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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 dynamic adjustment of aggregate and sectoral goods exports due to the exchange rate shock in January 2015. In absence of a comprehensive J-curve type adjustment we find that Swiss nominal export values increase in Euro, while they drop in Swiss Franc. In real quantities, exports remain largely unaffected indicating a high degree of resilience of the Swiss export industry. On the sectoral level, we observe heterogenous adjustment of exports consistent with varying degrees of flexibility for supply side adjustment and market power.

Keywords: exchange rate shock, goods exports, export sectors, synthetic control method

JEL: F14, F31, F41

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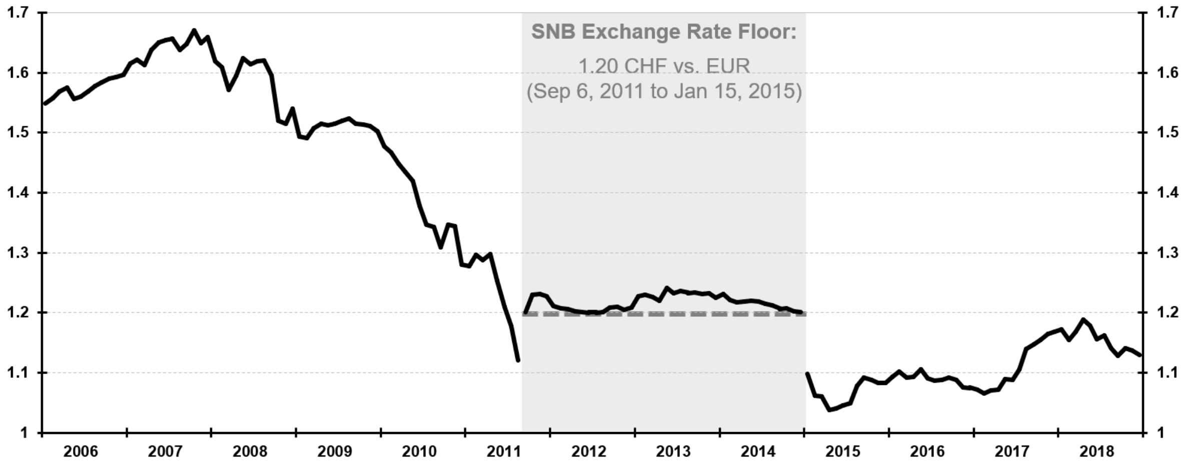
1. Introduction

Exchange rate fluctuations are key determinants of the domestic and international propagation of macroeconomic shocks, with implications for, among others, relative prices, external imbalances, and the effectiveness of monetary policy. At the same time, as evident through 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, exchange rate shocks are important drivers of the business cycle. 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; Fernandez and Winters, 2021; Itskhoki and 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 export quantities 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 Figure 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. 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 was unanticipated and surprised markets and pundits of monetary policy alike (Jermann, 2017).

Figure 1: Exchange rate (CHF per EUR, monthly averages)



Notes: The figure shows the historical development of the CHF-EUR exchange rate. The shaded area indicates the period of the exchange rate floor against the EUR. Data is from the SNB.

We analyze the effects of the exchange rate shock to aggregate export quantities as well as different categories of goods. 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 of 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).

Our focus on the sectoral level complements the existing literature on 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 and Goldberg, 2005; Forbes et al., 2018), or is geared towards 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 aggregate nominal values and real quantities. At the same time, we can take account of adjustment heterogeneities associated with goods' characteristics.

To evaluate the effects of the exchange rate shock we employ the synthetic control method proposed by Abadie and Gardeazabal (2003), which allows for 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/EUR exchange rate within 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/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 and Renkin, 2017).

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.

On the aggregate level, we observe a marked immediate effect of the exchange rate shock through 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 6 percent over a horizon of 18 month. Considering the adjustment in domestic currency, we find that Swiss exports in CHF drop due to the shock by approximately 6 percent, at least in the short run. In real terms, Swiss exports remain largely unaffected and, if at all, only decrease slightly, suggesting pronounced resilience of the Swiss export industry on the aggregate level.

Considering the adjustment on the sectoral level, we uncover the drivers behind the resilience and adjustment channels active. Across sectors, the effects of the exchange rate shock are distinctly heterogenous 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, exports in EUR gradually go up, with an increase amounting to 11 percent on average over a one-year horizon, a similar order of magnitude as the size of the exchange rate shock. Exporters in this sector tend to be more productive, more import-intensive, and less financially constrained relative to other sectors. As a result, the *chemicals/pharmaceuticals* sector was able to significantly reduce prices in response to the appreciation shock.[3] Moreover, even though decreases in export prices did not fully compensate the appreciation, export quantities of *chemical/pharmaceuticals* were essentially unaffected by the appreciation, indicating that market power and price elasticity played a role in addition to supply side adjustments. 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 exports in EUR being largely unaffected by the appreciation. We find supply side adjustment in these two sectors to be less effective such that the price decrease was smaller compared to the *chemical/pharmaceutical* sector. In turn, pronounced negative real effects can be detected for *mechanical engineering* and *precision instruments/jewelry*.

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; Fernandez and Winters, 2021). We generalize these arguments to the sectoral level and provide indications for their quantitative relevance on the aggregate and sub-aggregate level.

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

Our paper adds to a large literature on the effects of exchange rate fluctuations to economic activity and prices (see Burstein and Gopinath, 2014). Several papers study exchange rate elasticity of exports 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 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] Fernandez and Winters (2021) study the depreciation of the British Pound following the Brexit vote on 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 prices and quantities 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.

A second strand of literature we contribute to comprises papers that apply the synthetic control method by Abadie and Gardeazabal (2003) in macroeconomic contexts. Puzello 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 presidency on growth and job creation.

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

[4] Moreover, our paper is related to an abundance of academic and applied papers discussing aggregate and 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).

2. Empirical strategy

We introduce a research design that exploits the quasi-natural experimental setting of the discontinuation of the minimum exchange rate floor by the Swiss National Bank (SNB) to evaluate the sensitivity of sectoral exports to exchange rate shocks. The SNB's sudden termination of the minimum exchange rate target of 1.2 Swiss Francs against the Euro, which was in effect from September 2011 to January 2015, led to a sharp and persistent appreciation of the Swiss Franc (CHF) of roughly 10 percent versus the Euro. The unanticipated shift in SNB policy qualifies as an unexpected exchange rate shock that is otherwise difficult to identify because of the endogenous relationship between the exchange rate and economic activity.[5]

The impact of the exchange rate shock is evaluated applying the synthetic control method by Abadie and Gardeazabal (2003), which enables causal inference and circumvents the endogeneity problem noted above. 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 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 Figure 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 after the 2015 shock, in the period from January 2015 until July 2017.

2.1 Export 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), international trade data are well documented. The 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 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 Harmonized System (HS). HS is a six-digit code system at the international level covering the universe of traded goods. The HS system follows a legal

[5] See e.g. Jermann (2017) for market reactions surrounding January 2015 indicating that the policy shift was not anticipated.

(i.e. customs) logic and its categories can only be used to a limited extent for economic analyses. 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) 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 towards differentiating between economic (industrial) sectors.[7] These sectors are sufficiently homogenous to allow for a meaningful 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 29 OECD countries in the synthetic control donor pool, for which customs data as well as implicit deflators are available for November 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 sectors *energy*, *precious metals, precious and semi-precious stones* and *works of art and antiques* from the analysis, as they can potentially alter the results due to non-cyclical and idiosyncratic factors or feature breaks in the reporting procedures that distort the aggregate.[9] We thus only consider sectors 1 and 3–12 in the analysis.

[6] SITC as well as BEC are only of limited usefulness for our analysis because the categories are either too crude or too heterogenous 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.ezv.admin.ch/ezv/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, USA.

[9] Major structural breaks are associated with the sector *precious metals, precious and semi-precious stones precious*, 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.ezv.admin.ch/ezv/en/home/topics/swiss-foreign-trade-statistics/daten/gesamtexporte-und-importe.html for further details.

Table 1: Sectoral export share in NCU (FOCBS nomenclature)

Share of exports in NCU (sample averages: 2011M10–2017M7)			
	Sectors	Switzerland	Country average donor pool
1	Forestry and agricultural products, fisheries	2.8%	11.0%
2	Energy	1.2%	22.3%
3	Textiles, clothing, shoes	1.5%	4.3%
4	Paper, articles of paper and products of the printing industry	1.0%	3.2%
5	Leather, rubber, plastics	2.0%	4.3%
6	Products of the chemical and pharmaceutical industry	38.0%	13.9%
7	Stones and earth	1.2%	4.7%
8	Metals	5.6%	15.2%
9	Machines, appliances, electronics	15.2%	22.7%
10	Vehicles	2.3%	11.4%
11	Precision instruments, clocks and watches and jewelry	20.4%	4.1%
12	Various goods	0.6%	2.3%
13	Precious metals, precious and semi-precious stones	8.6%	2.7%
14	Works of art and antiques	0.8%	0.01%

Notes: Averages of the 29 OECD countries in the donor pool are unweighted.

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

2.2 Data Preparation

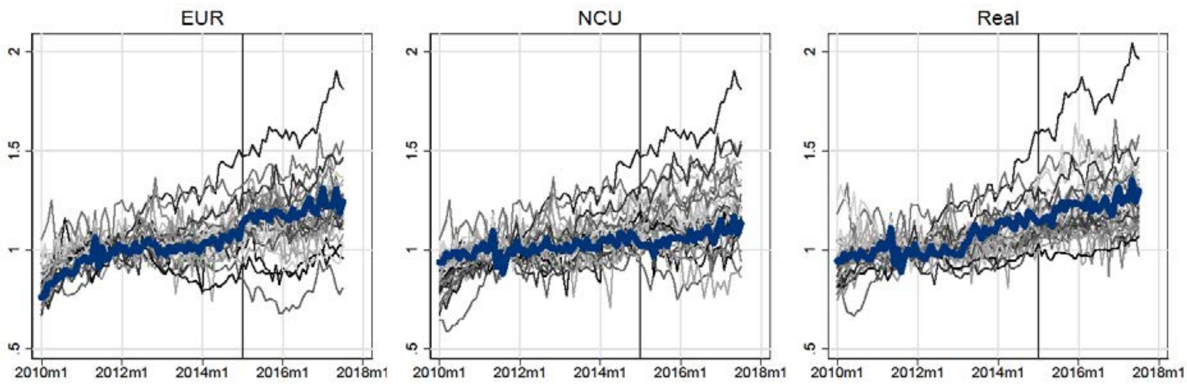
Using international trade data in the estimation exercise to construct counterfactuals for Swiss exports on the aggregate and disaggregate level involves several data processing steps. Most importantly, trade data is very volatile, likely exhibits seasonal patterns and potential classification changes or reporting errors. The data we use is administrative customs data which is not pre-processed. We thus remove the seasonal and the calendar component by applying the Census X-13 method developed by the U.S. Census Bureau. Seasonally and calendar adjusted data still contains 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 as outlined below. We apply the seasonal and calendar adjustment and the outlier treatment to all the data series on both the aggregate and disaggregate level.

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 RegARIMA models for automated outlier detection and removal, for calendar effect identification, and for fore- and backcasting the time series before the actual seasonal adjustment procedure is carried out. 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, X13 temporarily removes the outliers and by default re-imputes them in the finally adjusted 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 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.[10]

Figure 2 shows aggregate export series of both Switzerland and all the donor pool countries converted in Euro (EUR, left panel) and in national currency units (NCU, middle panel). As all series are indexed to the beginning of the employed time sample (October 2010), we can construct a weighted average that acts as synthetic control to evaluate the effects of the exchange rate shock in Section 3. The difference between the 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 takes account of potentially varying developments of exports in domestic and in foreign currency. The vertical line in Figure 2 indicates the termination of the minimum exchange rate regime and the blue lines represent Swiss exports.

Figure 2: Goods export series



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

In addition to export values in nominal currency units, the trade data series are converted and deflated into real export quantities (right panel in Figure 2). We deflate goods export values in a harmonized way using implicit deflators from the OECD Quarterly National Accounts (QNA) as goods exports are

[10] Our analysis comprises 1'287 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.

reported in nominal as well as real values. 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) and then compute monthly real values.

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 sectoral Swiss 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. They are constructed on the basis of a donor pool of sectoral exports in a wide range of countries.

Specifically, the counterfactual is a weighted average of $J = 29$ OECD countries in the donor pool. Switzerland is labelled as $j = 1$, the donor countries as $j = 2, \dots, J + 1$. The weights are determined by minimizing the distance between Swiss exports and the counterfactual over the period preceding the exchange rate shock.[11] Formally, to construct the counterfactual the following optimization problem has to be solved: country weights, $w = \left(w_2, \dots, w_{J+1}\right)'$, minimize the mean squared error

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

The vector x_1 denotes Swiss data and the matrix X_0 collects data of the J countries in the donor pool. V is a diagonal matrix with weights for the relative importance of the 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 real export quantities prior to the end of the minimum exchange rate floor, subperiod growth rates, and the average real effective exchange rate as an indication for international competitiveness.[12] The optimization problem is solved separately for each dimension (nominal EUR export values, nominal NCU export values, real export quantities) and with data from September 2011 up to December 2014, the month the SNB discontinued the lower bound of the exchange rate (Swiss Franc against Euro).

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

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

To evaluate whether the effect size of the shock, i.e. the difference between the synthetic control and the actual realization of goods exports, we construct placebo synthetic controls for each donor country.

[11] In addition, we can account for individual country characteristics to increase the accuracy of the counterfactual (see Abadie et al. 2010).

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

A test statistic can be obtained using the ratio of post-event fit relative to pre-event fit (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 $j = 1, \ldots, J+1$:

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

and the permutation distribution is given as

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

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:

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

$I_+(\cdot)$ is an indicator function that returns one for nonnegative 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 in the adjustment we then evaluate the adjustments on the sectoral level.

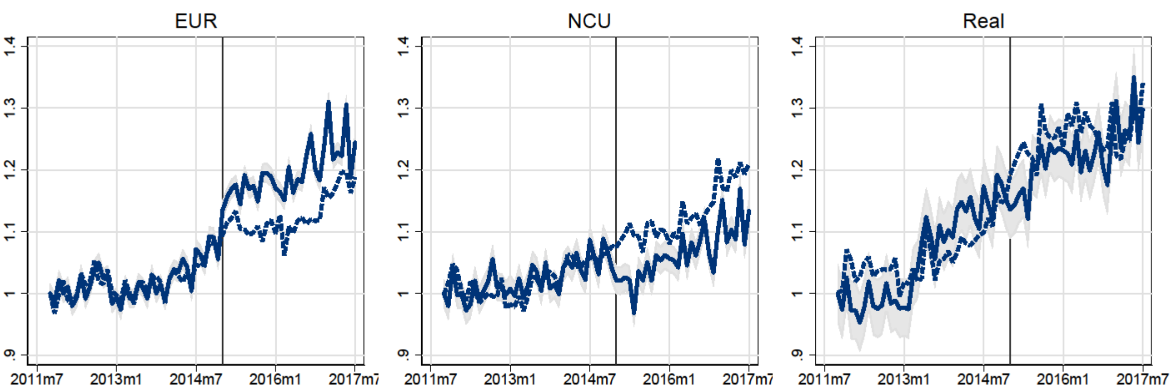
3.1 Adjustment of goods exports on the aggregate level

The solid line in Figure 3 shows 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 month of the exchange rate floor. This gives us

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

the dashed line in Figure 3, which serves as benchmark against which we compare realized exports. As an indication for the estimated precision of the counterfactual and as a measure for usual deviations between the two series, the grey shaded areas around the realized exports show the standard deviation of the difference between realized exports and the counterfactual (both 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 export values denominated in Euro (EUR), the second on nominal export values denominated in national currency units (NCU) and the third on exports in real quantities. Comparing the actual development of total goods exports against the counterfactual, we see that the effects vary, depending on the representation of exports.

Figure 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 grey bands indicate one standard-deviation of the difference between the two series before January 2015.

In EUR we observe that due to the exchange rate shock the value of total nominal export values in EUR increases immediately as the shock sets in and remain 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 change in the exchange rate (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 export values 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 adjustment, 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 off-set the negative appreciation effect on demand for export quantities, at least to a considerable extent. 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 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 6 percent. Exports in domestic currency fell by about 6 percent, but the effect turns insignificant within one year. For real exports, effects tend to be negative, but are not significant at conventional scales.

Table 2: Average effect size relative to 2014m12 (p-values in parenthesis)

	Nom. Exports (EUR)	*Nom. Exports (NCU)*	*Real Exports*
$T_0 + 6$	0.05 (0.07)	−0.07 (0.07)	−0.05 (0.63)
$T_0 + 12$	0.06 (0.07)	−0.06 (0.17)	−0.04 (0.70)
$T_0 + 18$	0.06 (0.07)	−0.06 (0.27)	−0.04 (0.77)

Notes: The p-value is the percentage of donor pool countries with placebo effects greater than the actual treatment effect observed for Switzerland.

Nominal exports in EUR and CHF being affected by the appreciation by similar orders of magnitude, albeit in opposite directions, suggests that price increases due to the appreciation were both passed on as well compensated through price reductions in domestic currency by similar extents. This is consistent with an incomplete pass-through (see e.g. Burstein and 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 and Campa, 2010; Fernandez and Winters, 2021) to balance the appreciation, as we discuss in greater detail below. However, domestic price adjustments did not fully offset the appreciation, which indicates at least some market power of Swiss exporters consistent with models of monopolistic competition (see e.g. Devereux et al., 2017). We next turn to sectoral heterogeneities in the adjustment to the exchange rate shock, as these factors are tightly related to the nature of goods.

3.2 Adjustment of goods exports on the sectoral level

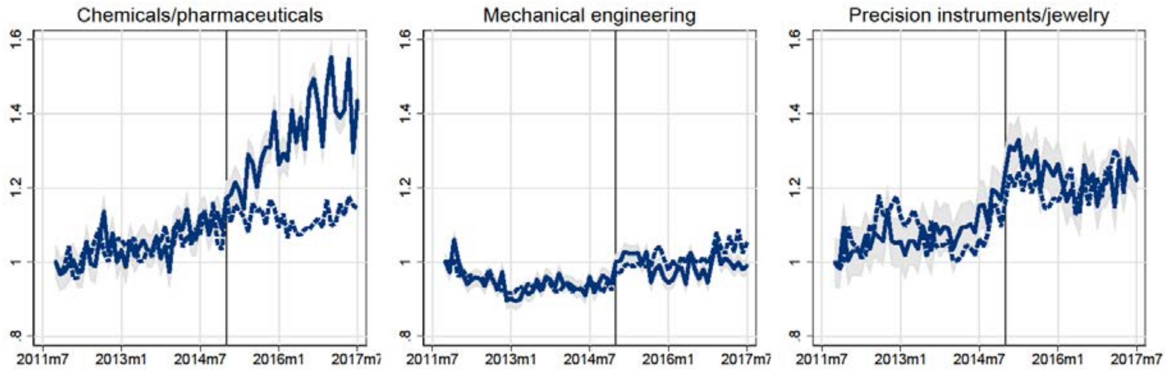
The Swiss export industry is rather concentrated in single sectors as e.g. visible by internationally rather high values of the Herfindahl-Hirschman Index measuring sectoral concentration (Brunhart et al., 2019). Among the twelve FOCBS sectors applied in this study only *chemicals/pharmaceuticals* (FOCBS sector

6 in Table 1), *mechanical engineering* (FOCBS 9) and *precision instruments/jewelry* (FOCBS 11) exceed a sectoral share of ten percent, as shown in Table 1 with the sectoral composition of Swiss exports. The three inspected sectors amount to about 73% of total exports and therefore are the main drivers of the aggregate development.

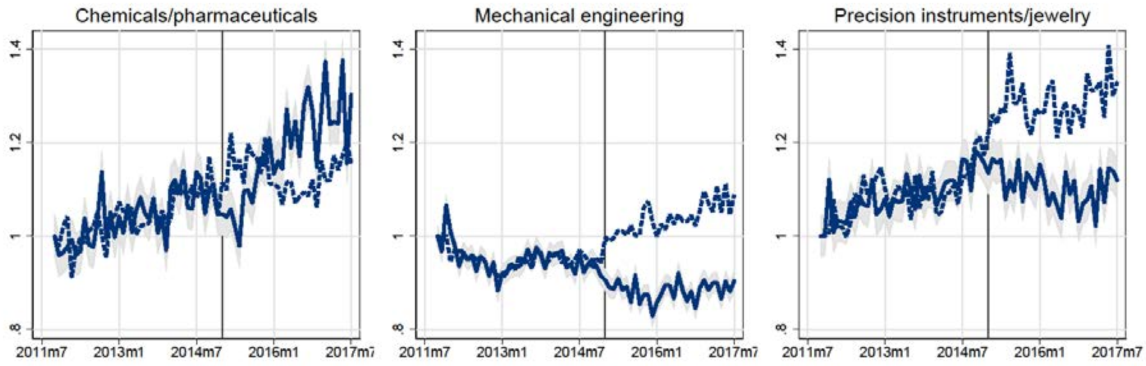
To examine potential heterogeneities in the sectoral adjustment following the exchange rate shock we evaluate the adjustment of the export activity in the three largest export sectors. We aggregate customs data in HS-six-digit nomenclature into FOCBS nomenclature. Doing so, we obtain sectors that are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

Figure 4: Swiss sectoral exports with counterfactual (dashed line)

Panel A: Euro



Panel B: NCU



Notes: See notes of Figure 3.

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 Figure 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. These visual impressions are 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 exports in EUR, 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.

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

Nominal Exports (EUR)			
	Chemicals	**Mechanical Engineering**	**Instruments**
$T_0 + 6$	0.07 (0.17)	0.03 (0.53)	0.06 (0.57)
$T_0 + 12$	0.11 (0.07)	0.00 (0.47)	0.06 (0.60)
$T_0 + 18$	0.14 (0.07)	−0.01 (0.50)	0.04 (0.80)

Nominal Exports (NCU)			
	Chemicals	**Mechanical Engineering**	**Instruments**
$T_0 + 6$	−0.10 (0.10)	−0.13 (0.00)	−0.13 (0.10)
$T_0 + 12$	−0.06 (0.17)	−0.15 (0.00)	−0.13 (0.13)
$T_0 + 18$	−0.01 (0.17)	−0.15 (0.00)	−0.14 (0.13)

Notes: See notes of Table 2.

Following Table 3 and Panel B of Figure 4, *mechanical engineering* and even more so *precision instruments/jewelry* face adverse effects of the exchange rate shock on 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 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 explanation is that *chemicals/pharmaceuticals* can on the one hand pass-on prices more easily because of lower price elasticity of demand. However, as turns out in Section 4, this sector was on the other hand 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 nature of exported goods. Sectors with higher shares of production costs in domestic currency, in particular labor, and a plausibly higher price elasticity of demand, i.e. *precision instruments/jewelry* and even more so *mechanical engineering*, suffer more from exchange rate shocks, which is consistent with previous findings indicating different degrees of pricing-to-market and market power (Berman et al., 2012; Burstein and Gopinath, 2014; Devereux et al., 2017) as well as different exposure to exchange rate shock related to the share of intermediary goods (Goldberg and Campa, 2010; Fernandez and Winters, 2021).

On the aggregate level, export price deflators are available through the OECD QNA. On the sectoral level, we cannot construct real export values because deflators are either not comparable because of different sector definitions, or they are simply not available. As a result, we cannot replicate the synthetic control 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* and *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 which channels dominate in the respective sectors, we evaluate Swiss data, in particular sectoral price and survey data, that are indicative for sectoral quantity and price adjustments in the sectors in the next Section.

4. Discussion

Adjustment in nominal export values can be associated with both price and quantity adjustment. 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 in foreign currency, depending on the currency of invoicing. The extent to which the immediate effect of the conversion can be offset depends on supply side adjustments determined by factors such as the foreign demand's price elasticity, the supplier's market power, or the structure of the distribution chain. 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 and Campa, 2010; Devereux et al., 2017; Fernandez and Winters, 2021).[14]

[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

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), almost 90% of the negatively affected Swiss companies in the sample suffered from lower mark-ups, about 75% reported a drop of prices in CHF, almost 50% lower export quantities and about 15% a lower market share. Only few reacted with an increase of prices in foreign currency (about 13%). On the other hand, cost reductions in domestic currency were central. Almost 30% reported both a decrease of their employment stock and a hiring halt, more than 50% a reduction of purchasing prices (30% an increase of purchases from abroad), and more than 30% responded by innovation and process optimizing. Only 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) on aggregate as well as sectoral level and real exports (Q) only on the aggregate level. In contrast to total exports, the unavailability of price deflators for the donor pool of 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 real quantities Q_{it} from the observed nominal export series $P_{it}*Q_{it}$.[15]

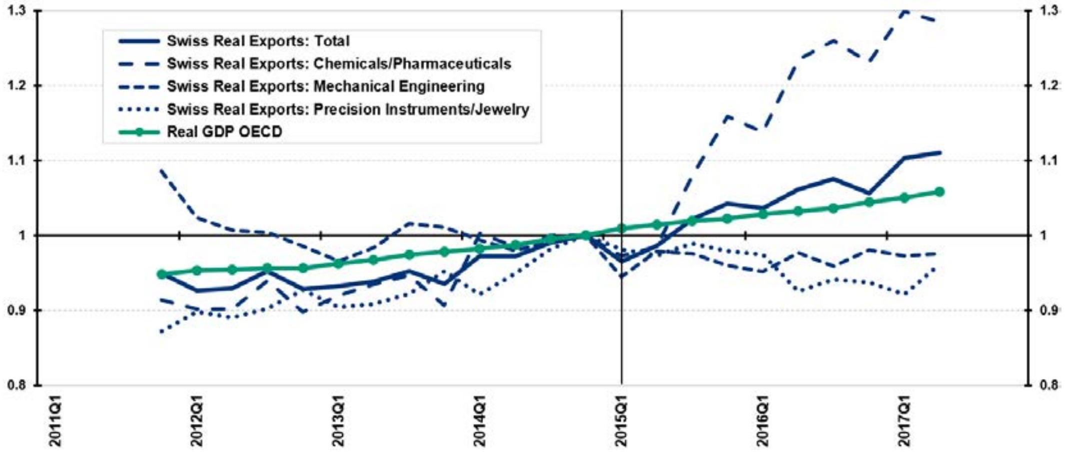
Figure 5 displays the quarterly evolution of aggregate and sectoral exports together with the OECD real GDP as rough indication for the economic development in the donor pool countries. All series are indexed to December 2014, the month before the appreciation shock. While the total real exports were 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

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 exporter sector.

15 Disaggregated data on sectoral export prices was provided by the Federal Office of Statistics by request of the authors, as publically available sectoral data comprise producer prices no matter if products are sold inside or outside of Switzerland (export prices are only published on aggregated base). 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 sections 20 and 21 are applied, for *mechanical engineering* NACE 28, and for *precision instruments/jewelry* NACE section 26. The applied monthly price indexes are denoted in CHF, those product prices set 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 eye-balling 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_iQ_i and P_i in CHF instead of EUR to obtain the sectoral Q_i, as this perspective is more relevant to the domestic Swiss exporter. But then again, the test run for aggregate Q shows that the determined quantities are very similar when determined via EUR (which should be the case by identity, but is not in the actual data usage due to data noise or the data transformation process of outlier treatments and seasonal adjustment).

chemicals/pharmaceuticals represent the quantitatively most important Swiss export sector (export share 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 exports were hardly affected by the appreciation.[16]

Figure 5: Quarterly real GDP (OECD) and estimated Swiss sectoral real exports



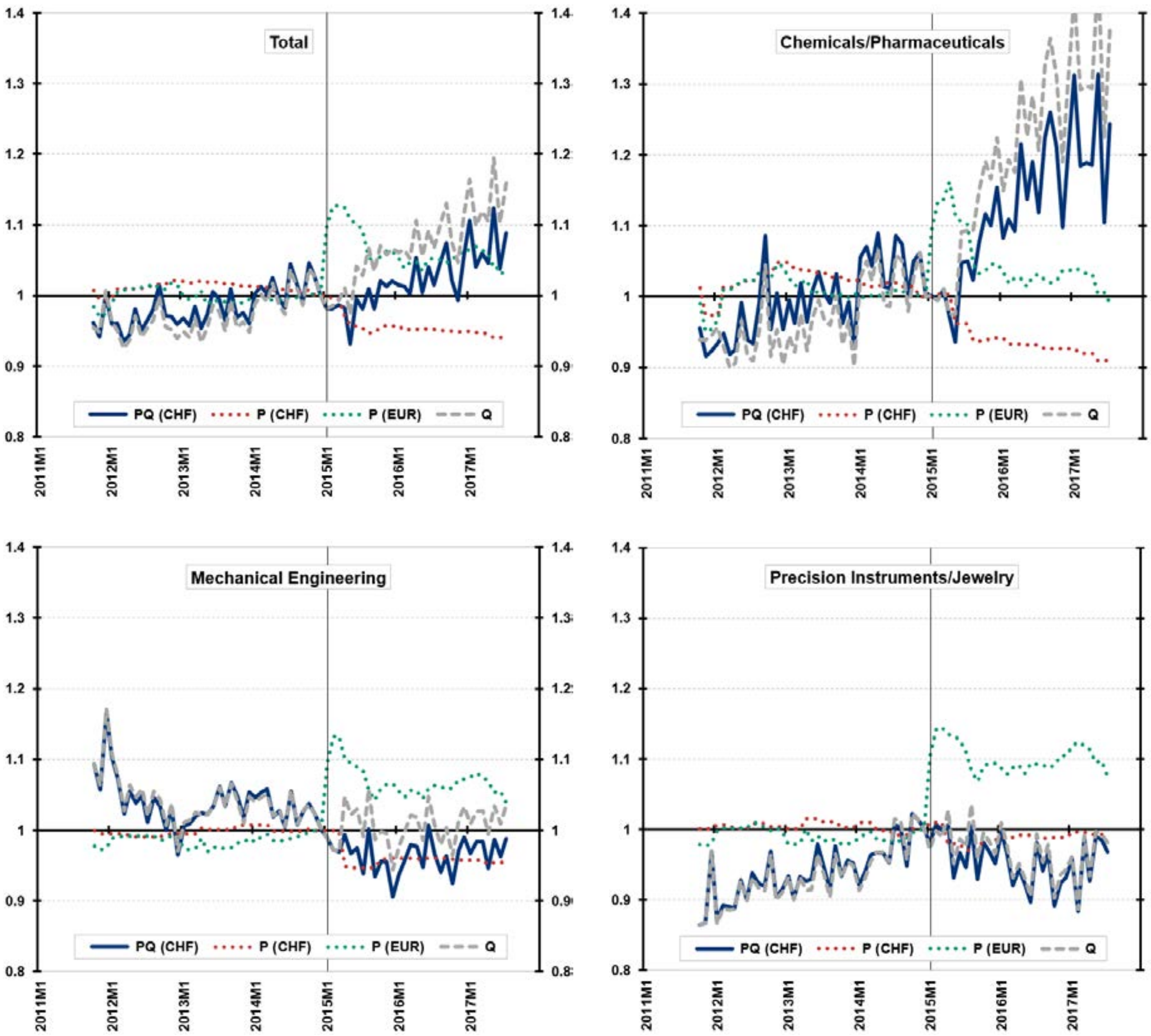
Notes: Deflators are from the Swiss Federal Office of Statistics.

To further investigate quantity and price adjustments, Figure 6 shows the evolution of export values $P_{it}Q_{it}$, prices P_{it} and export quantities Q_{it} (indexed to 2014M12), again on the aggregate and disaggregate level regarding the three inspected sectors. It seems that the appreciation shock in January 2015 had strong effects on both, prices in CHF and EUR, on the aggregated as well as in all the three sectors. These patterns are consistent with imperfect pass-through already pointed out above.

Interestingly, price dynamics vary considerably across sectors. After the initial hike induced by the exchange rate shock, export prices in EUR gradually decreased in all three sectors, with the *chemicals/pharmaceuticals* sector decreasing prices most swiftly and most pronouncedly. Along the same lines, domestic prices decreased more markedly in *chemicals/pharmaceuticals*, whereas price decreases in domestic currency are modest 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*). As already noted, the *chemicals/pharmaceuticals* sector was the driving factor behind the aggregate export evolution.

[16] The three outlined sectors under consideration make up about 81% of the covered total exports.

Figure 6: 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, price indexes (CHF and converted to EUR) and approximatively computed real export quantities.

Intuitively, one might expect a low price elasticity of the demand for medical products. Thus, at first sight it is surprising that price reductions in CHF were relatively large. Yet, the prices for medical products are regulated to a large extent and the prices had already fallen before the exchange rate shock (Federal Office of Statistics 2016, p. 10). Moreover, given that profit margins in the *chemicals/pharmaceuticals* sector are much higher compared to other sectors, price reductions could be implemented more easily. Looking at balance sheet/income statement figures (Federal Office of Statistics 2016) of the Swiss pharmaceutical sector[17] 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

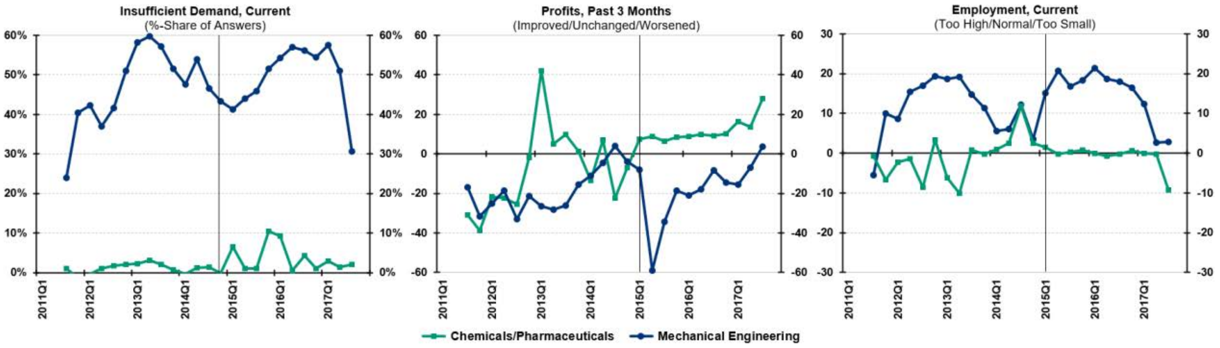
[17] Pharmaceuticals are dominant in the sector *chemicals/pharmaceuticals*: According to the Swiss national accounts 2014 (Federal Office of Statistics), the gross value added of the sub-sector “pharmaceuticals” was about four times higher than the sub-sector “manufacture of coke, chemicals and chemical 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.

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, and 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 enhanced the robustness against the appreciation shock explaining the pronounced price decreases in EUR and CHF 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 poor development despite the benign international macroeconomic environment surrounding the sudden stop of the exchange rate floor. 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. One explanation is that the general exposure was noticeably 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. Furthermore, the earnings by sales revenues of 95% and the share of personnel expenses with 28% were clearly larger compared to pharmaceuticals. 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 not feasible so that the exchange rate shock dragged on real export quantities. This is consistent with Fernandez 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.

In the *precision instruments/jewelry* sector, nominal and real exports strongly comoved, both before and after the appreciation event, indicating only minor price fluctuations in CHF. The exchange rate shock almost fully transmitted into an upward shift in EUR prices. One explanation is that in this sector, a 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 Fernandez and Winters (2021) who show that a large share of intermediary goods in the production is associated with lower exchange rate pass through.

Figure 7: Swiss business survey



Notes: Survey data provided by KOF Swiss Economic Institute.

Finally, we turn to Swiss business surveys data (provided by KOF Swiss Economic Institute) for the sectors *chemicals/pharmaceuticals* and *mechanical engineering*.[18] 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 are largely unaffected, we observe a pronounced 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 demand was affected to a lesser extent.

5. Robustness

We conduct several robustness checks in order to evaluate the sensitivity of our results with respect to sample period and data pre-processing.

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 2011m10, 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 A.1 and A.2 show the respective estimations. Results are hardly affected when using a longer sample.

[18] The KOF data is 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 does 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.

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 A.3 and A.4 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 sub-period growth rates or leaving the effective exchange rate out of consideration.[19] The results are robust against 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.

On 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, we find pronounced heterogeneities in the reaction to the shock. Reductions in operating costs and in mark-ups effectively offset lower demand resulting from the exchange rate shock. However, the effects of the exchange rate shock are heterogenous and dependent on the nature of goods.

We relate differences of the sectoral adjustment to type-of-good specific foreign demand elasticities, the share of foreign intermediary goods or services in the production process that are denominated in foreign

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[19] Results are available upon request.

currency, and profit margins. For instance, a lower demand elasticity, plausibly the case for *chemicals/pharmaceuticals*, and more room to maneuver for supply side adjustment renders the exchange rate shock less adverse in this sector. Our results suggest that the higher the share of foreign intermediary goods or services in the production, the more of the income decrease in domestic currency is offset by a decrease in costs in domestic currency units. Additionally, 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. In respect to fiscal policy, the uncovered sectoral vulnerability heterogeneities may also be considered in the calibration and choice of stabilization efforts carried out by fiscal authorities.

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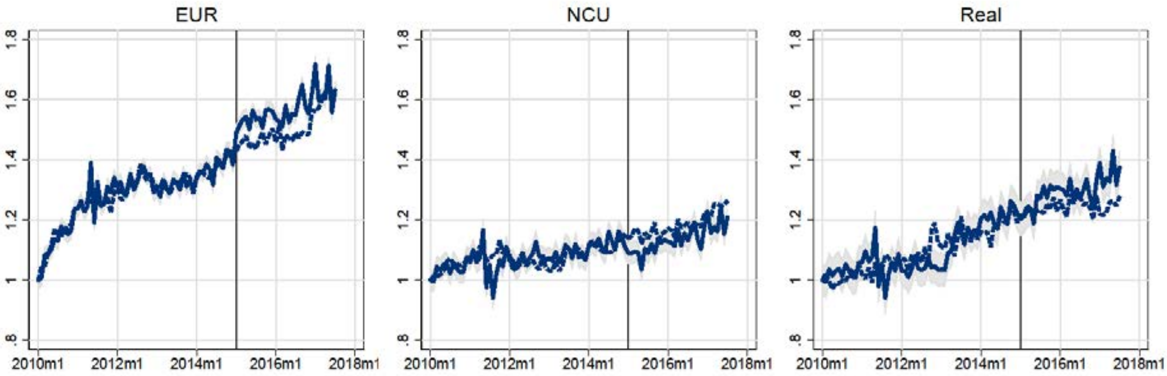
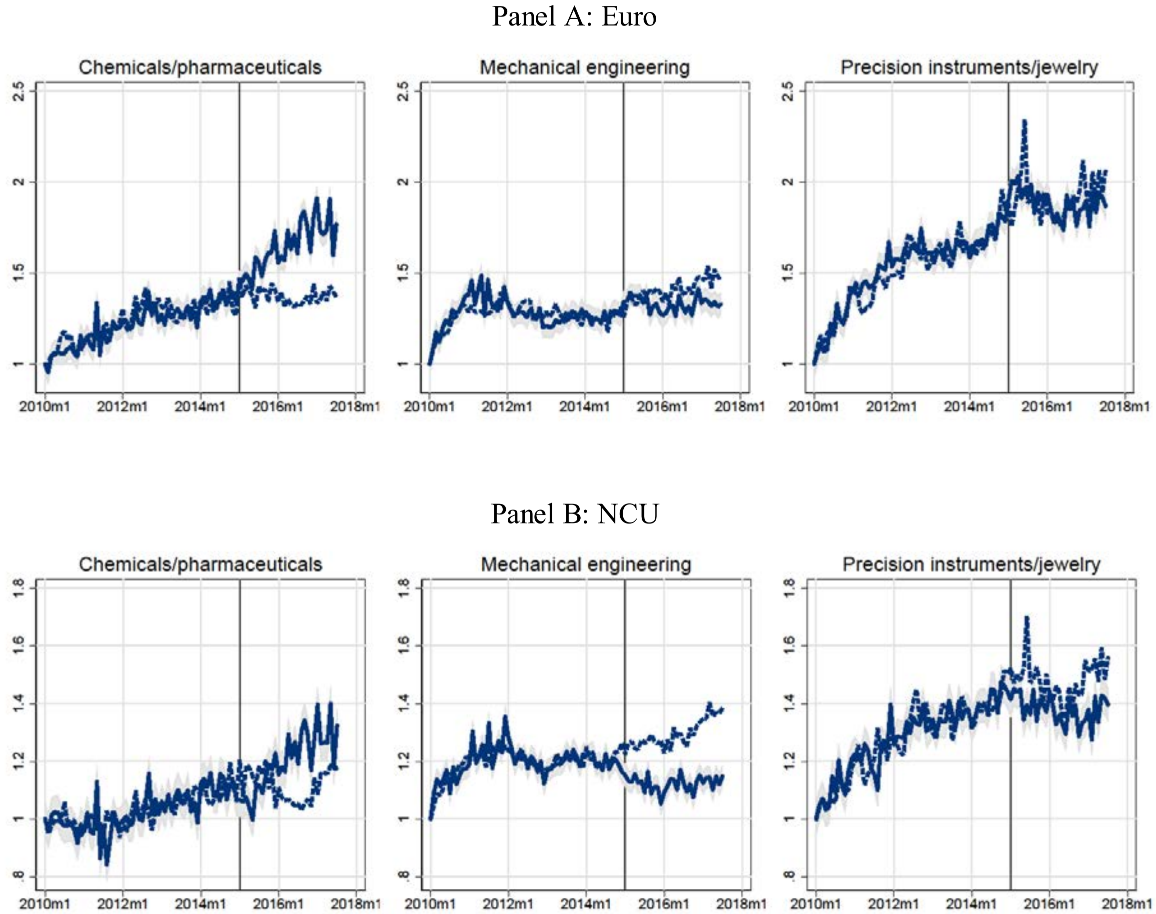
Appendix A: Additional Figures

Figure A.1: Swiss exports in EUR, NCU and real quantities with counterfactual (full sample)



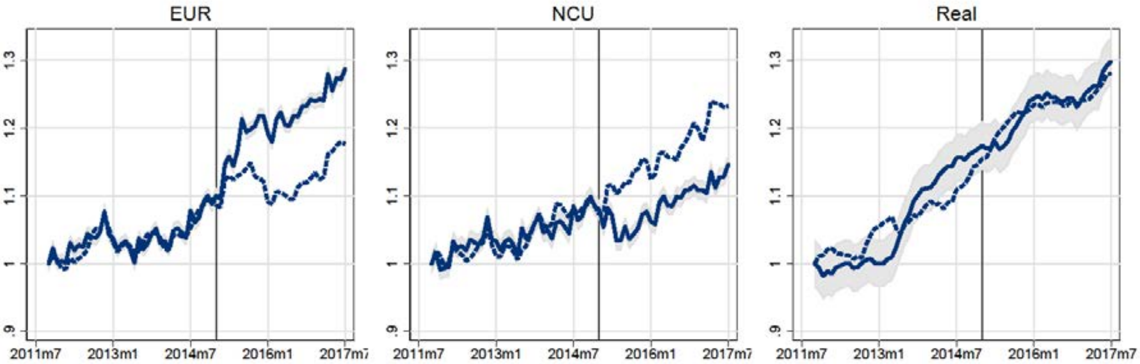
Notes: See notes of Figure 3.

Figure A.2: Swiss sectoral exports with counterfactual (full sample)



Notes: See notes of Figure 3.

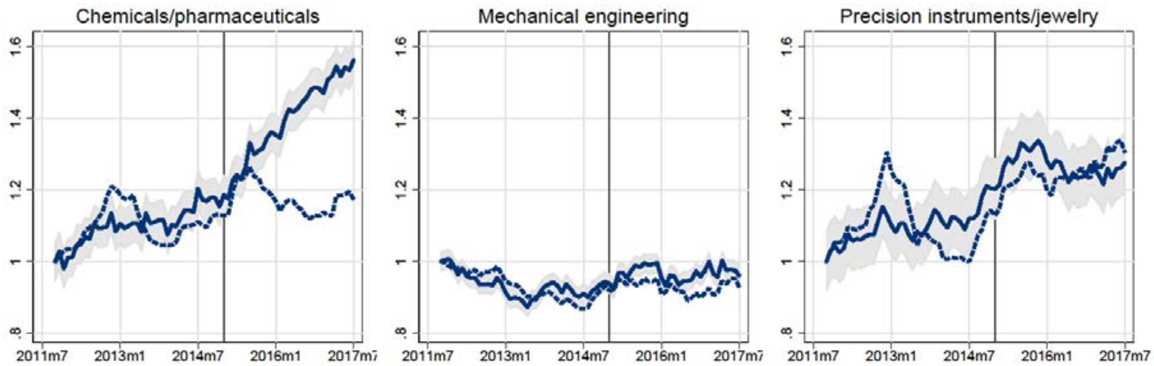
Figure A.3: Swiss exports in EUR, NCU and real quantities with counterfactual (moving averages)



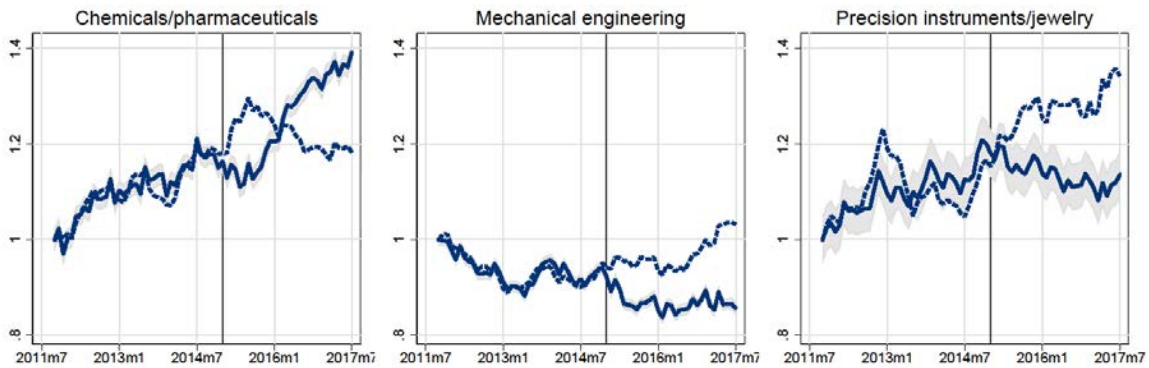
Notes: Notes: See notes of Figure 3.

Figure A.4: Swiss sectoral exports with counterfactual (moving averages)

Panel A: Euro



Panel B: NCU



Notes: See Notes: See notes of Figure 3.