonally and calendar adjusted data still contain the aggregate of what time series analysis refers to as the trend component, the cycle component, and the irregular component. To remove at least some noise from the irregular component, we also apply a thorough outlier treatment.[12]

Figure 2 shows aggregate nominal export series of both Switzerland and all the donor pool countries converted in Euro (EUR, upper panel) and in national currency units (NCU, middle panel). As we index all series to the beginning of the employed time sample (October 2011), we can construct a weighted average that acts as synthetic control to evaluate the effects of the exchange rate shock in Sect. 3. The difference between the actual EUR and NCU series is solely due to the nominal conversion. However, the synthetic control indicating the counterfactual evolution represents different combinations of donor countries and therefore also takes account of potentially varying developments of nominal exports in domestic and in foreign currency. The vertical line in Fig. 2 indicates the termination of the minimum exchange rate regime and the blue lines represent Swiss exports.

In addition to export values in nominal currency units, the trade data series are converted and deflated into real export quantities (lower panel in Fig. 2). We deflate goods export values in a harmonized way using implicit deflators from the OECD Quarterly National Accounts (QNA) as goods exports are reported in nominal as well as real terms. To fully exploit the monthly frequency of the nominal export data, we apply temporal disaggregation to the obtained quarterly price deflators by using the method of Cholette (1984) to proxy monthly real export quantities.

Even though the conversion of nominal exports from EUR to domestic currency and to real export quantities is mechanical, we construct synthetic controls separately for each dimension. As a result, we allow for potential

[9] Major structural breaks are associated with the sector *precious metals/precious and semi-precious stones*, which includes currency gold since 2012 and with the sector *energy* including the part of energy trade that is carried out virtually and without physical exchange (procedures changed in 2013). See https://www.bazg.admin.ch/bazg/en/home/topics/swiss-foreign-trade-statistics/daten/gesamtexporte-und-importe.html for further details.

[10] The real effective exchange rate data are obtained from the Bank of International Settlements.

[11] Because all three national indicators are computed as relative measures in comparison with the USA, there are no data available for USA, which is why it cannot be included in the OECD donor pool of the SCM.

[12] The most frequently used seasonal adjustment methods, Census X-13 and TRAMO/SEATS, include an automated outlier detection, since outliers can affect the estimation of the seasonal and the calendar component of a time series and therefore also have an undesirable impact on the generated seasonally adjusted series. To enable a better identification of the seasonal component, the X-13 method applied here uses ARIMA models with additional regressors for automated outlier detection and removal, for calendar effect identification, and for fore- and backcasting the time series as pre-step of the actual seasonal adjustment procedure. X-13 offers the option to track additive outliers, transitory changes, level shifts, and seasonal outliers. Since the purpose of seasonal adjustment is not outlier adjustment itself, X-13 temporarily removes the outliers and by default re-imputes them in the final seasonally adjusted output series. As trade data, even more so on a granular level, is likely to contain outliers and structural breaks associated with potential reporting errors and classification adjustments, we apply the mentioned outlier removal routine to the seasonally adjusted output series. By explicitly executing the implicit outlier removal procedure of X-13, we can process the large number of country and sectoral aggregates of goods examined in this paper, without the need of potentially arbitrary user intervention to remove outliers in the data. In short, we seasonally adjust the data and then additionally apply the outlier removal routine of X-13. Our analysis comprises 1′287 export time series (aggregate and sectoral export series of Switzerland and donor countries) and we identify a total of 1′115 outliers across the 135′552 observations. Within the period of half a year before and after the 2015 appreciation, no outlier was detected for the 39 Swiss export series.

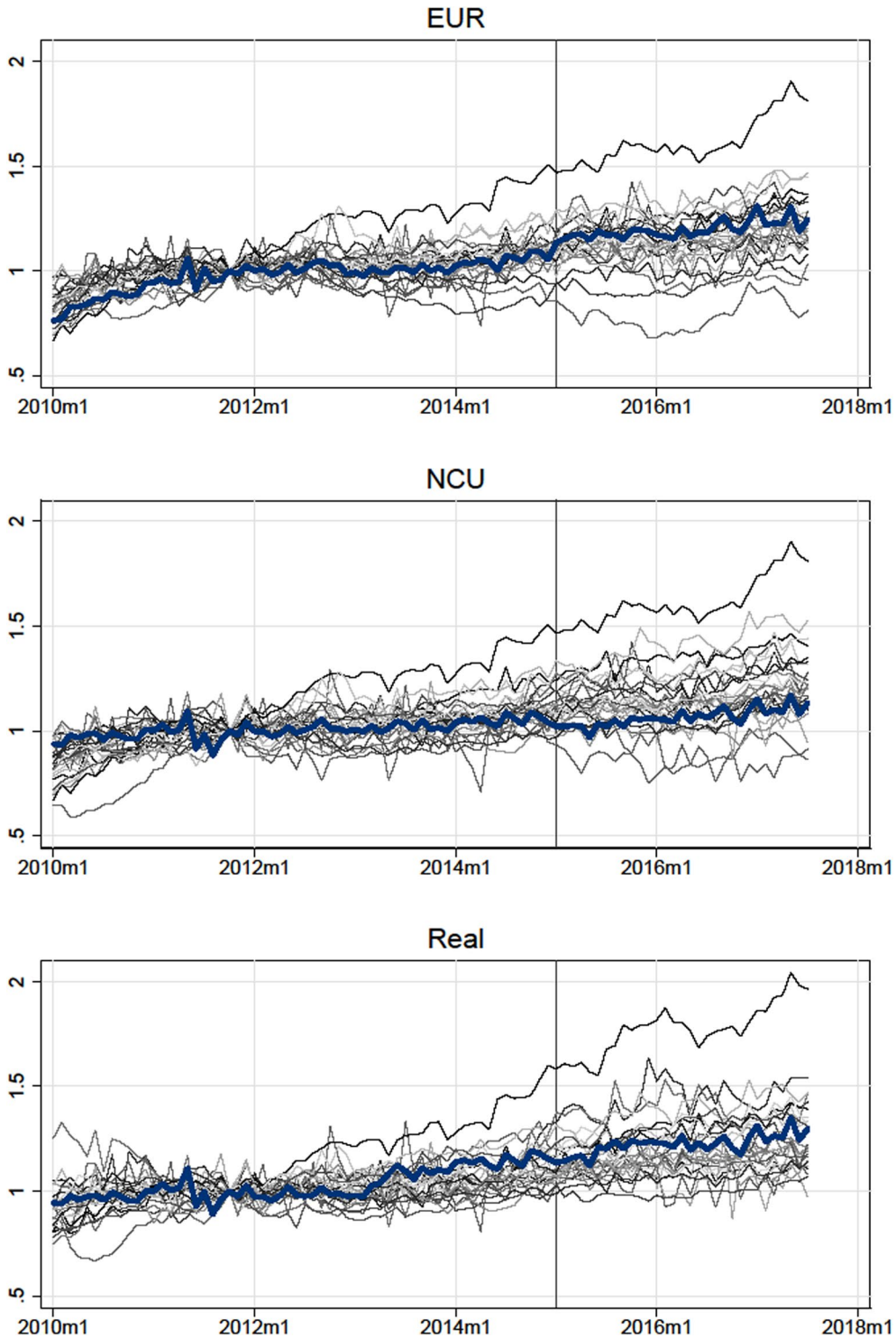

Fig. 2 Goods export series. *Notes*: The figure shows time series for Swiss exports (blue line) together with the respective series for donor countries (gray lines). Series are indexed to 1 in October 2011

heterogeneities in the effects of exchange rate fluctuations depending on economic structures such as, e.g., the sectoral composition.

2.3 Causal inference and the synthetic control method

In order to measure the impact of the termination of the exchange rate floor target, we need to define accurate

counterfactuals of Swiss sectoral exports. To construct these counterfactuals, we use the synthetic control method introduced by Abadie and Gardeazabal (2003) and Abadie et al., (2010, 2015). The counterfactuals are desired to behave just like realized Swiss exports but under the premise that the SNB exchange rate floor policy would have been continued.

Specifically, the counterfactual is a weighted average of $J = 28$ OECD countries in the donor pool. Switzerland is labeled as $j = 1$, the donor countries as $j = 2, \ldots, J+1$. The weights are determined by minimizing the distance between Swiss exports and the counterfactual over the period preceding the exchange rate shock. Formally, to construct the counterfactual the following optimization problem has to be solved: country weights, $w = (w_2, \ldots, w_{J+1})'$, minimize the mean squared error.

$$\min_{w} (\boldsymbol{x_1} - \boldsymbol{X_0 w})' \boldsymbol{V} (\boldsymbol{x_1} - \boldsymbol{X_0 w})$$

The vector x_1 denotes Swiss data and the matrix X_0 collects the respective data of the J countries in the donor pool. V is a diagonal matrix with weights $v = (v_1, \ldots, v_k)$ for the relative importance of the k included variables according to the minimization of the prediction error between treated unit and synthetic control in the pre-treatment period. The vector x_1 consists of average exports prior to the end of the minimum exchange rate floor and subperiod growth rates. Additional control variables are the average real effective exchange rate and the impossible trinity indicators (monetary independence, exchange rate stability, financial openness) provided by Aizenman et al., (2010, 2013). The optimization problem is solved separately for each dimension—nominal EUR export values, nominal NCU export values, real export quantities (nominal export values deflated)—and with data from October 2011 up to December 2014, the month before the SNB discontinued the lower bound of the exchange rate (CHF per EUR).

Given the set of country weights, w, the synthetic control estimate is.

$$\widehat{\boldsymbol{Y}}_{\boldsymbol{1t}} = \sum_{j=2}^{J+1} \boldsymbol{w_j Y_{jt}}$$

To evaluate whether the effect size of the shock, i.e., the difference between the synthetic control and the actual realization of goods exports, is significant, we construct placebo synthetic controls for each donor country. A test statistic can be obtained using the ratio of post-event fit relative to pre-event fit (Abadie, 2021; Abadie et al., 2010). Specifically, we compute pre- and post-event root mean squared prediction errors (*RMSPE*) of the difference between the export series and the synthetic control of the $J+1$ countries. For $1 \leq t_1 \leq t_2 \leq T$ and$j = 1, ..., J+1$:

$$RMSPE_j(t_1, t_2) = \left(\frac{1}{t_2 - t_1 + 1} \sum_{t=t_1}^{t_2} \left(Y_{jt} - \widehat{Y}_{1t} \right)^2 \right)^{0.5}$$

and the permutation distribution is given as.

$$\boldsymbol{r_j} = \frac{\boldsymbol{RMSPE_j(T_0, T)}}{\boldsymbol{RMSPE_j(1, T_0 - 1)}}$$

Where T_0 corresponds to the event period, i.e., January 2015.

Corresponding p-values are given by comparing r_j with the unit affected by the event, r_1, i.e., Switzerland:

$$\boldsymbol{p} = \frac{1}{J} \sum_{j=2}^{J+1} \boldsymbol{I_+}(\boldsymbol{r_j} - \boldsymbol{r_1})$$

$I_+(\cdot)$ Is an indicator function that returns one for non-negative arguments and zero otherwise. The p-value can be interpreted as the percentage of donor pool countries with placebo effects greater than the actual treatment effect observed for Switzerland.[13]

3 Results

To evaluate the effects of the 2015 exchange rate shock, we examine the deviation of the actual development of Swiss goods exports from the synthetic control. First, we consider the dynamics of aggregate goods exports to characterize the overall effects of the exchange rate shock. To scrutinize potential heterogeneities we then evaluate the adjustments at the sectoral level. Several sensitivity and robustness checks that support the results of Sects. 3.1 and 3.2 are discussed in Sect. 5, along with the country weights w derived by the SCM and respective placebo indicators used for the computation of the p-values (see Table 4). Table 5 in the Appendix shows the pre-intervention fit of the predictors for the synthetic Switzerland compared to actual Switzerland together with the predictor weightings v for the baseline estimations.

3.1 Adjustment of goods exports on the aggregate level

The solid line in Fig. 3 displays the development of Swiss total exports indexed to 1 in October 2011, the month after the minimum exchange rate regime was introduced. We also apply the same indexation to the OECD countries in the donor pool. To construct the counterfactual in order to see how Swiss exports would have developed if there had been no exchange rate shock, we employ the synthetic control method using data including December 2014, the last full month with the exchange rate floor in place. This gives us the dashed

[13] Note that a relatively large p-value can arise from a small effect size as well as from a poor pre-event fit.

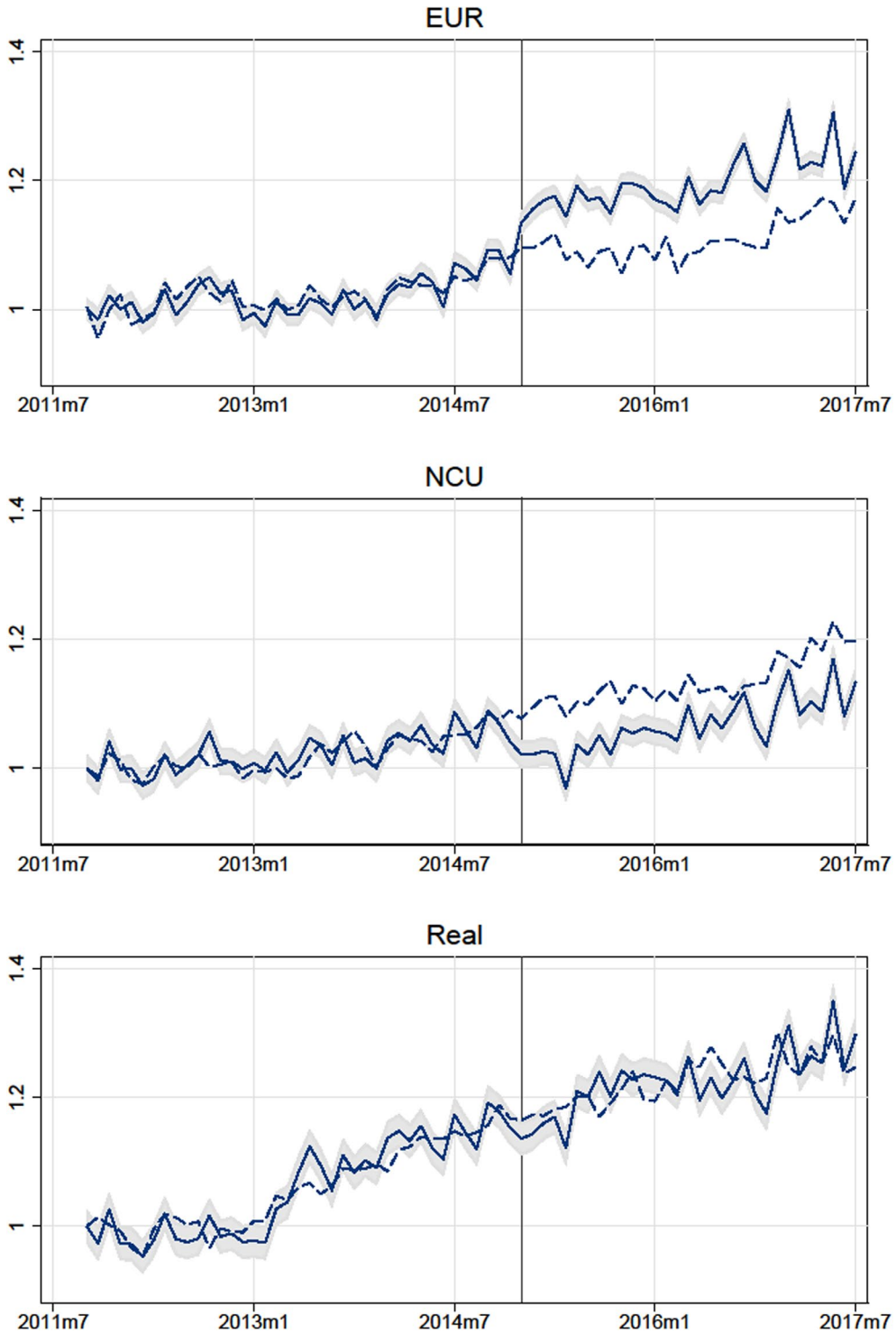

Fig. 3 Swiss exports in EUR, NCU and real quantities with counterfactual (dashed line). *Notes*: The figure shows the development of indexed Swiss exports (solid blue line) together with the synthetic control (dashed blue line). The gray bands indicate plus/minus one standard deviation of the difference between the two series before January 2015

lines in Fig. 3, where each synthetic control is estimated separately. The dashed lines serve as benchmark against which we compare realized exports. As an indication for the precision of the estimated counterfactual and as a measure for usual deviations between the two series, the gray shaded areas around the realized exports show the standard deviation of the difference between realized exports and the counterfactual in the pre-shock period. The difference between the solid and dashed lines beginning with January 2015 can be interpreted as the effect size of the exchange rate shock. The first panel shows the effects on nominal exports denominated in Euro (EUR), the second on nominal exports denominated in national currency units (NCU) and the third on exports in proxied real quantities (nominal values deflated). Comparing the actual development of total goods exports against the counterfactual, we see that the effects vary, depending on the representation of exports.

We observe that due to the exchange rate shock the value of total nominal exports in EUR increases immediately as the shock sets in and remains above the synthetic control for at least two years. This type of persistent adjustment is not in line with the so-called J-curve. While the J-curve would indeed imply an initial increase of the export value measured in foreign currency due to the appreciation and the conversion effect because of the exchange rate change (rise in EUR export value), it also implies a subsequent decrease in foreign demand in foreign currency (drop in exported quantities), which does not seem to be the case for Swiss exports after January 2015.

In contrast to the increase in exports in EUR due the appreciation, we observe that nominal exports in NCU fall short of the synthetic counterfactual immediately after the appreciation. After approximately six months, effects are less clear as the realized export series picks up compared to the synthetic control.

To see to what extent the decrease in exports in NCU can be explained by price and quantity adjustments, we also consider real values, i.e., exports in NCU deflated by OECD export price indexes, giving us an indication for quantity adjustments. Export prices in Switzerland showed marked deflationary tendencies after the Financial Crisis 2008/2009, and also decreased after the minimum exchange rate regime. Notably, it appears that as the appreciation sets in, price adjustments offset the negative appreciation effect on demand for export quantities, at least to a considerable extent. These price adjustments are discussed in more detail below. Even though realized real export quantities are slightly below the synthetic control as the shock sets in, the difference between the two series is not very large and not particularly systematic.

Table 2 shows the estimated average effect sizes of the shock for horizons of 6, 12, and 18 months (i.e., 2015m7, 2016m1, and 2016m7) together with corresponding *p*-values. The appreciation that amounted to approximately 10 percent against the EUR lead to a persistent and significant increase in exports denominated in EUR amounting to approximately 8 percent. Exports in domestic currency fell by about 7 percent, but the effect turns insignificant after one year. For real exports are very close to zero and not significant at conventional scales.

Nominal exports are the multiplicative product of export prices in the respective currency and real export quantities (and these quantities must be the same for nominal exports in both currencies). Since there is no pronounced shock effect on real export quantities detectable, the shock magnitude on nominal exports can be approximately interpreted as effects on prices in the respective currency. The result of opposite effects on nominal exports in EUR and in CHF therefore suggests that price increases due to the appreciation were both passed on with price increases in foreign currency as well as compensated through price reductions in domestic currency by similar orders of magnitude. This is consistent with an incomplete pass-through (see, e.g., Burstein & Gopinath, 2014; Auer et al., 2019; Bonadio et al., 2020). Exporters may lower prices by means of lower input prices, pricing-to-market motives and lower profit margins (see Goldberg & Campa, 2010; Fernandes & Winters, 2021; Steiner, 2024) to balance the appreciation, as we discuss in greater detail below. We next turn to sectoral heterogeneities in the adjustment to the exchange rate shock, as these factors are closely related to the nature of goods.

3.2 Adjustment of goods exports on the sectoral level

The Swiss export industry is rather concentrated in single sectors as, e.g., visible by internationally rather high values of the Herfindahl–Hirschman Index measuring sectoral concentration (Brunhart et al., 2019). Among

Table 2 Average effect size relative to 2014m12 (*p*-values in parentheses)

	Nom. Exports EUR	Nom. Exports NCU	Real Exports
$T_0 + 6$	0.07 (0.04)	−0.08 (0.04)	−0.02 (0.61)
$T_0 + 12$	0.08 (0.04)	−0.07 (0.07)	0.00 (0.61)
$T_0 + 18$	0.08 (0.07)	−0.07 (0.21)	0.00 (0.68)

The *p*-value in parentheses is the percentage of donor pool countries with placebo effects greater than the actual treatment effect observed for Switzerland

the twelve FOCBS sectors applied in this study only *chemicals/pharmaceuticals* (FOCBS sector 6 in Table 1), *mechanical engineering* (FOCBS 9) and *precision instruments/jewelry* (FOCBS 11) exhibit sectoral shares of more than ten percent, as shown in Table 1 depicting the sectoral composition of Swiss exports. The three inspected sectors amount to about 82% of the nominal exports (NCU) covered in the analysis and therefore are the main drivers of the aggregate development.

To examine potential heterogeneities in the sectoral adjustment following the exchange rate shock, we evaluate the evolution of the export activity in the three largest export sectors. We aggregate customs data in HS-six-digit nomenclature into FOCBS nomenclature. Doing so, we obtain sectors that are constructed on a harmonized basis.

Figure 4 shows the development of actual goods exports together with the synthetic control for *chemicals/pharmaceuticals*, *mechanical engineering* and *precision instruments/jewelry*. Comparing the effect size of the exchange rate shock across sectors, pronounced differences in the reaction to the shock arise.

As visible in Panel A of Fig. 4 with nominal exports in EUR, *chemicals/pharmaceuticals* show a pronounced upward shift shortly after the exchange rate shock and an increased slope compared to the counterfactual, while *mechanical engineering* and *precision instruments/jewelry* appear to be rather unresponsive. This visual inspection is supported by the *p*-values shown in Table 3. The findings on the aggregate level are mirrored by the combination of the sectoral findings and it becomes evident that *chemicals/pharmaceuticals* are the main driving force behind the positive shock impact on aggregate nominal exports in EUR (see upper panel in Fig. 3), which seems plausible given its relative importance. *Chemicals/pharmaceuticals* exhibited an increase of nominal exports in EUR due to the shock, which amounted to a similar percentage magnitude as the exchange rate appreciation itself.

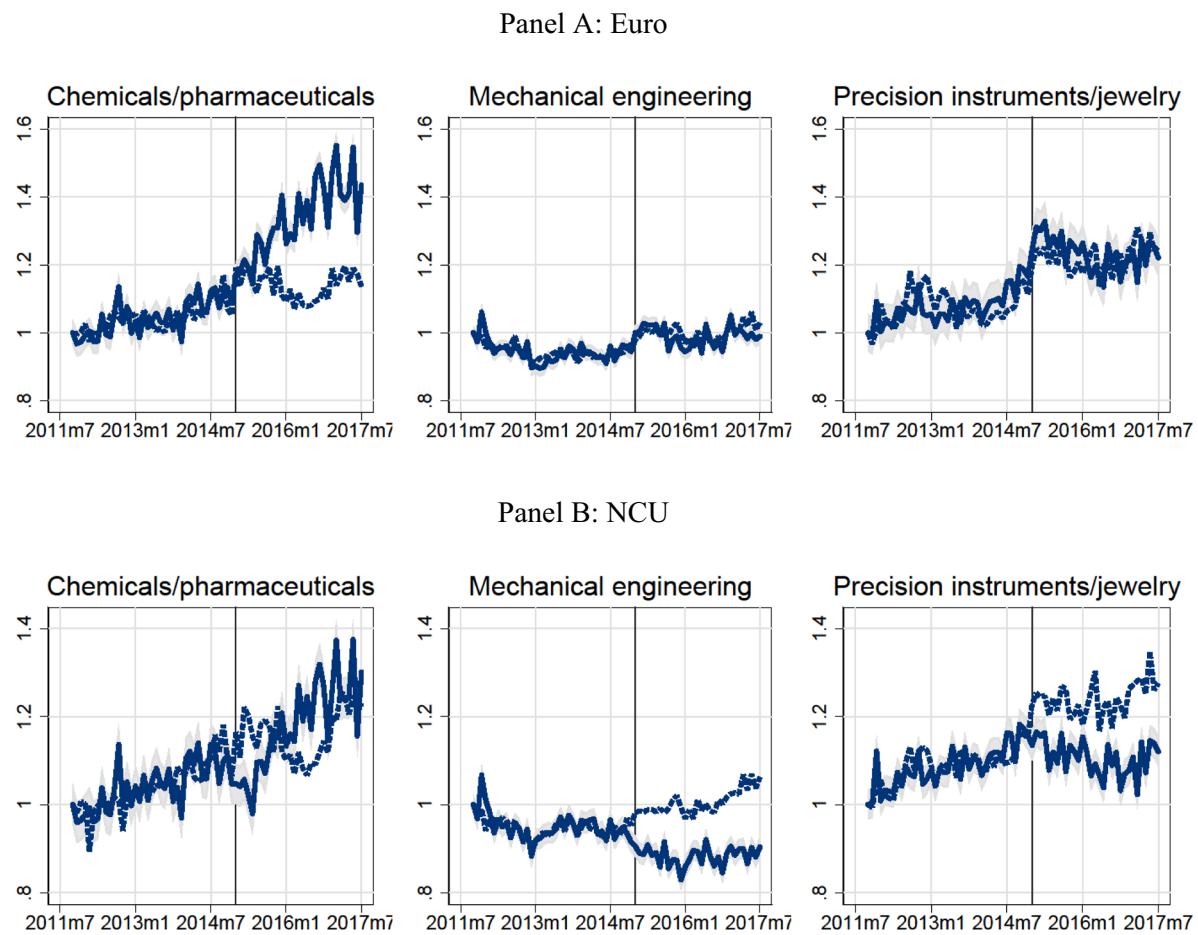

Fig. 4 Swiss sectoral exports with counterfactual (dashed line). *Notes*: See notes of Fig. 3

Table 3 Average sectoral effect sizes relative to 2014m12 (*p*-values in parentheses)

Nominal Exports EUR			
	Chemicals	**Mechanical Engineering**	**Instruments**
$T_0 + 6$	0.04 (0.25)	0.02 (0.89)	0.05 (0.75)
$T_0 + 12$	0.09 (0.04)	0.00 (0.68)	0.05 (0.71)
$T_0 + 18$	0.13 (0.00)	0.00 (0.79)	0.03 (0.86)
Nominal Exports NCU			
	Chemicals	**Mechanical Engineering**	**Instruments**
$T_0 + 6$	−0.11 (0.11)	−0.11 (0.00)	−0.09 (0.11)
$T_0 + 12$	−0.07 (0.21)	−0.12 (0.00)	−0.09 (0.18)
$T_0 + 18$	−0.01 (0.21)	−0.12 (0.00)	−0.10 (0.18)

See notes of Table 2

Following Table 3 and Panel B of Fig. 4, *mechanical engineering* and even more so *precision instruments/jewelry* face adverse effects of the exchange rate shock on nominal exports in NCU. By contrast, *chemicals/pharmaceuticals* were less affected by the shock. In fact, it appears that after one year after the initial shock the exports of this sector even surpass the synthetic control potentially indicating catch-up effects. Over the whole considered horizon, however, positive and negative shock effects seem to cancel out.

The sectoral adjustments of nominal exports in EUR and in NCU range from persistently positive effects for *chemicals/pharmaceuticals* (in EUR) to persistently negative effects in the case of *precision instruments/jewelry* and even more so for *mechanical engineering* (both in NCU). One reason could be that *chemicals/pharmaceuticals* can on the one hand pass-on prices more easily because of lower price elasticity of demand. However, as shown in more detail in Sect. 4, it is rather the case that this sector was also able to reduce prices to a larger extent compared to the other sectors.

Summing up, we find that on the sectoral level responses to exchange rate shocks are distinctly different depending on the type of exported goods. Sectors such as *precision instruments/jewelry* and even more so *mechanical engineering* with lower margins, higher shares of production costs in domestic currency, in particular labor, suffer more from exchange rate shocks (as discussed in Sect. 4), which is consistent with previous findings indicating different degrees of pricing-to-market and market power (Berman et al., 2012; Burstein & Gopinath, 2014; Devereux et al., 2017) as well as different exposure to exchange rate shocks related to the share of intermediary goods (Fernandes & Winters, 2021; Goldberg & Campa, 2010).

At the aggregate level, export price deflators are available through the OECD QNA. At the sectoral level, we cannot construct proxies for real export quantities because deflators are either not comparable because of different sector definitions, or they are simply not available. As a result, we can only execute the synthetic control method for nominal sectoral exports and cannot replicate the exercise for real sectoral export quantities. However, given the response of aggregate real exports and the sectoral nominal response in domestic currency, we can already infer that the fact that we do not observe pronounced effects of the exchange rate shock on aggregate real export quantities is driven by the *chemical/pharmaceuticals* sector rather than by *mechanical engineering* or *precision instruments/jewelry*. For the latter two sectors we can infer adverse effects on real exports given their responses of nominal exports, which are distinctly worse compared to *chemicals/pharmaceuticals*. This, in turn, implies that demand- and supply-side channels are active to different degrees across sectors.

To further understand the active channels in the respective sectors and to relate our findings to existing evidence on the adjustment of firms to exchange rate shocks, we evaluate Swiss data, in particular sectoral price and survey data, that are indicative for sectoral quantity and price adjustments in the next section.

4 Discussion

Adjustments in nominal export values can be associated with both price and quantity changes. Through conversion, an exchange rate appreciation makes domestic products more expensive abroad. However, to offset the appreciation, exporters may change prices in domestic and/or foreign currency. The extent to which the producers are willing and able to offset the immediate effect of the conversion through supply-side adjustments depends on factors such as the foreign demand's price elasticity, the supplier's market power, or the structure of the distribution chain. Additionally, a price decrease in domestic currency is associated with lower mark-ups and can be accompanied by the supplier's attempt to stabilize mark-ups by reducing costs, for example through cheaper

(imported) input goods (see, e.g., Goldberg & Campa, 2010; Devereux et al., 2017; Fernandes & Winters, 2021).[14]

Economic surveys, media coverage and press releases by exporters indicate that various channels were active after the 2015 appreciation shock. According to a SNB survey carried out in the summer of 2015 (Swiss National Bank, 2015, pp. 32–37), about 70% of the industrial firms in the industrial sector and the service sector claimed to be negatively affected (81% of the industrial firms). Almost 90% of the negatively affected Swiss companies in the whole sample suffered from lower mark-ups, about 75% reported a drop of selling prices in CHF, almost 50% lower export quantities, and about 15% a lower market share (see Tables 5 and 6). Only few reacted with an increase of selling prices in foreign currency (about 13%). On the other hand, cost reductions in domestic currency were central to compensate for price reductions in CHF values. Almost 30% reported both a decrease of their employment stock or a hiring halt, more than 50% a reduction of domestic purchasing prices (more than 30% an increase of purchases from abroad), and more than 30% responded by innovation and process optimizing. Only roughly 13% shifted business activity to abroad and only about 15% did not react at all.

In the estimations above, we so far have examined exports in nominal values as the implicit product of export quantities (Q) times prices (P) at aggregate as well as sectoral level and real exports (Q, proxied by deflated nominal values) only at the aggregate level. In contrast to total exports, the lack of price deflators for the donor pool countries at sectoral level does not permit the construction of a synthetic control. However, we can consider sectoral price indexes available for Switzerland to get an intuition of price and quantity adjustments on the sectoral level. Specifically, we use price indices P_{it} for Swiss export sectors i to residually derive the approximate evolution of the proxy for real quantities Q_{it} from the observed nominal export series $P_{it} \cdot Q_{it}$.[15]

Figure 5 displays the quarterly evolution of aggregate and sectoral exports together with the OECD real GDP as a rough indication for the economic development in the donor pool countries (monthly sectoral estimates for real exports are shown in Fig. 8). All series are indexed to December 2014, the month before the appreciation shock. While the total real exports were well aligned with the real GDP dynamics in the OECD countries, we observe a marked divergence on the sectoral level: After a short-lived decline in 2015Q1, real exports of *chemicals/pharmaceuticals* actually performed more than favorably, whereas real exports in *mechanical engineering* and *precision instruments/jewelry* fell short of OECD GDP with a widening gap over time. Since *chemicals/pharmaceuticals* represent the quantitatively most important Swiss export sector (export share of about 42% of all eleven sectors covered in the analysis, see Table 1), they were the key factor behind the total export growth in the second half of 2015 and in 2016 and behind the fact that the total real exports were hardly affected by the appreciation.[16]

To further investigate price and quantity adjustments, Fig. 6 shows the evolution of aggregate and sectoral prices P_{it} together with the exchange rate (indexed to 2014m12), while Fig. 8 additionally shows export quantities Q_{it} for the aggregate and sectoral level. It seems that the appreciation shock in January 2015 had strong effects on both prices valued in the domestic currency (CHF) and prices valued in EUR. This holds for the aggregated level as well as for all the three sectors with varying degrees of pass-through across time and sectors. We first focus on prices in a sectoral comparison (see Fig. 6), before the developments of export prices and quantities are discussed as a whole and sector-specifically (with reference to Fig. 8).

[14] Whether smaller mark-ups are bearable depends on pre-event mark-ups and the company's overall profitability and reserves. Cost reductions are usually achieved by efficiency increases, investment stops, reductions of vacancies/employment, short-time work, pay freezes, or temporary work time increase. Or they can be obtained by natural hedging through increasing the share of intermediate goods imported from a destination with foreign currency or shifting production to foreign manufacturing sites. Other possibilities are financial hedging (financial market instruments and/or delivery contracts), product portfolio adaptations or lobbying for political support for the exporting industry.

[15] Disaggregated data on sectoral export prices were provided by the Swiss Federal Office of Statistics on request of the authors, since publicly available sectoral data contain producer prices regardless of whether products are sold inside or outside of Switzerland (export prices are only published at aggregated level). Note that the sectoral NACE categories in the producer price index data are not fully consistent with the FOCBS nomenclature. In the calculations of the discussion section, for the sector *chemicals/pharmaceuticals* the NACE code Sects. 20 and 21 are applied, for *mechanical engineering* NACE Sect. 28, and for *precision instruments/jewelry* NACE Sect. 26. The applied official monthly price indexes are denoted in CHF, those product prices invoiced in foreign currency are converted to CHF before they enter the indexes. To obtain export prices in EUR, we convert prices in CHF by using the monthly exchange rate. To evaluate the estimation strategy for the sectoral export quantities, we run the test of estimating real export quantities on the total aggregated level for which real export data is available to compare. The match between the estimated Q and the actual observable Q is very satisfactory, both via eyeballing of the time series plots and the correlation coefficients between the two (0.96 for 2015m1–2017m6, 0.93 for 2010m12–2017m6). We apply $P_i Q_i$ and P_i in CHF instead of EUR to obtain the sectoral Q_i, as this perspective is more relevant for Swiss domestic exporters. Constructing aggregate Q from EUR values yields very similar results, which should be the case by identity, but is not fully achievable in the actual use of data due to data noise or due to the data transformation process of outlier treatment and seasonal adjustment.

[16] The three outlined sectors under consideration make up about 82% of the covered total exports.

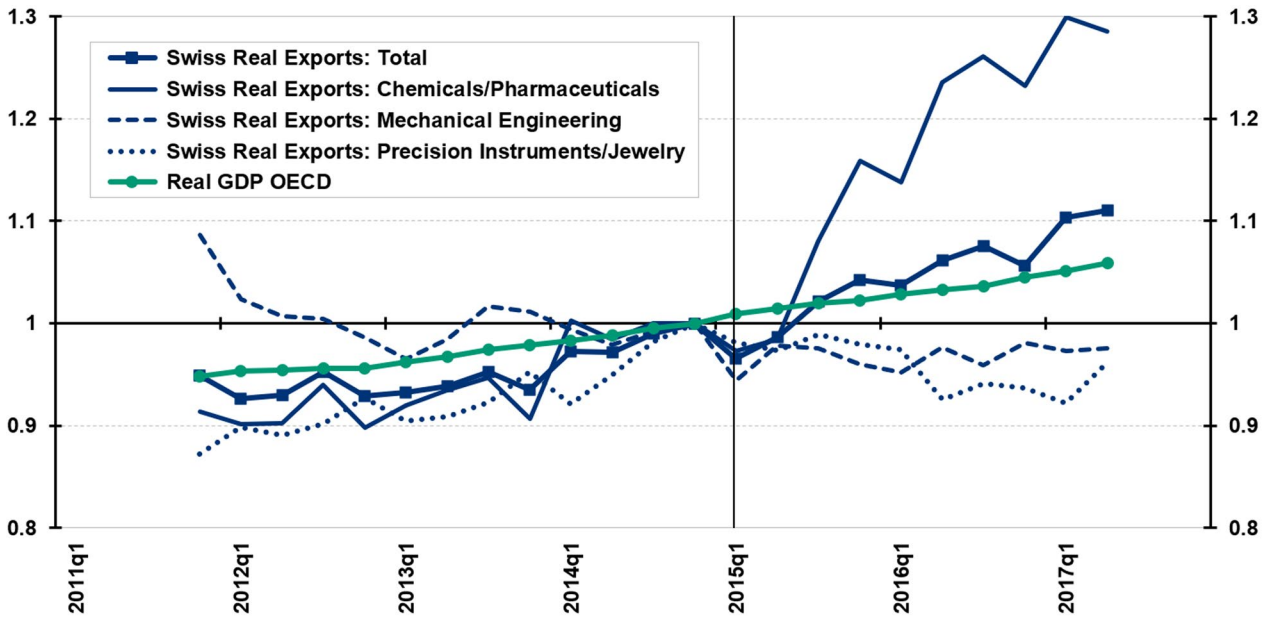

Fig. 5 Quarterly real GDP (OECD) and estimated Swiss sectoral real exports. *Notes*: Deflators are from the Swiss Federal Office of Statistics

Note that the derived price indices record all prices regardless of the invoiced currency (expressed in EUR value). Specifically, the officially published export price indices used are denominated in CHF and those prices invoiced in foreign currency are converted into CHF using the respective exchange rate in the construction of the official price indices. Thus, we consider price changes for products invoiced in domestic or foreign currency together and capture sectoral heterogeneities that are attributable to factors other than the currency of invoicing.[17]

While the sectors under consideration exhibit a synchronized price development in 2014, increasing heterogeneity can be observed in response to the exchange rate shock. As the shock sets in, we observe a synchronized, almost one-to-one effect of the exchange rate shock to prices indicating an almost perfect pass-through in the short run. From February and especially March 2015, however, the picture becomes increasingly divided: the *mechanical engineering* sector reacted very quickly with price reductions in EUR value, but then appeared to reach a floor by beginning of 2016. The *chemicals/pharmaceuticals* sector, on the other hand, initially did not adjust for more than three months, but was then able to cut prices sharply and returned to its pre-shock price levels in mid-2017. In contrast, the *precision instruments/jewelry* sector showed no further adjustment in the medium term.

To what extent can these different price developments be linked to heterogeneities in structural characteristics across the sectors? Intuitively, one might expect that a presumably low price elasticity of the demand for medical products leads to low price adjustments in the respective sector. In addition, the *chemicals/pharmaceuticals* sector is highly concentrated and dominated by few very large companies (in 2016, the five largest pharmaceutical companies had an export share of 75.2% in the *chemicals/pharmaceuticals* sector with 800 companies[18]). Thus, even though we observe a relatively complete pass-through as the shock sets in, the fact that subsequent price reductions were relatively large compared with the evolution of the exchange rate is somewhat surprising at first glance.[19]

However, it appears that profit margins and supply-side flexibility in the *chemicals/pharmaceuticals* sector are much higher compared to other sectors, so that price reductions were implemented more easily. Looking at balance sheet/income statement figures (Federal Office

[17] No strong, systematic differences in the invoicing currency can be identified between the sectors considered here (see Kaufmann and Renkin 2017, p. 84).

[18] According to statistics from the FOCBS, which publishes data on Swiss export concentration for the years since 2016.

[19] Freitag and Lein (2023) document that Swiss exporters shifted their supply from lower-quality to higher quality products or advanced the quality of products in response to the 2015 appreciation. While we cannot isolate quality changes in our analysis, they report positive quality changes in the large export sectors with no pronounced differences between the sectors that we analyze here. Thus, quality changes do not appear to explain the differences in the sectoral price indexes.

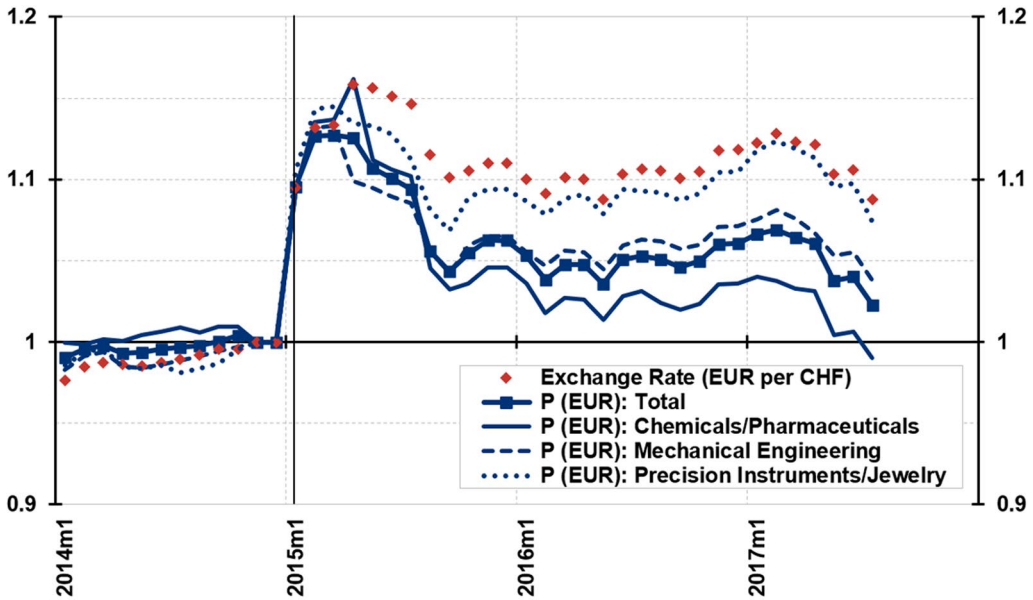

Fig. 6 Export prices (EUR) and exchange rate (EUR per CHF). *Notes*: The figure shows the total and sectoral evolution of export price indices (CHF converted to EUR)

of Statistics, 2016) of the Swiss pharmaceutical sector[20] in 2014—the year before the exchange rate shock—the average profitability (122% of equity) and the profit margins (24% of turnovers, 386′000 CHF per employee in full time equivalents) are striking. Also, just 82% were earned by sales revenues (18% by other revenues, e.g., financial), making overall profits less sensible to price reductions. Additionally, the personnel expenses played a minor role with 11% of total expenses, which is advantageous since wages are normally paid in domestic currency and cannot be as easily hedged as spending on intermediate goods or services can. These factors—large firms dominating the sector, high profitability and mark-ups—enhanced the robustness against the appreciation shock explaining the pronounced price decreases following the appreciation that contributed to the protracted rise of the real export quantities.

By contrast, the *mechanical engineering* sector was characterized by a rather weak nominal and real export development despite the benign international macroeconomic environment surrounding the sudden stop of the exchange rate floor. In this sector, the exchange rate shock is associated with a persistent drop in the CHF price level of 5% below the price level in December 2014 together with a respective increase in EUR prices. Compared to the *chemicals/pharmaceuticals* sector, prices fell to a lesser extent over the medium run. One explanation is that the general exposure was higher than in the *chemicals/pharmaceuticals* sector, since the profitability (18%) and the profit margins (6% of turnovers, 25′000 CHF per employee in full time equivalents) in 2014 were considerably lower in comparison so that lower prices were not achievable due to lower mark-ups. Furthermore, the earnings by sales revenues of 95% and the share of personnel expenses with 28% were clearly larger compared to pharmaceuticals. Moreover, unlike *chemicals/pharmaceuticals*, which are dominated by few very large pharmaceutical companies, the machinery sector is highly fragmented (in 2016, the five largest *mechanical engineering* companies had an export share of only 18.1% of the 1′813 companies in the whole sector, the largest 100 companies only 69.6%). Thus, it appears that the *mechanical engineering* sector was less able to compensate the appreciation as price reductions in CHF (and therefore in EUR selling prices abroad) were less feasible so that the exchange rate shock dragged on real export quantities. This is consistent with Fernandes and Winters (2021), who find that more productive, import-intensive and financially unconstrained exporters can decrease prices to larger extent thereby stabilizing the quantity of exports. And this explanation is also in line with Steiner (2024), who shows that following the CHF appreciation in 2015 Swiss manufacturing firms showed a very heterogenous response across their firm characteristics and

[20] Pharmaceuticals are dominant in the sector *chemicals/pharmaceuticals*: According to the Swiss national accounts 2014 (Federal Office of Statistics), the gross value added of the sub-sector "pharmaceuticals" was about four times higher than the sub-sector "manufacture of coke, chemicals and chemical products", which also consists of products other than chemicals. This is why we rely on balance sheet/income statement figures of the pharmaceuticals sub-sector.

therefore also across sectors: Large firms are more likely to have high mark-ups and reduced their mark-ups considerably. Although large firms represent a small minority compared to small firms, the response of large firms—especially among pharmaceutical companies—has driven the impact on the aggregate evolution of mark-ups, prices and export quantities due to their large export share in the respective sector.

In the *precision instruments/jewelry* sector, nominal and real exports strongly comoved, both before and after the appreciation shock, indicating only minor supply-side flexibility. The exchange rate shock almost fully transmitted into an upward shift in EUR prices, which had a negative impact on real export quantities. One explanation is that in this sector, a rather large fraction of production costs, in particular labor, are incurred in domestic currency (personnel expenses were 21% in 2014). This is also reflected in Goldberg and Campa (2010) and Fernandes and Winters (2021) who show that a large share of intermediary goods in the production is associated with lower exchange rate pass-through.

Overall, the price dynamics vary considerably across sectors and influence the aggregate partly in opposite direction. The sectoral heterogeneity in price adjustments can be linked to structural differences between the sectors. A few very large firms with large mark-ups in the *chemicals/pharmaceuticals* sector not only drove the respective sector but also the whole total of Swiss exports. After the exchange rate shock induced an initial price hike, which was sharpest in the *chemicals/pharmaceuticals* sector, export prices in EUR gradually decreased in all three sectors. The decrease was most pronounced in the *chemicals/pharmaceuticals* sector, which was feasible due to large mark-ups in that sector, whereas price decreases were limited in *mechanical engineering* and particularly in *precision instruments/jewelry*. As a result, *chemicals/pharmaceuticals* exhibit positive growth shortly after the shock, both in nominal ($P \cdot Q$) and real terms (Q). Real exports in the other sectors strongly decrease (*precision instruments/jewelry*) or stagnate below the pre-shock average (*mechanical engineering*).

These observations regarding the development of export prices and real quantities help to sharpen the interpretation of the cross-sectoral differences in SCM-results from above. Recall the nominal exports of *chemicals/pharmaceuticals* sector in domestic currency slightly fell due to the 2015 exchange rate shock, before they overshot within less than a year (see Fig. 4). The limited and short-lived negative effects appear to reflect the relatively high supply-side flexibility together with pronounced reduction in export prices in this sector. Even though we observe an almost perfect pass-through in *chemicals/pharmaceuticals* on impact, export prices in this sector fell considerably after approximately three months out, almost completely offsetting the appreciation over one year. As a result, in total over one year, exports in domestic currency were largely unaffected by the shock, and exports in EUR increased, as evident in Fig. 4. Turning to *precision instruments/jewelry* and *mechanical engineering* we observe a different pattern. Nominal exports in domestic currency decreased markedly due to the appreciation, while exports in EUR, if anything, increase only slightly as the shock sets giving rise to pronounced negative real effects of the exchange rate shock. These patterns square well with the lower adjustment in prices, lower supply-side flexibility and lower market power of firms in these sectors.

Finally, we turn to Swiss business surveys data (provided by KOF Swiss Economic Institute) for the sectors *chemicals/pharmaceuticals* and *mechanical engineering*.[21] These data help to see whether the channels discussed above are also reflected in the perception of firms. Figure 7 summarizes survey answers to questions about demand, profits and employment. Looking at the reactions of the survey data following the appreciation, it becomes evident that the termination of the minimum exchange rate floor worsened the business outlook to various degrees. Whereas in the *chemicals/pharmaceuticals* sector, survey responses were largely unaffected, we observe a pronounced negative revision in perceptions in the *mechanical engineering* sector. These results indicate that in the *chemicals/pharmaceuticals* sector it was not only easier to counteract the appreciation through supply-side adjustments, as suggested by more pronounced price decreases, but that also that demand was affected to a lesser extent (in line with the sectoral price decreases and real export evolution discussed above).

5 Checks and robustness

We conduct several checks in order to validate the applicability of the SCM focusing on total goods exports, and explore the sensitivity of our results with respect to the sample period and data pre-processing for the aggregate and sectoral level (Fig. 8).

To allow for causal inference, the comparison group in the form of the donor pool countries should be unexposed to the intervention in order to allow the construction of an appropriate trajectory for the synthetic control. While this appears conceivable due to the small size of

[21] The KOF data are classified in NACE sectors/branches and could not be fully reshaped to the FOCBS classification of the export data (see footnote 15). Also, the KOF data do not distinguish between exporters and producers for domestic demand only. Yet, if the sectoral nominal exports figures 2014 are compared with the sectoral production value from the national accounts, it can be concluded that all the three sectors inspected in this section produced more than two third of their goods for markets abroad.

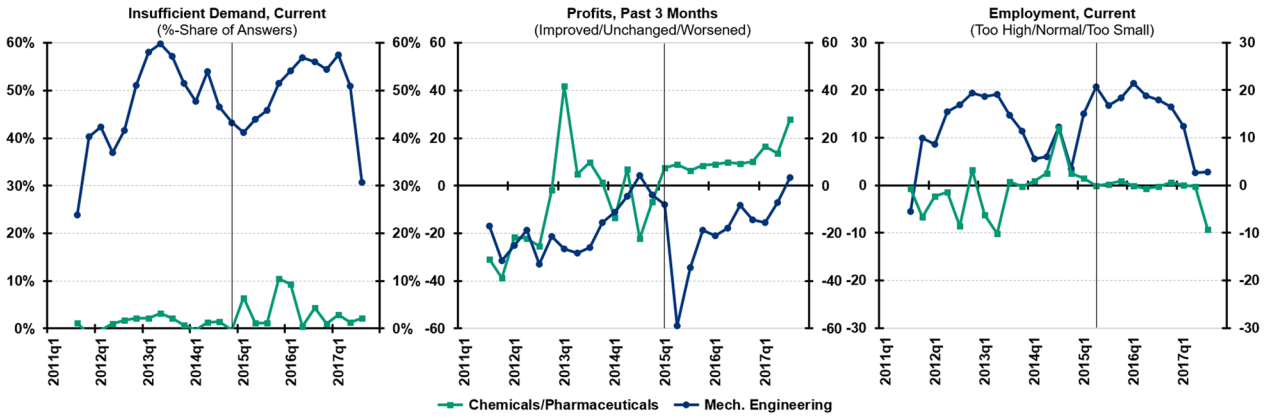

Fig. 7 Swiss business survey. *Notes*: Survey data provided by KOF Swiss Economic Institute

the Swiss economy and low trade shares with Switzerland of donor countries, we further elaborate on this assumption in our setup. Table 4 shows the share of total goods exports with Switzerland per country in the donor

Table 4 Share of goods exports to Switzerland per country in donor pool, SMC weights, and placebo indicators decisive for *p*-values

	Export share to Switzerland	EUR		NCU		Real	
		SCM Weight	Placebo Indicator	SCM Weight	Placebo Indicator	SCM Weight	Placebo Indicator
AUS	0.2%	0.00	1	0.00	1	0.20	1
AUT	5.6%	0.00	0	0.15	0	0.05	0
BEL	1.6%	0.00	0	0.00	0	0.00	1
CZE	1.6%	0.00	0	0.00	0	0.00	1
DEU	4.2%	0.00	0	0.00	0	0.00	0
DNK	0.9%	0.00	0	0.25	0	0.19	1
ESP	1.5%	0.00	0	0.00	0	0.00	0
EST	0.4%	0.19	0	0.00	0	0.00	1
FIN	0.8%	0.00	0	0.00	1	0.00	1
FRA	3.0%	0.00	0	0.00	1	0.00	1
GBR	6.9%	0.16	0	0.09	0	0.00	0
GRC	0.4%	0.00	0	0.00	0	0.00	1
HUN	1.0%	0.04	0	0.00	1	0.41	1
IRL	5.7%	0.00	1	0.00	1	0.00	1
ISL	1.6%	0.00	0	0.00	0	0.00	0
ISR	2.1%	0.00	0	0.00	0	0.00	1
ITA	4.8%	0.00	0	0.00	0	0.00	1
JPN	0.4%	0.00	0	0.00	1	0.00	1
LTU	0.4%	0.00	0	0.12	0	0.00	1
LVA	0.3%	0.00	0	0.00	0	0.00	0
NLD	1.3%	0.00	0	0.00	0	0.00	1
NOR	0.4%	0.09	0	0.00	0	0.00	1
NZL	0.2%	0.37	0	0.20	0	0.00	0
POL	0.9%	0.00	0	0.00	0	0.00	1
PRT	0.9%	0.05	0	0.00	0	0.15	1
SVK	1.7%	0.00	0	0.00	0	0.00	0
SWE	1.0%	0.10	0	0.19	0	0.00	1

A placebo indicator value of 1 reflects that the SCM performed on the respective country suggests an effect larger than observed for Switzerland (from 2015m1 to 2016m7)

pool together with the respective weights in the SCM calculation. In addition, we show the indicators decisive for the computation of the *p*-values assessing the effectiveness of placebo interventions. A value of 1 indicates that the SCM performed on the respective country suggests an effect larger than observed for Switzerland (from 2015 to 2016ml). Looking at the first column, we see that the Swiss trade shares are generally small. And higher trade shares are not visibly associated with higher weights in the SCM. In other words, the synthetic control is not driven primarily by countries that are closely connected to Switzerland. Also, the indicators from the placebo exercises estimated from goods exports data measured in EUR or NCU, for which we observe systematic effects of the appreciation, are not closely linked to the trade shares or the SCM weights.[22]

In a similar vein, we make sure that the synthetic control is not driven by single countries by replicating the estimation for specifications in which we leave one country out in turn (see Fig. 9). The effects of the exchange rate shock on total exports in EUR and NCU are similar to those in Fig. 3 and the effects for real exports are unsystematic reflecting that no effect can be detected and therefore also resemble the findings of Fig. 3.

We have already pointed out in the introduction that the removal of the minimum price target was unexpected and also referred to literature where this was shown. However, we would also like to examine this in our methodological setting because the assumption of non-anticipation is essential for the identification of the shock. In the overall (visual) inspection it strongly appears that the abrupt end of the minimum exchange rate floor sharply identifies an intervention that lets the export development deviate from its trajectory in January 2015. Also, a specific placebo-time-exercise, where we run the SCM until June 2014 instead of December 2014, does not indicate anticipation or pre-intervention adjustment (see Fig. 10).

After we have demonstrated that important preconditions for the applications of the SCM are fulfilled, we turn to conventional robustness checks next, for which we additionally show the sectoral effects. The six-digit HS data from UN Comtrade used in our analysis is available at monthly frequency beginning with 2010m1. To have a benchmark period to fit the synthetic control separated as accurately as possible from confounding factors, we consider data only beginning with October 2011, after the exchange rate floor became effective. To evaluate the effects of this modeling choice, we replicate our analysis using the data with the earliest possible starting point. Figures 11 and 12 show the respective estimations. Results are hardly affected when using a longer sample.

The administrative customs data that we exploit cannot be readily used in empirical analyses. Product group aggregates not only have to be mapped in economically meaningful sectoral and total aggregates, also potential seasonality, reporting errors and classification adjustments have to be accounted for. For the baseline estimation, we seasonally adjust the data and then additionally apply the outlier removal routine of X-13. Alternatively, one may use moving averages. While this approach is arguably less prone to misspecification, the isolation of the exchange rate shock timing is confounded by the construction of moving averages. Figures 13 and 14 present the estimation results using backward-looking moving averages of the respective time series of goods exports calculated from t to $t-6$. Even though effects of the exchange rate shock are slightly deferred, which is not surprising because of the moving averages, results are very similar compared to the baseline approach.

In addition, we experimented with different specification of the set of predictors, e.g., using alternative subperiod growth rates or leaving the real effective exchange rate out of consideration.[23] The results are robust to the permutations of the specification. Overall, additional checks conducted to evaluate potential sensitivities of the estimation corroborate the generality of our results.

6 Conclusion

In this paper, we exploit the quasi-natural experimental setting of the discontinuation of the minimum exchange rate by the Swiss National Bank (SNB) vis-à-vis the Euro in 2015 to evaluate the sensitivity of nominal and real aggregate exports and nominal sectoral exports to exchange rate shocks. Using granular customs data available for a wide range of countries, we construct a counterfactual for the evolution of Swiss exports under the premise that the minimum exchange rate policy would have been continued. We study the adjustment dynamics due to the exchange rate shock in January 2015.

[22] In addition to these pieces of suggestive evidence indicating that the SCM results are not driven by general equilibrium effects and spillovers, it should be noted that the placebo exercises are also indicative for affectedness: If countries were affected directly by the event, they may be assigned a value of 1 in the placebo test.

[23] Results are available upon request.

At the aggregate Swiss export level, we observe an immediate positive effect of the exchange rate shock on nominal exports in foreign currency (through the conversion) and an overall adverse effect on nominal exports in domestic currency, but no significant effect on real export quantities. This indicates that demand- and supply-side channels are active in the transmission of the shock and suggests a high degree of resilience of the Swiss export industry.

On the sectoral level, however, we find pronounced heterogeneities in the response to the shock depending on the type of exported goods. We relate differences of the sectoral adjustment to sectoral characteristics such as profit margins. For instance, more room to maneuver for supply-side adjustment in the *chemicals/pharmaceuticals* sector renders the exchange rate shock less adverse in this sector. Larger profit margins allow price reductions in domestic currency in order to prevent an increase of the product prices in foreign currency as a result of the appreciation.

Our results have implications for monetary and fiscal policy alike. To the extent that monetary policy affects the exchange rate, real effects will depend on the export industry's sectoral composition. Regarding fiscal policy, the uncovered sectoral vulnerability heterogeneities may also be considered in the calibration and choice of stabilization efforts carried out by fiscal authorities. The prevalence of large companies with high mark-ups within sectors plays a key role here. And to the extent that there are regional sectoral clusters—as in the case of the Swiss chemical and pharmaceutical sector, which is dominated by large companies that are mainly concentrated in the greater Basel region[24]—this also implies pronounced regional differences of the effects of monetary and fiscal policy.

Appendix

See Tables 5 and 6 .

See Figs. 8 , 9 , 10 , 11, 12, 13 and 14 .

Table 5 Pre-intervention fit and predictor weighting

	Euro			NCU			Real		
	CHE	Synthetic	*v* weight	CHE	Synthetic	*v* weight	CHE	Synthetic	*v* weight
Av. exports	1.02	1.02	0.66	1.02	1.02	0.68	1.06	1.06	0.62
REER	104.58	104.88	0.01	104.58	102.54	0.01	104.58	97.94	0.00
ERS	0.54	0.54	0.09	0.54	0.56	0.05	0.54	0.49	0.06
MI	0.35	0.35	0.06	0.35	0.36	0.16	0.35	0.33	0.08
OPEN	1.00	1.00	0.04	1.00	0.96	0.03	1.00	0.96	0.09
Growth I	5.16	5.16	0.01	−1.83	−0.17	0.01	−4.55	1.34	0.01
Growth II	−0.63	−0.63	0.10	1.76	0.90	0.01	5.88	6.75	0.12
Growth III	6.22	6.24	0.03	3.92	4.11	0.05	9.12	6.75	0.03

The table shows the pre-intervention fit of the synthetic control together with the Swiss predictor values. In addition, the predictor weights v are shown. Subperiod (I-III) growth rates pertain to periods 2012m1–2012m3, 2013m3–2013m9, and 2014m9–2014m12

[24] In 2021, 61% of employees in the Swiss pharmaceutical sector worked in the three neighboring cantons of Aargau, Basel-City and Basel-Country (out of 26 cantons in Switzerland), although these three cantons account for only 14% of the Swiss population (data source: Swiss Federal Statistical Office). The strong dependence on the chemical/pharmaceutical sector is particularly evident in the canton of Basel-City, where the sector was responsible for 96% of total exports in 2022 (data source: FOCBS).

Table 6 Answers of Swiss firms negatively affected by the appreciation, survey results from Swiss National Bank (2015, pp. 32–37)

Consequences of appreciation (percentage of firms for which the following applies, multiple entries possible)	
Lower mark-ups	88%
Drop of selling prices	76%
Lower export quantities	48%
Lower market share	15%
Response to appreciation (percentage of firms for which the following applies, multiple entries possible)	
Increase of selling prices in foreign currency	13%
Decrease of employment stock/hiring halt	28%
Reduction of domestic purchasing prices	52%
Increase of purchases from abroad	33%
Innovation and process optimizing	34%
Shift of business activity to abroad	13%
No reaction	15%

Covered in the SNB survey were firms from the industry, construction and services sectors. About 70% of the surveyed firms reported to be negatively affected by the Swiss Franc appreciation. Shown are the answers of negatively affected firms only

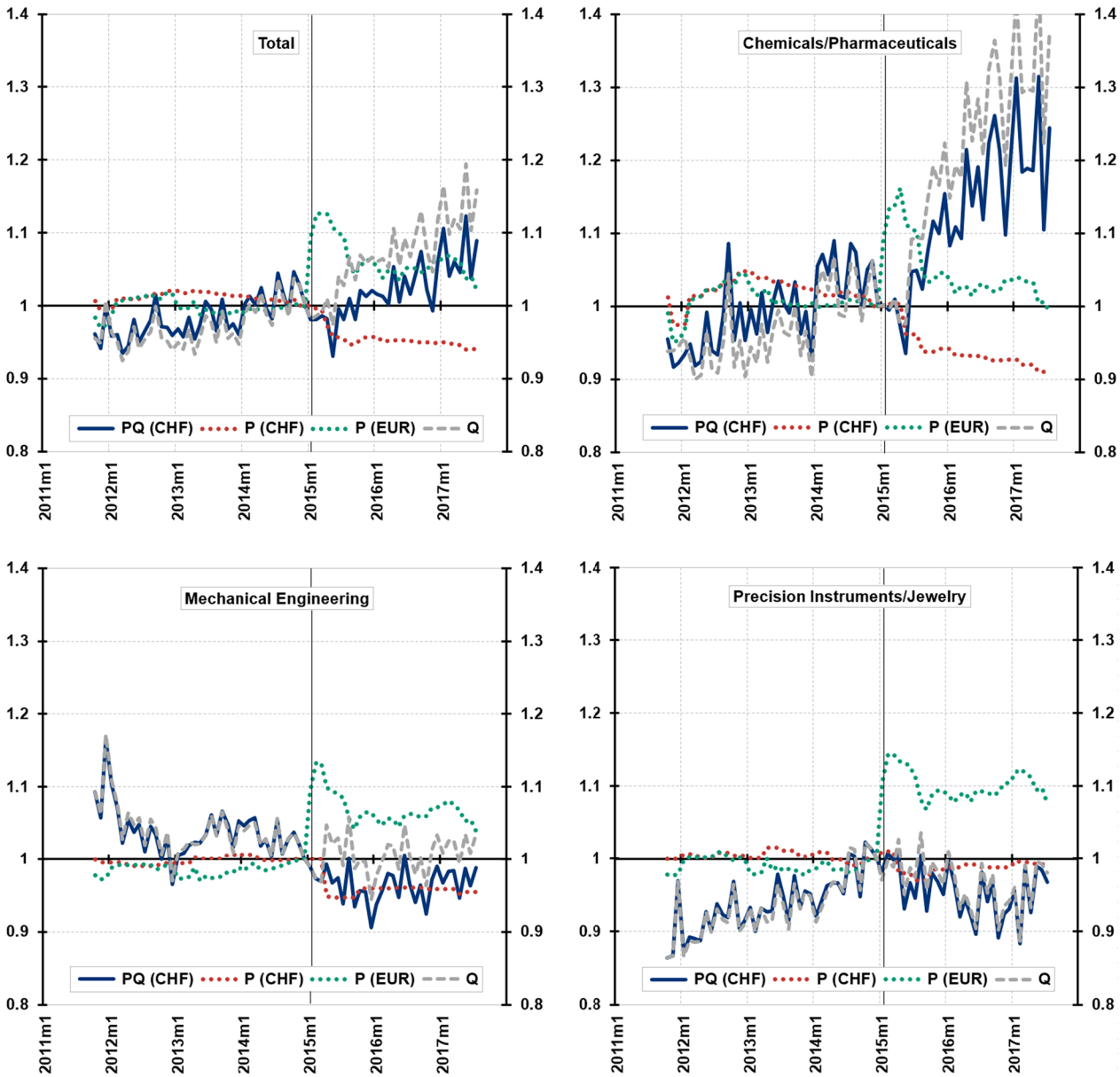

Fig. 8 Nominal exports (CHF), prices (CHF and EUR), and approximated real exports. *Notes*: The figure shows the total and sectoral evolution of nominal export values in CHF, export price indexes (CHF and converted to EUR) and approximatively computed real export quantities

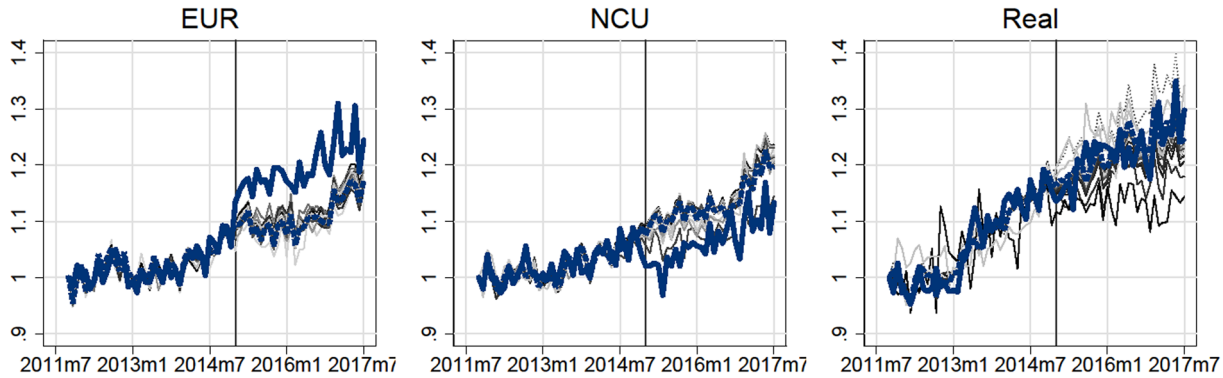

Fig. 9 Swiss exports in EUR, NCU and real quantities with counterfactuals where one country is left out in turn. *Notes*: See notes of Fig. 3

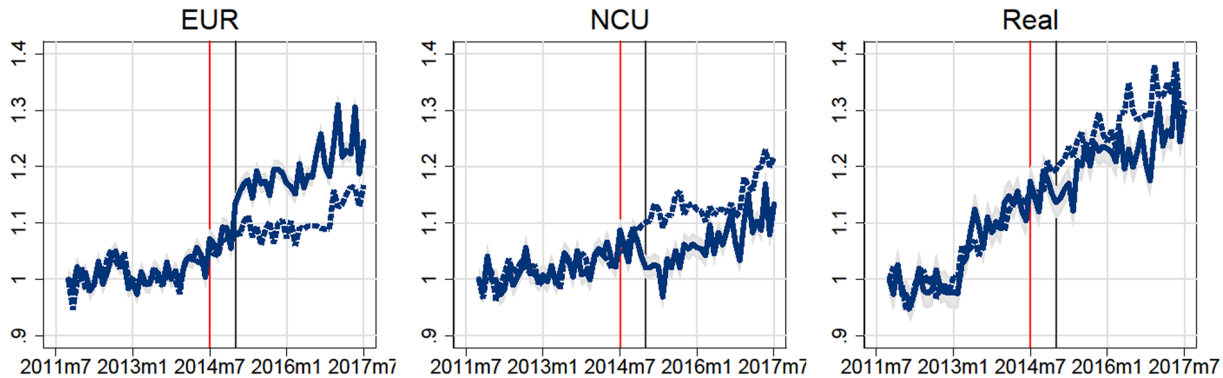

Fig. 10 Swiss exports in EUR, NCU and real quantities with counterfactuals where the SCM fits data until 6 months before the exchange rate shock. *Notes*: See notes of Fig. 3

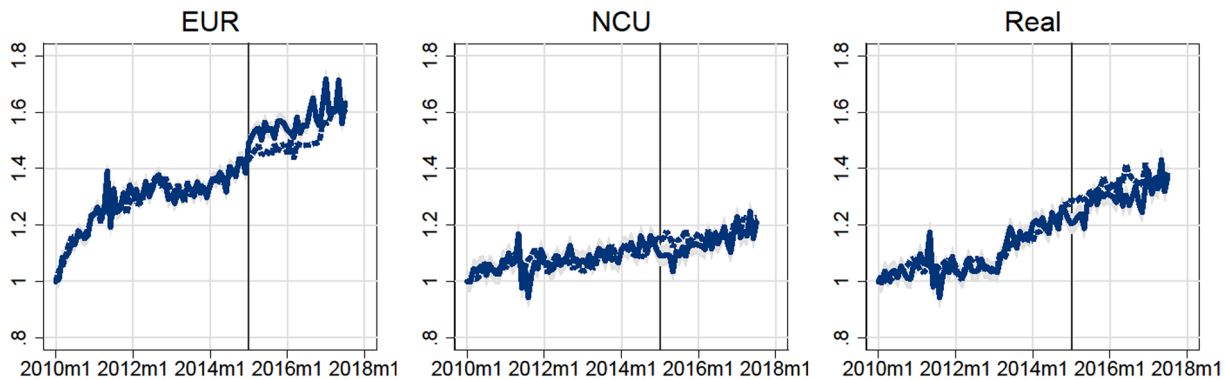

Fig. 11 Swiss exports in EUR, NCU and real quantities with counterfactual (full sample). *Notes*: See notes of Fig. 3

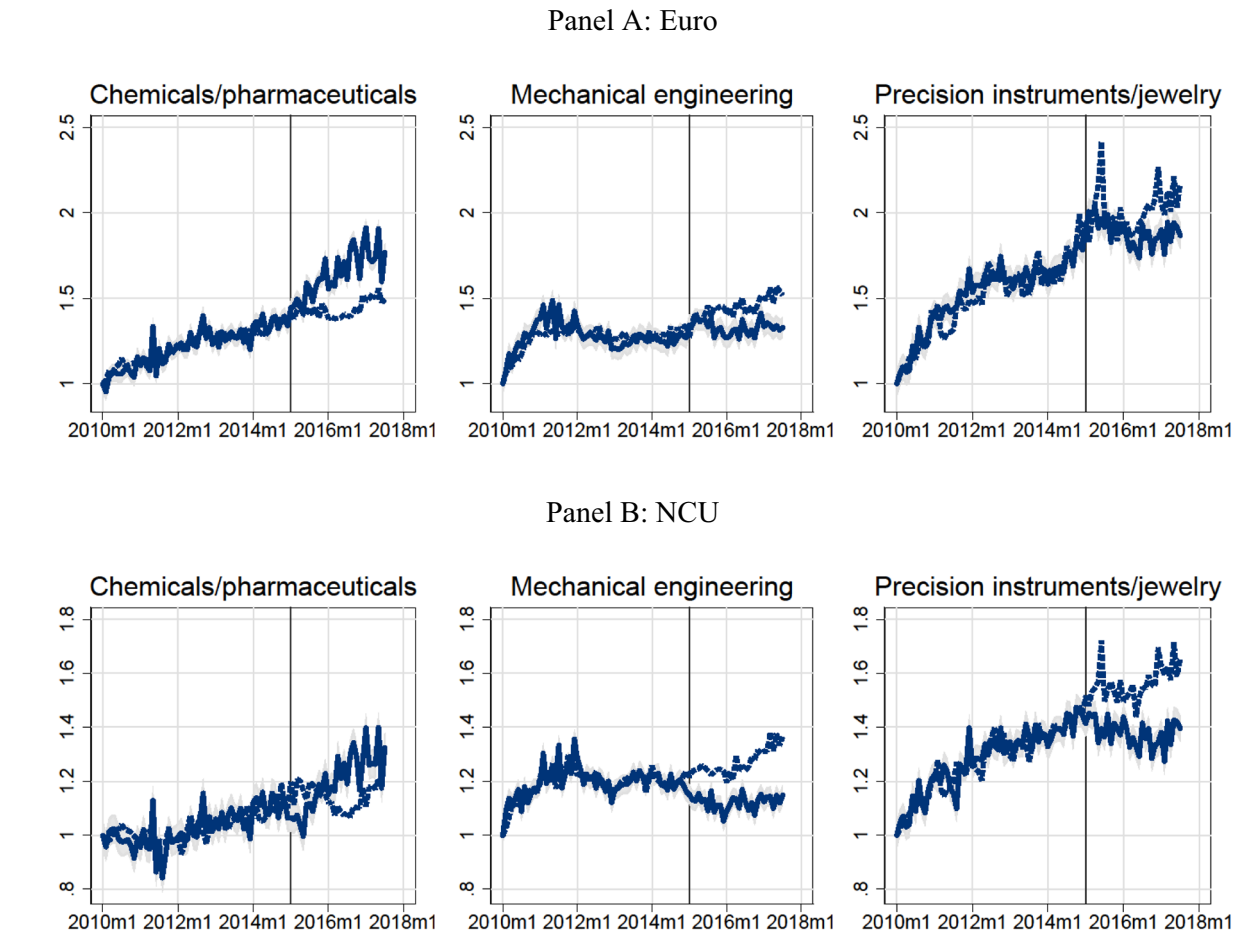

Fig. 12 Swiss sectoral exports with counterfactual (full sample). *Notes*: See notes of Fig. 3

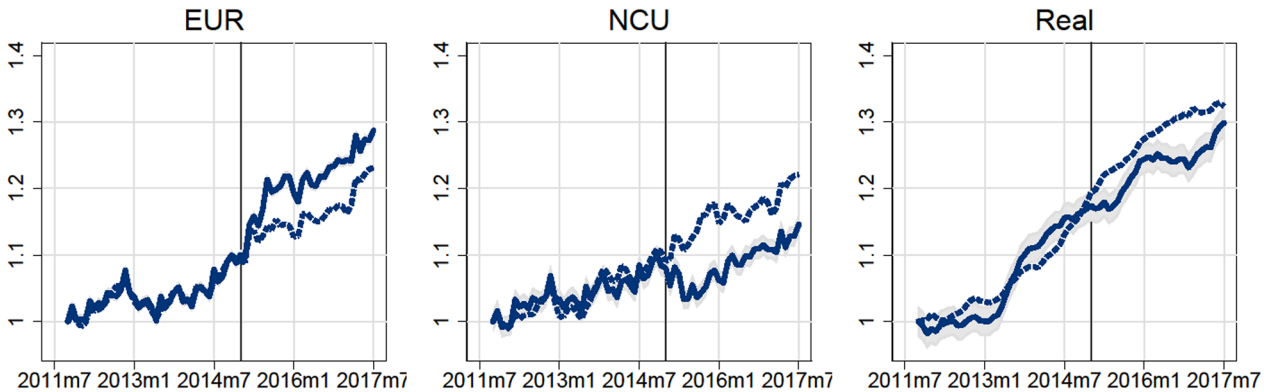

Fig. 13 Swiss exports in EUR, NCU and real quantities with counterfactual (moving averages). Notes: See notes of Fig. 3

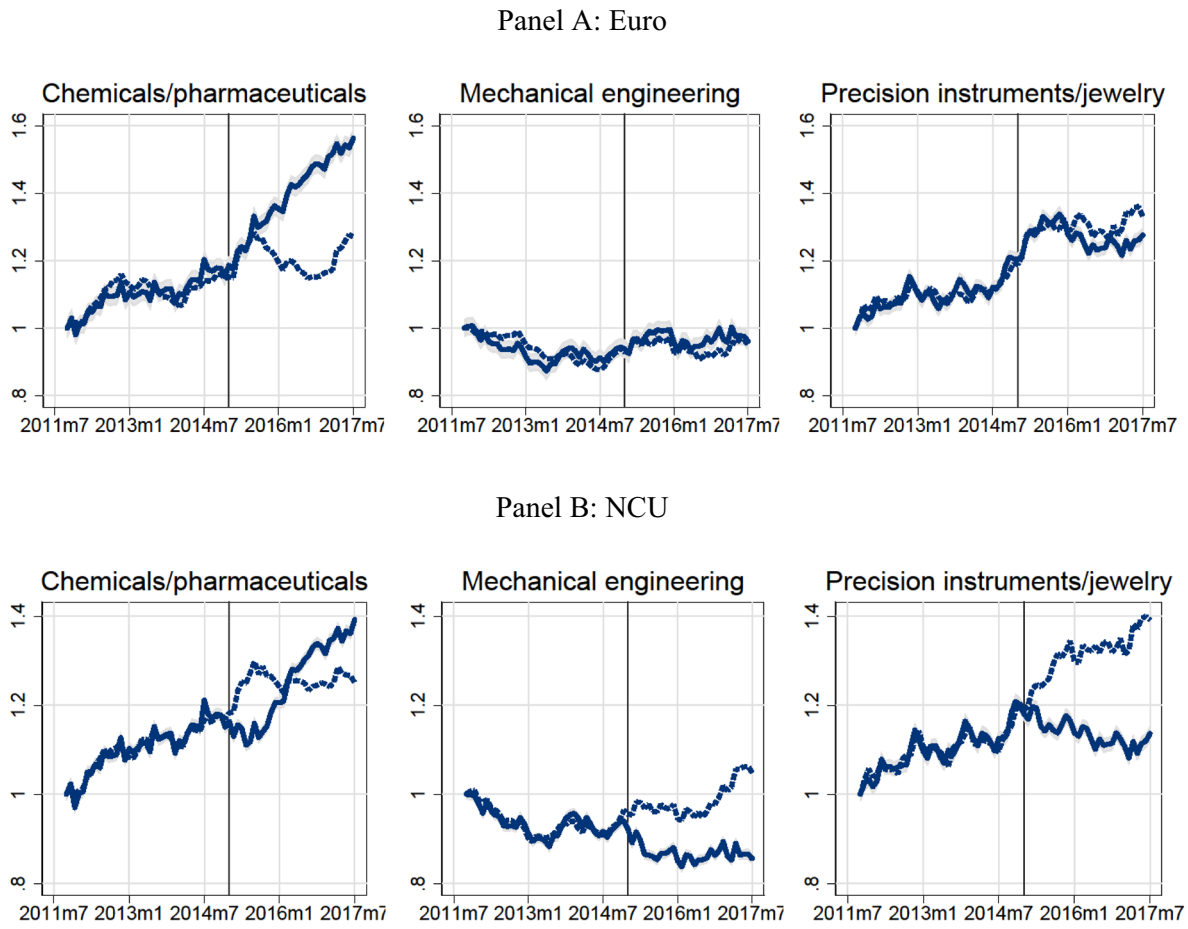

Fig. 14 Swiss sectoral exports with counterfactual (moving averages). *Notes*: See notes of Fig. 3

Acknowledgements
We are grateful to the Editor, Daniel Kaufmann, and two anonymous referees for their comments and suggestions. We would like to thank Berno Büchel, Jochen Güntner, Martin Kocher, and Andreas Peichl for helpful discussions, and Elias Hasler and Johannes Lehmann for excellent research assistance. The paper has also greatly benefitted from comments received at research seminars at the University of Bern, the University of Innsbruck, and the Liechtenstein Institute, as well as at the Money, Macro and Finance conference and the FIW workshop on international economics. We are indebted to the Federal Office of Statistics, the Swiss Federal Office for Customs and Border Security, and the KOF Swiss Economic Institute for data supply and the provision of valuable support.

Author contributions
Both authors equally contributed to the paper. MG collected the customs data, while AB pre-processed the time series before estimations. MG implemented the synthetic control method. AB conducted additional analyses shown in the discussion. Writing was a joint, sequential process where MG drafted the first version of Sect. 1, 3, 5 and while AB initially drafted Sect. 2 and 4.

Funding
This article has not received funding.

Availability of data and materials
Data and code are available from the corresponding author on request.

Declarations

Competing interests
The authors declare no competing interests.

Received: 8 August 2024 Accepted: 7 May 2025
Published online: 09 July 2025

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